ATIONAL DRINKING WATER MISSION
SEMINAR ON WATER HARVESTING SYSTEMS AND THEIR MANAGEMENT

WATER MISSION

VOLUME - II

DESIGN PACKAGES AND GUIDELINES AT BANGALORE

22-24 December, 1988

SPECIFICATIONS

AND

GUIDELINES

OF

VARIOUS STRUCTURES

COMPILED BY A COMMITTEE CONSISTING OF :

- SHRI P.S. RAJVANSHI
  Chief Engineer, PHED, Rajasthan

- SHRI O.P. GOYAL
  Superintending Engineer, Rajasthan

- DR. U.D. SHARMA
  CAZRI

- SHRI N.S. VANGANI
  CAZRI

- SHRI P.C. SHARMA
  Department of Rural Development

CONTENTS

PAGE NO.

INTRODUCTION

Water Harvesting is relatively a new term and has been interpretted in different ways. Some consider that it includes water conservation and water augmentation. Actually the term harvesting implies getting or capturing use of water (either surface or ground water) which was naturally not accruing to these systems and in that sense covers such diverse practices like Cloud seeding, construction of dams, Bunds etc. For arresting surface run off, aforestation, digging of ponds, construction of surface storage tanks and artificial recharge of ground water through water spreading, percolation tanks, recharge basins, injection well etc. The term water harvesting should thus cover "Augmentation" but not conservation.

Since time immemorial, water harvesting systems in the form of surface and sub surface storage have been widely used. With the advent of piped water supply, the traditional water harvesting systems have been neglected and abandoned. Recently, due to consecutive droughts all surface water sources dried up and the yield from bore wells reduced considerably in most parts of the country. Besides, water table has lowered down and salinity has increased which have once again drawn the attention to the role of water harvesting structures in drinking water supply systems.

Since the water harvesting structures are site specific, various design parameters are followed through out the country. Further, due to constant neglect, the traditional systems developed problems such as reduction in the catchment areas due to land encrochment resulting in lesser availability of water, heavy water losses, heavy siltation due to Biotic interference and water pollution leading to health-hazard. To mitigate the above problems, standard design parameters and specifications on the basis of recent available technology are to be developed and followed so that water harvesting structures can become a vital part of the integrated drinking water supplies.

Before proceeding with the designs and specifications of water harvesting structure, the basic parameter required is the water demand. As per the present guidelines from GOI under 'Minimum Needs Programme' and 'Accelerated Rural Water Supply Programme', 40 LPCD water requirement is to be provided through water supply systems in the rural areas except in the western desert part where live stock population is high. In this desert part of the country, the water supply systems are to provide 70 LPCD based on human population, but designed to cater water requirement of cattle also. Out of the above requirement of water, the water required for drinking and cooking is estimated to be 10 LPCD. It is felt that the water harvesting structures, if provided to cater for the total demand of water, will become prohibitively expensive. Water harvesting structures may be considered for use in conjunction with normal water supply systems as a supplementary source and not as a replacement. Another important consideration while designing the capacity of water harvesting strcuture is the evaporation and seepage losses in the area. Studies have been carried out about the evaporation losses in different parts of the country and due provision will have to be made while estimating the capacity of the water harvesting structure for the likely evaporation losses in the area. As regards seepage losses, various lining systems are available like lining with clay and murrum, tile lining, polytheline film lining etc. The third most important consideration while arriving at the capacity of the storage is the period for which water is required to be stored. While in some parts of the country, where rain fall occurs around 9 months in a year, storage required may be only for 60-90 days but in the areas where rain fall occurs for 30-60 days only during a year, storage may be required for 10 months in an year.

Different practices are prevalent in different parts of the country for water harvesting and some practices are prevalent in other countries which have not been tried here. The water harvesting structures may be classified in the following manner :

1. **FOR DRINKING WATER SUPPLY**

   a) **Nadi**

      i) water harvesting from natural surfaces for surface storage structures,
      ii) Augmentation of surface water from treated catchments,
      iii) Evaporation control measures.
      iv) Seepage control measures.

   b) **Tanka**

   c) **Roof Water Harvesting**

   d) **Sanitary Diggi**

2. **FOR CONJUNCTIVE WATER USE**

   a) **Khadin**

   b) **Percolation tank**

c) **Anicuts/Check dams**

d) **Gully Plugging**

e) **Sub surface barriers for artificial recharge**

f) **Abandoned querries for water harvesting development**

3. OTHER POTENTIAL WATER HARVESTING SYSTEMS

a) **Sand filled reservoir**

b) **Flat batter tank**

c) **Roaded catchments for maixmum runoff**

Details about each of the above structures referred above follows.

NADI

Nadis are small excavated or embanked village ponds, harnessing the meagre precipitation, to mitigate the scarcity of drinking water in the Indian desert. Water from Nadis is available from two months to a full year after rain, depending on the catchment characteristics, the amount of rainfall received, intensity and its distribution. This is an ancient practice and the Nadis are the most important resource of the region. However, the first recorded masonry Nadi was constructed in 1520 A.D. near Jodhpur during the regime of Rao Jodhaji.

Prevalence

Since Nadis are the vital water resource in the Indian arid zone, each village has one or more of these, depending on the water demand and availability of suitable sites. As a case study, the number of Nadis in Nagaur, Barmer and Jaisalmer districts were surveyed by CAZRI, Jodhpur and were found to be 1436, 592 and 1822 respectively (as per 1981 Census). In Nagaur district, the dependency on Nadis was found to be 13.18% through out the year (Table 1) and 32.06 as a group percentage.

Table 1

Dependency of drinking water source in % (No. of villages - 1257)

Nadi water (months) / Well water (months)	No well water	Upto 3	Upto 6	Upto 9	Upto 12	Group (%)
No Nadi water	7.03	0.14	-	-	16.85	24.02
upto 3	3.95	-	-	9.08	2.49	15.52
upto 6	6.88	-	4.39	16.40	0.73	28.40
upto 9	1.02	1.46	8.64	-	0.44	11.56
upto 12	13.18	2.20	0.14	-	4.98	20.50
group (%)	32.06	3.80	13.17	25.48	25.49	100.00

Details of system

Nadis are consisting of two components viz. catchment area and water storage area. The characteristics of these vary as per the amount of rainfall and environment.

The highest Nadi volumes per unit of catchment area were observed on dunes and sandy plain areas (Table 2) with slopes of 1-2%. In younger alluvial plains rocky/gravel pediments, Nadi volumes per unit of catchment area increase with increasing slope. Similarly, the Nadi volumes per unit of catchment area under different rainfall zones are given in Table 3. In dune complexes, the Nadi volumes were highest in the 300-350 mm rain fall areas because of stabilisation of the sands with grasses.

Table 2

Effect of catchment slope on Nadi volume catchment area ratio under different physiographic settings

Physiographic setting	Nadi volume (m^3) per ha of catchment area slope group (%)					
	< - 1	1 - 2	2 - 3	3 - 4	4 - 5	> - 5
Dune complex	54.3	108.2	45.7	29.0	-	13.8
Sandy plain	110.6	154.2	121.1	-	-	-
Younger alluvial plain	466.4	578.5	731.8	-	-	-
Rocky/gravel pediment	51.4	421.5	724.7	945.9	-	1236.5

Table 3

Effect of rainfall on Nadi volume/catchment area ratio under different physiographic settings

Physiographic setting	Nadi volume (m3) per ha of catchment area Rainfall zone (mm)				
	250-300	300-350	350-400	400-450	450-500
Dune complex	55.3	110.5	53.0	37.1	-
Sandy plain	120.4	128.0	131.1	137.3	-
Younger alluvial plain	-	-	-	349.9	1066.9
Rocky/gravel pediment	491.7	518.9	785.5	1644.7	2264.7

Drawbacks

The traditional Nadis are affected with heavy sedimentation, high evaporative and seepage losses and water pollution. These limit the proper utilisation of water from the Nadis.

Wider variations were observed in the annual sediment deposition under various environmental settings. The older alluvial plain has the highest sedimentation rate, while the younger alluvial plains have the least.

Table 4

Rate of sediment deposition in Nadis

Physiographic setting	Average sediment yield (m^3/ha yr)	Average reduction in Nadi volume (%)
Sandy plain	3.1	1.9
Dune complex	4.8	2.2
Younger alluvial plain	2.7	3.4
Older alluvial plain	18.4	5.3
Rocky/gravelly pediment	14.3	7.8

Sediment yields from the rocky/gravelly pediment, dune complex and sandy plain lie between these two extremes.

Nadis usually have large surface areas compared with the volume of water stored and heavy losses occur since evaporation is a function of surface area. On the other hand, seepage increases with the depth of the stored water. The highest evaporative losses were observed during the period March - June i.e. in the driest season when the demand for water was highest. High evaporation also occurred in October and November after the rainy season. Seepage losses were greatest during the rainy season (July-September) when the Nadis were completely filled. Evaporative losses varied from 55 to 80% of the total losses in various environment. The highest losses from evaporation (2473 mm/yr) and the lowest from seepage (66 mm/yr) were observed from a rocky/gravel pediment due to large surface areas and impervious beds. The highest seepage losses were recorded in the older alluvium (1577 mm/yr) followed by the sandy environment (1493 mm/yr).

Due to poor maintenance and improper utilisation, the Nadi water is highly polluted and is not free from the health hazards in the form of guinea worms, water hyacinth, mosses, algae etc. Diseases of the stomach, infectious diseases and guinea worms infection are associated more with the villages where Nadi water has been in use.

Adaptability/Limitations

The Nadis can be constructed virtually at all places depending on the water demand and availability of appropriate run off areas. However, the following points must be examined before selecting a Nadi site :

1. Availability of commensurable catchment areas which can yield the needed quantity and quality of water.

2. Generally, the Nadi catchments should be dominated with fine grained, hard and compact formations so as to minimise the sediment input.

3. The water storage area should be underlain with impervious strata to minimise the seepage losses. The rocky beds should be uniform and free from fissures/fractures etc. or if present, should be sealed properly.

Suggestions/Recommendations

1. Sediment input to the Nadis can be reduced appreciably either by promoting vegetation growth in the basins or by constructing silt traps at the inlet of the Nadi. The sediment yield was reduced by 65.2, 94.4 and 76.6% from the blown sand, younger alluvium and older alluvium areas respectively, by preserving vegetation in their basins. However, from the basins with biotic interference, the silt trap reduced the sediment input by 71.1 and 71.4% from the older alluvium and shale formations, respectively under the similar rainfall and basin characteristics.

2. At present no established system is known that will control the evaporation from the Nadis. However, use of fatty alcohols like cetyle Alcohol may be made to reduce evaporation losses. Different types of treatments and linings are available to reduce seepage losses which may be adopted depending upon their cost effectiveness. However, these losses could be minimised by optimizing the depth and surface area of the Nadis in various environments (Table 5).

Table 5

Optimised Nadi characteristics to minimise the evaporative and seepage losses

Physiographic setting	Optimised depth (m)	Optimised surface area ($m^2 \times 10^3$)	Water availability (months)
Sandy plain	2.0	27.1	8.3
Dune complex	2.5	29.1	4.8
Younger alluvium	5.0	161.0	12.0
Older alluvium	3.0	96.3	12.0
Rocky/gravel pediment	6.0	126.5	12.0

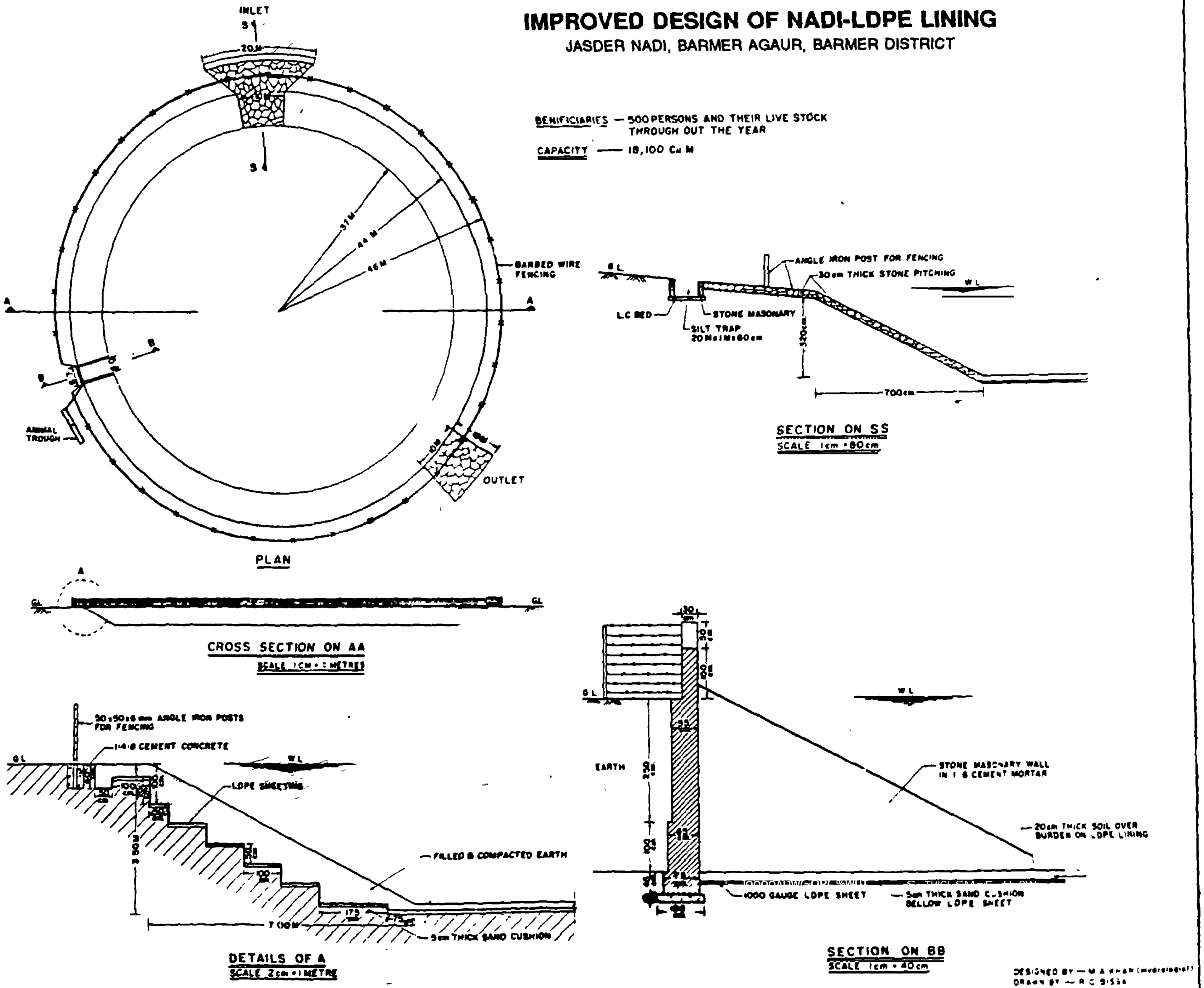
3. To minimise the pollution of water, the entry of animals and human beings into the Nadi must be restricted. Use of catchment areas for the purpose of defecation, etc. by the villagers and movement of livestock must also be checked. Providing wind mills, handpumps on Nádis may be considered to check entry of human beings/cattle in the Nadis.

IMPROVED DESIGN OF NADI-LDPE LINING

JASDER NADI, BARMER AGAUR, BARMER DISTRICT

BENIFICIARIES — 500 PERSONS AND THEIR LIVE STOCK THROUGH OUT THE YEAR

CAPACITY — 18,100 Cu M



DESIGNED BY — M A KHAN (Hydrologist)
DRAWN BY — R C BISSA

AUGMENTATION OF SURFACE WATER FROM TREATED CATCHMENTS

History

Before the development of gasoline engines and electric motors, water harvesting was fairly a common practice in a number of arid and semi arid regions. It has been reported that water harvesting systems in the Negev Desert, which are thought to have first been built about 4000 years ago. These system involved clearing hillsides to smooth the soil and increase run off and then building contour ditches to collect the water and carry it to low lying fields where water was used to irrigate crops.

In terms of recent history, collection and storage of run off from treated catchments was developed by using various materials like steel sheets, concrete blocks, plastic and artificial rubber membrances etc. In 1961, United states of America adopted entirely different approach to the problem and investigated the methods of utilizing the soil itself as the catchment structure. Sprayable asphaltic compounds, plastic and metal films bounded to the soil, soil compaction and dispersion and field fabricated asphaltic fibreglass membrance materials were found to be promising, causing soil to become hydrophobic or water repellent.

The concept of water harvesting is not new to India. Water harvesting has been a traditional practice from natural catchments in arid and semi arid zones, in form of dug out or impounding type of ponds & under different land use. However, no sizable work on water harvesting from treated catchment have been initiated in our country. Several examples on water harvesting from natural catchments are visible, such as, intercepting and diverting of road side culvert outflow for raising crops in the Hirakund catchment area in Orissa, low earthern check buttressed of loose boulder pitching for diverting the flow into pick up channels and then into irrigated fields, collecting water by constructing the earthen bund across the slope in the form of Khadins and dug out tanks (Nadis) in Rajasthan etc. Only after 1970, efforts have been made by various Research Institutes, such as, CAZRI, Jodhpur, CRIDA - Hyderabad, ICRISAT - Hyderabad, CSWCRTI - Dehra Doon, to carry out some experiment on various treatment materials for inducement of run off. However, their application and efficiency on wider scale in fields is to be tested. The high limitation to the use of treated catchments has been the cost per unit of water produced.

Scope

The aims and importance of treating the catchments is to render the soil surface impermeable, thereby eliminating infiltration, whether it be deep percolation to the ground water reservoir, or shallow top soil infiltration followed by evaporation loss.

The importance of the technique is felt in desertic region of western Rajasthan particularly in border districts - Barmer, Bikaner and Jaisalmer where soils are having high rate of infiltration and acute problem of drinking water exist. Keeping in view the various problems, Central Arid Zone Research Institute, Jodhpur carried out experiment for a period of four years involving the techniques of water harvesting from small catchments to increase the water yield for dug out Nadis and Tankas in the desert region.

The treatment materials were so selected that these materials are easily or locally available. These were : (1) Bentonite (20%) mixed with soil, (2) Soil cement (8%) mixture, (3) Mud plaster (Tank silt + wheat husk), (5) Lime concrete, (6) Jantha emulsion premix (a type of asphalt), (7) Mechancal stabilisation, (8) Sodium carbonate spray (Dhobi soda) 1 kg/10 sqm., (9) Mud plaster (tank silt + husk 3% + Jantha emulsion 2%). The technique consists in the preparation of artificial catchments and compacting these with different materials mentioned above to the thickness of 1.25 cm. The results of treatments studies are given in the following table:

S. No.	Years	1972	1973	1974	1975	Cost of treatment material per sq.m (Rs.)
	Rainfall in mm	316.90	502.05	130.60	497.32	
	No. of rainy days	11	19	5	21	
	Treatments	Run off %	Run off %	Run off %	Run off %	
1.	Control (No treatment)	57.42	22.15	29.81	6.62	0.00
2.	Bentonite 20% mixed with soil, 1.25 cm thick	87.53	62.71	51.30	12.80	1.25
3.	Cement 8% mixed with soil 1.25 cm thick	41.14	28.52	22.74	7.17	0.90
4.	Mud plaster (local) 1.25 cm thick	66.62	52.00	38.23	9.18	0.45
5.	Lime concrete 5 cm thick	74.48	65.21	47.99	36.07	0.45
6.	Jantha emulsion premixed 1.25 cm thick, 8% solution of Jantha emulsion and K. Oil @ 4.1	94.06	82.26	66.20	29.20	3.10
7.	Mechanical stabilization	65.22	48.28	28.15	7.78	0.30
8.	Sodium Carbonate spray @ 1 kg/10 sq. m over 1.25 cm thick tank silt compacted	91.75	75.70	63.46	34.40	0.60
9.	Mud plaster (RRL) mixture of mud, bhusa and Jantha emulsion (95:3:2)	78.76	67.62	48.82	20.27	1.20

From the results given in table, it is inferred that in first year, the percentage of run off was the highest i.e. 94.06 percent of rainfall from Jantha emulsion treatment followed the next highest yield i.e. 91.75 percent of rainfall by sodium carbonate spray. In subsequent years the run off generated from Jantha emulsion treatment and sodium carbonate spray was 82.26%, 66.20%, 29.20% and 75.70%, 63.46%, 34.40% respectively. While comparing these results with respect to control (no treatment) it can be seen that the Jantha emulsion and sodium carbonate spray generated 63.81% and 59.78% more run off in the first year. Due to inherent problems with other treatments, the run off generated by them in first year was much less than these two treatments except Bentonite mixed with sand. Bentonite treatment, initially though it creates water proofing in the surface, but subsequently it fails in long run due to the development of cracks at the surface on drying. In general the efficiency of all the treatments was reduced year by year becuse of deterioration of materials. But still sodium carbonate spray generated the maximum i.e. nearly 5 times than the control even after four years of application of treatment. In general its efficiency varies from 34.4 to 91.75 percent of rainfall occured within the years. University of Arizona (1974) had estimated the indefinite life of this treatment. Looking to the cost of treatment per sq.m, percentage of run off generated and life span of sodium carbonate spray is much economical than any other tried treatment.

EVAPORATION CONTROL

In Indian desert harnessing and storing rain water in existing storage facilities is still an important source of water supply for human and livestock consumption. Evaporation of this water from open water surfaces is very high. The annual average evaporation in this area ranges from 3102 mm at Jodhpur to 2809 mm at Ahmedabad and is several times greater than the annual precipitation of the area. Reducing evaporation losses is desirable for maintaining dependable good quality water supplies for a longer period.

The process of evaporation requires both a source of energy to vaporize the water and a transfer mechanism such as dry air and wind. Reduction in evaporation can be achieved by reducing energy available for evaporation. Solar energy entering the water is usually reduced by suspending a shade above the surface, reflecting more of the incoming solar radiation than does a natural water surface, or by a combination of the above. Wind baffles placed around on, or above the water surface have been used to reduce the transport of water vapour.

Evaporation control methods

Evaporation control methods involve the reduction of surface area to volume ratio, the use of mono molecular layer forming chemicals, shading the water surface, floating covers that either provide a mechanical barrier preventing vapour transfer and or reduce the sun's energy from reaching the water surface. Mechanical wind break can also be used on smaller ponds to reduce evaporation.

Liquid chemicals

Research on reducing evaporation from water surface has been concerned primarily with floating mono-molecular films of long chain-alkanols. Although improved methods of applying the alkanols have been developed, disruption of film by wind remains a serious and unsolved problem.

National Chemical Laboratory, Pune has been carrying out extensive work on water evaporation by mono-molecular films both from fundamental and applied points of view. NCL has developed new types of compounds called Alkoxy ethanols having general formula $C_n H_{2n} + 1 OC_2 H_4 OH$ where n = 16, 18, 20, 22. These compounds are more effective evaporation retardants than the corresponding alcohol having general formula $C_n H_{2n} + 1 OH$. Recently, it was observed by them from the preliminary experiments with mixed mono layers of Alkoxy Ethanols that they can withstand high wind velocities in the Laboratories' wind tunnel experiments using wind velocities upto 39 kms/hr. It was observed that Alkoxy ethanol mixtures especially $C_{18} OC_2 H_4 OH + C_{22} OC_2 H_4 OH$ (1:9) gave very high results at 39 kms/hr compared to $C_{16} OH + C_{18} OH$ (1:1) which is commonly used. However, these results are only with initial experiments and require to be confirmed through repeated experiments and in the field.

However, fatty alcohols such as cetyl Alcohol (C_{16} OH) and Stearyl Alcohol (C_{18} OH) are used as Monolayers for evaporation control. These chemicals reduced the evaporation rate by about 25% but it is found that monolayer film of this compound could not withstand wind speed greater than 15 kms/hr and are not stable in field conditions. However, by continuous supply of these alcohols on the water surface, it is possible to maintain Monolayer film reducing evaporation losses by about 25%. Properties such as rate of spreading, equilibrium spreading pressure, specific resistance to evaporation and surface viscosity are required to be measured for evaluating the effectiveness of any monolayer compound.

Shading Water Surface

Shading the water surface with polyethylene or any similar material is found very efficient in reducing solar energy entering the water. Evaporation reduction with 100 percent plastic sheet shading of water surface has been about 90 percent.

The shading material must be fastended to the supporting structure to reduce the potential for wind damage. Shading the water surface has the major problem of proper holding of shading material above the water surface. On larger tanks or ponds, the supporting structures may cost as much as, or more than the shading material itself, thus making the approach economically unacceptable.

Floating covers

The use of floating materials is an effective method for reducing evaporation by increasing the reflectance of water surface and thereby reducing the energy available for evaporation.

Use of floating butyl sheets, polystyrene sheets and polystyrene raft are effective means of evaporation reduction. Evaporation reduction with floating these materials have been about the same percentage as the percentage of surface covered. Polystyrene rafts are coated with cationic asphalt and coarse sand to reduce wind problems and weathering protection.

Reflective properties of continuous wax and butyl rubber foam are much less significant than the ability of film or sheeting to present vapour transfer, since the surface is almost completely sealed. When floated on the surface of water they have been found to reduce evaporation by 87 percent and 90 percent, respectively.

Perlite ore, polystyrene beads, wax blocks and white spheres covering the same percentage of area, i.e. 78 percent have evaporation reduction efficiencies of 19 percent, 39 percent, 64 percent and 78 percent, respectively. Use of floating spheres appears to be a promising method of evaporation reduction. Spheres are made out of plastic, glass or ceramics. Glass bottles, available as waste product, can be used. The use of ceramic or glass spheres will provide an evaporation control method that will last indefinitely. One ceramic expert from Brazil claimed that if the ceramic sphere was properly made and prorperly fixed, it could last over 1000 years floating on the water surface unless the sphere was broken. Sufficient number of spheres need to be applied to the surface of any reservoir to reduce wave action against shoreline. The range in size of sphere has been from7.5 cm to 45 cm in diameter.

Wind Barriers

Plantation of trees or constructing wall around the periphery of tanks or ponds, evaporation can be reduced by only about 11 percent. The energy balance anlayis indicated that reduction of the wind velocity alone usually would not produce large saving.

Compartmented Reservoirs

Reducing the surface area to volume ratio of the reservoir for reducing evaporation can be achieved by constructing compartmented reservoir. This method has been in paractice in Sudan, Maxico, Brazil and Thailand.

The reservoir consists of a receiving compartment - A, for storing runoff and is usually shallow, and two other compartments B and C, which are smaller in surface area but of greater depth. As runoff occurs during the rainy season water is pumped from the compartment 'A' to compartment B and C. Water is then withdrawn as needed for consumptive use from B until water remaining in B is equal to the unused capacity in C. At this time, the pump is used again to move the remaining water from B into C.

This eliminate further evaporation and seepage losses from B. At this point 'A' and 'B' are empty.

Water storage efficiencies of 40 to 50 percent are easily obtained with the compartmented reservoir where as a conventional reservoir of the same depth covering the same area would not even be able to sustain its own evaporation losses and would go dry. Higher savings are possible by covering the last (c) compartment.

Research activities

Central Arid Zone Research Institute, Jodhpur has initiated field study on evaporation supression using different locally available materials. The eight treatments are (1) Shading water surface with white polyethylene sheet, (2) Monomolecular film of cetyle alcohol, (3) floating thermocool blocks, (4) floating rubber foam sheet, 95) floating polyethylene sheet, (6) floating bamboo sticks, (7) floating cenchrus Moonja, and (8) control.

Shading the water surface with polyethylene sheet has been found most effective in controlling evaporation, followed by floating thermocol blocks, polyethylene sheet and rubber foam sheets. Floating material of cenchrus Moonja has not been very effective as its life is only few month and need replacement at regular intervals.

SEEPAGE CONTROL SYSTEM

Introduction

The loss of water in canal system or in the impounding reservoirs takes place through evaporation and through seepage. While evaporation of water from Canal system or from impounding reservoirs results only loss of water without other side effects, loss of water through seepage has many side effects. Seepage also leads to other problems such as breach in the embankment, water logging and increased salinity in the adjacent areas. In case of reservoirs used for effluent storage, seepage loss leads to damage to ground water as well as harmfaul effects on agricultural land. By mentioning these side effects the intention is not to undermine the impact of loss of water. The seepage losses in some soil types is as high as 11 cum/sec. per million sq.m. area resulting in rapid depletion of reservoir/tank water levels.

With appropriate lining of the reservoirs/ponds, the seepage loss could be minimised. Particularly in arid and semi-arid regions, storage of water in seepage proof tanks provides water for human beings as well as live stock and in some cases for Irrigation also.

General storage considerations

To minimise seepage and evaporation losses, storage structure volume should be maximised and containment and exposed surface areas should be minimised. The ratios of volume stored to containment or water surface area increases as the depth of the storage increase in relation to the breadth. Excavated ponds associated with water harvesting systems generally have depth-to-breadth ratios ranging from 1:5 to 1:15. It would be more advantageous if storage systems were constructed deeper but there are problems about soil stability and excavation of the ponds. Also depth of water storage structure is limited by need to maintain a gravity inflow-outflow set-up. Some of these limitations can be overcome by using constructed side wall tanks. Spillway or overflow must be part of the excavated pond design and it must be stabilised to reduce to the eroding effect of the water.

Water Barrier characteristics required

When considering a lining material for a storage reservoir, certain features should be evaluated as follows:

1. Degree of seepage control that can be expected;
2. Resistance to deterioration by soil micro organisms, atmospheric elements (heat, ozone, oxygen, sunlight, wind and subgrade movement);
3. Mechanical puncture and vermin attack;
4. Toxicity;
5. Ease of installation.
6. Transportability with respect to the use of site.
7. Maintenance requirements; and
8. Economy

The seepage loss is directly related to the nature and porosity of the soil, the depth, turbidity and temperature of water, the age and shape of the reservoir and position of ground water level. Seepage losses through different types of soils in completely unlined canals are given in table below :

Seepage Loss Characteristics of Different Soils

Character of Material	Seepage Loss in Cumecs/million m2 of wetted perimeter		
Impervious clay loam	0.90	to	1.20
Medium clay loam underlaid with hard pan at depth of not over 0.60 to 0.90 m below ground level	1.20	to	1.80
Ordinary clay loam silt soil or lavash loam	1.80	to	2.70
Gravelly or sandy clay loam cemented gravel, sand and clay	2.70	to	3.60
Sandy loam	3.60	to	5.20
Loose sandy soil	5.20	to	6.10
Gravelly sandy soil	7.00	to	8.80
Porous gravelly soil	8.80	to	10.70
Very gravelly soil	10.70	to	21.30

Different types of lining which can be applied to the Reservoirs/ponds at the bottom and sides are given below :

a) Mud plaster

b) Jantha Emulsion

c) Tank Silt or clay soil

d) Cement concrete lining

e) Asphaltic concrete lining

f) Brick lining (with single or double brick arrangement)

g) Bentonite and clay membrane lining

h) Plastic film and synthetic Rubber lining

While mud plastering and application of Jantha Emulsion or applying Bentonite or clay membrane reduce seepage losses to some extent but their life and effectiveness are limited. The cement concrete lining and Asphaltic cement concrete lining are effective but have high costs. Double brick lining of the reservoirs may be useful but the seepage losses increase with time

The lining using PVC/LDPE film and Butyl coated fabrics have been tried experimentally. Out of all the types tested so far, IDPE film appears to be the best. PVC lining has limitation about flexibility, thickness and width of sheets and are costly. However, LDPE films lining have been tried on experimental basis for past several years and is now extensively used in number of states by Irrigation Department.

LDPE films are available in various thickeness conforming to IS-2508/1984. The film is available in various widths from6 metres to 12 metres. The LDPE films are normally applied to reservoir/ponds lining in 250 micron thickness.LDPE films can be applied with various arrangements as follows :

i) In the bed of the reservoir, LDPE film may be laid on prepared uniform surface with soil cover of 30 cm to 60 cm.

ii) The film can be covered by a single brick dry pitching.

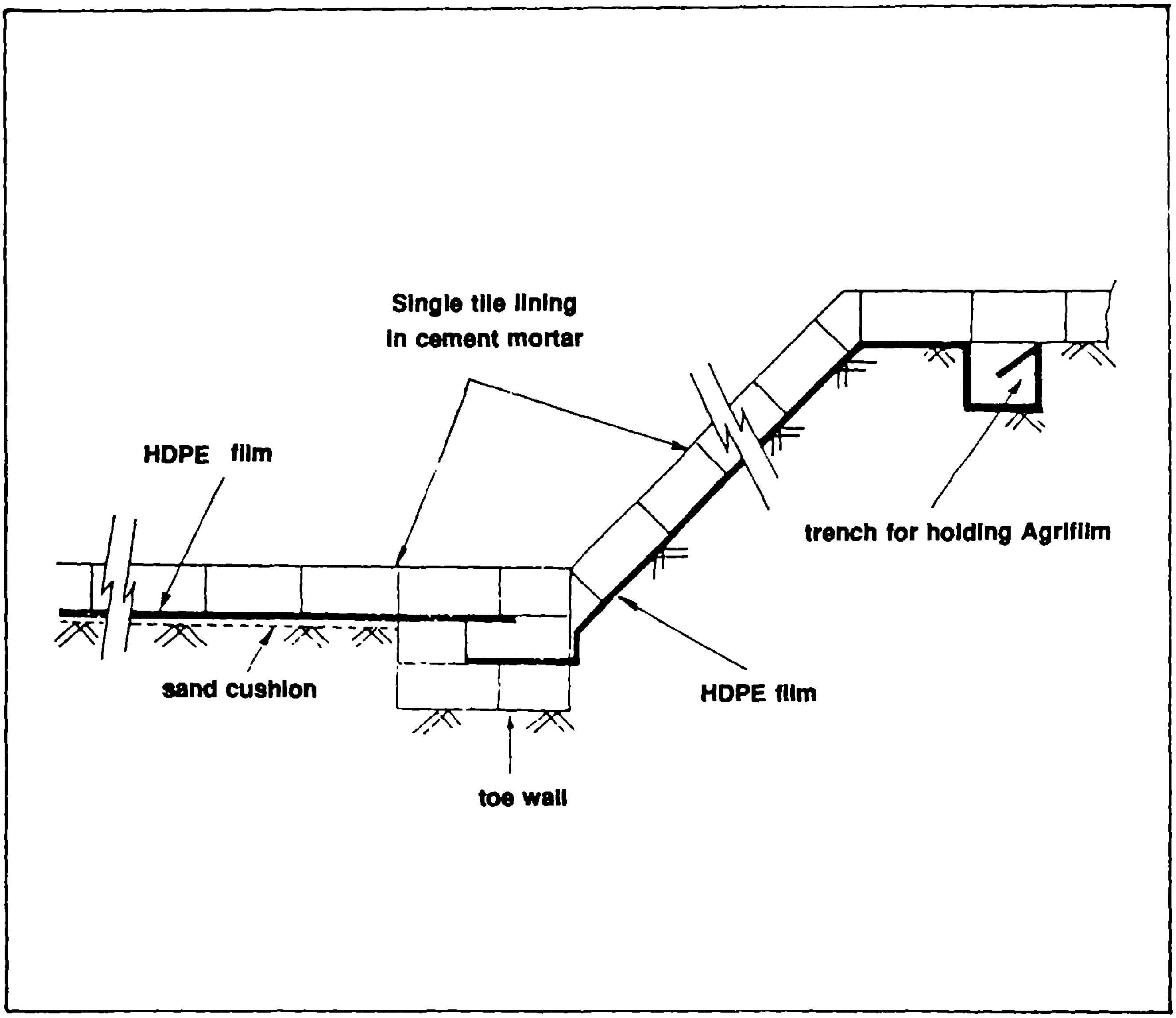
iii) LDPE film can be covered by cement mortar jointed brick lining.

iv) On the sides of the service reservoirs, either double brick lining or lining with LDPE film covered with single brick may be applied.

v) LDPE film can be jointed either through adhesive tapes or by hot Bituman or through thermal welding.

The typical section for applying LDPE film brick lining is given at figure 'A'.

It is to be taken care of that anti-weed and anti-termite treatment to sub-grade soil is given in places where these problems are anticipated while under normal conditions these treatments need not be given.


Single tile lining
in cement mortar
HDPE film
trench for holding Agrifilm
sand cushion
HDPE film
toe wall

TANKA

History

'Tanka' is a local name given to a covered underground tank, generally constructed of masonry or concrete for collection and storage of surface run off. The development of such structure can be one of the answers to the problems of perennial drinking water scarcity in the villages of western Rajasthan.

The provision of tanka near religious centres, schools and in the individual house hold has been the practice since old times. During the Mughal period tanks were constructed as part of the Public congregation places like the Dargarh and as part of the palaces, forts etc. in the 16th century to serve as source of drinking water. For household use, the tankas are usually small and fed by rain water from house tops. The history of Marwar reveals that the first known construction of tanka in this region was during the year 1607 A.D. by Raja sursinghji in village Vadi Ka Melan. Further in the Mehrangarh fort at Jodhpur a tanka was constructed during the regime of Maharaja Udaisinghji in year 1759 A.D. However, during the great famine of 1895-96 construction of tankas was taken up on the wider scale in this region. In the recent past, the development of such structures have also been reported from other developing countries such as Botswana, Ghana, Kenya, Yemen, Sri Lanka, Thailand and Indonesia naming as tanka or cisterns.

Traditional methods

Practially every dhani now has one or more tanka for rain water harvesting mainly for drinking purposes. According to the economic conditions, people of this area have devised their own methods for constructing these structures. Looking to the present status, it is obvious that the tanka system does not ensure an adequate supply of water through out the year; this is mainly due to the meagre rainfall and inadequate catchment areas left for harnessing the run off. Moreover the catchment areas prepared are not proper regarding generating run off. Due to all these factors including the type of constructions, tankas fail to meet the annual requirement of drinking water. In the constructional aspects, tankas on individual dhani basis are circular in shape having almost similar depth/diameter, varyig from 3.00 to 4.25 m. Since stones or bricks as building materials are not available at all places in duny areas and as these are relatively costly, after excavation in proper circular shape, lime mortar is used to plaster the bare horizontal and vertical soil surfaces to a thickness of about 6 mm. A second layer of plaster of cement mortar is applied to a thickness of about 3 mm. The top is covered with Zizyphus numularia thorns. With simple lime plastering on the bare soil surfaces, the useful life of a tanka becomes limited to a maximum extent of 3 years.

The catchments of tanka are made in variety of ways using locally available sealing materials. The generally used materials are pond silt, murrum, wood, coal ash, gravel etc. After clearing the soil surface of vegetation, land is given a smooth slope of 3 to 4 percent towards the tanka, pond silt is spread in a 3-4 cm thick layer. During the rainy season, after the first shower, this layer is compacted and made semi impervious by a local compaction technique consisting of rolling of crotalaria burhia and sand. In places where tank silt is not available, layer of 5-7 cm. of murrum is spread over the catchment. At the onset of monsoon, sheep and goats are made to move over the murrum again and again till the surface is compacted and becomes impermeable. During this process water is also sprinkled, if needed. Normally wood coal ash is not used as sole surface sealing material, yet it is used to repair the catchments made up of pond silt and murrum locally. The ash settles, fill the pores and makes the surface water proof.

Drawbacks in traditional system

Tankas constructed by traditional methods are temporary one and are subjected to leakage from bottom as well as from vertical surfaces. Moreover the prepared catchment areas are not in accordance with the amount of rainfall received and run off generated. Practically in almost all the cases, the catchment areas are prepared on the basis of above average rainfall years, so that the chance of filling to the optimum amoun of water becomes once in five years.Nevertheless, the water collected in the traditional system tanka is never free from pollution and evaporation losses. This is mainly, because the tanka is covered with thorns only and their is no provision of inlets and outlets, due to which the pollutants are having access to enter alongwith the run off and even at later stage in the stored water. Moreover the size of tanka constructed is very small and stored water is not sufficient for drinking through out the year.

Suggested improved design of tanka

To overcome the problems enumerated in the traditional tanka system, Central Arid Zone Research Institute, Jodhpur developed the design of the structure based on the due considerations on various parameters involved.

(a) **Rainfall probability**

Annual rainfall, distribution and intensity of rainfall plays an important role in designing of catchment are and structure. Most of times the structures are being designul on the basis of an average rainfall and have not been serving meaningful purpose. Structures are either overdesigned or underdesigned. Since peculiar rainfall conditions are existing in the arid and semi arid area, it may be worth while to predict the probability of rainfall of that particular zone where the structure is being proposed. Experience indicates that the dependable annual rainfall occuring at 60% probability worked out through the Log Pearson Type III will be the most suitable for designing the catchment area for the tanka. By considering such probability of rainfall and catchment area needed, it will be ensured that tanka will meet the drinking water requirement throgh out the dry season of the year.

(b) **Estimation of consumption**

The maximum yield possible from a rain water catchment system is directly proportional to the catchment surface area, its run off coefficient i.e. the ratio of harvestable rainfall to total rainfall and the amount of rainfall. Thus for a full hydrological year, the mean daily yield is given by the equation :

$$Y = \frac{f_i \quad R_i}{365}$$

Where

Y = mean daily catchment yield, litres/m^2

fi = run off coefficient

Ri = total probable rainfall, mm

The run off coefficient depends on the catchment treatment material and age of the catchment surface. Theoretically, the consumption can be set at constant level of Y litres/m^2/day if adequate storage capacity is available for dry season requirement. This is based on the assumption that evaporation and other losses from storage are negligible.

Per capita consumption from a catchment is calculated by :

$$C = \frac{Y}{N}$$

Where

C = per capita consumption, litres/m²/day
N = number of persons served by the catchment
Y = mean daily catchment yield litres/m²

It will be very clear from the illustrated following example taking the case of one of the districts of western Rajasthan.

Example

Six persons are to be served by tanka stored water, having treated catchment area of 500 sq.m. (f = 0.2). Annual rainfall is 200 mm.

$$\text{Mean yield - } Y = \frac{200 \times 0.2}{365} = 0.11 \text{ litres/m}^2\text{/day}$$

$$\text{Per capita consumption} \quad C = \frac{Y}{N}$$

$$= \frac{0.11}{6} \times 500 = 9 \text{ litres/day}$$

The above calculation indicates, a family of 6 members require nearly 19.70 cum. of minimum storage of water to survive through out the year solely using tanka water. However in case of unusual consumption of water of say 12-14 litres per capita per day during the summer period of 4 months, an additional provision of 2.88 cm of water may be made i.e. a tanka of 21-22 cum capacity for single family will ensure the supply of water through out the year. For schools, Panchayat Ghar and community water source, a tanka of 200 cum may be sufficient as source of drinking water.

(c) Catchment treatment

To provide reliable run off, a water harvesting catchment needs to be impermeable and smooth. However, perfect sealing the soil surface is expensive and some infiltration losses must be accepted. In these cases, ground forming can incrase the run off yield by improving the hydraulic efficiency of the catchments and thus reduce the time available for infiltration to take place.

Several experiments on use and efficiency of different treatment materials have been carried out in the different countries. Such treatment materials are sprayable asphaltic compounds, plastic and metal films bounded to the soil, soil comapaction and dispersion field fabricated asphalt fibreglass memberanes, sodium salts, gravel covered plastic membranes and melted wax, bentonite and few chemical treatments.

The experiment conducted by CAZRI, Jodhpur on use and efficiency of different sealing materials indicated the spray of sodium carbonate at the rate of 1 kg/10 sq.m. to be efficient and cheap which generateed 66.32% of rainfall as run off i.e. 37.32% of the run off more than the untreated soil. These figures are an average of four years experiment The treatment cost during 1972 was Rs. 0.60 per sq.m.

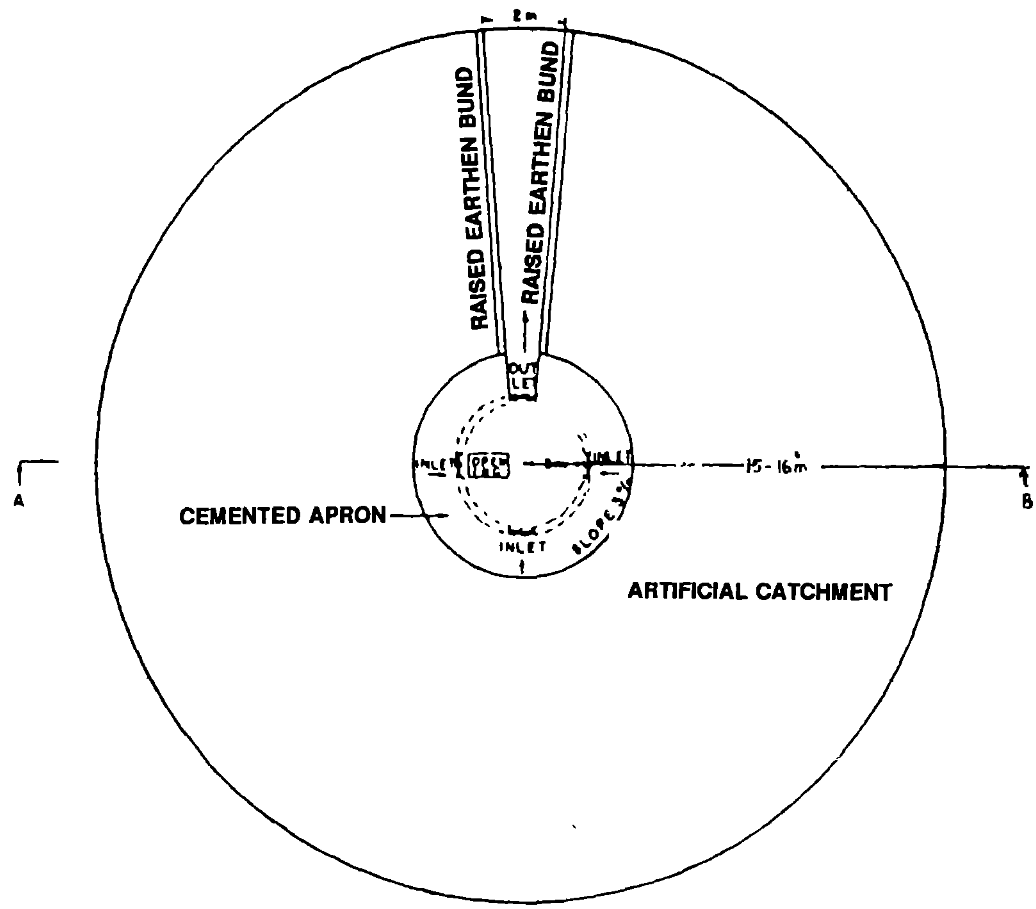
Suitable design of tanka

A tanka is usually circular or rectangular in shape. The circular tanka is the most economical form of the structure and found to be more stable as the pressure exerted by water is uniform radial pressure in all directions in the diametrical plane at right angle to the curved surface.

The successful construction of a tanka depends on the selection of site. In case, if natural catchment is available at site, the run off depends on catchment characteristics such as size, shape, topography, soil type, vegetation etc. So the catchment selected or artificially prepared should produce adequate run off to meet the storage requirement of the tanka and at the same time it should cause minimum soil loss. Experience indicates that two ha. catchment having 2 to

3 percent slope with compacted gravelly or heavy textured soil free from grass vegetation is generally sufficient for a tanka of 200 m^3 capacity. For artificially prepared catchment, the area required can be calculated as discussed earlier. After selection of site and size of catchment it is essential to carry out some minor treatment such as construction of earthen diversion bunds, removal of vegetation where practical, spreading and ramming of a layer of murrum or silt clay which results in reduction in the intake rates of the soil. The constructional details of tanka are given in fig. (1) and (2).

CONSTRUCTIONAL DETAILS OF A WATER TANKA FOR A SINGLE FAMILY (CAPACITY 21 Cu. M.)



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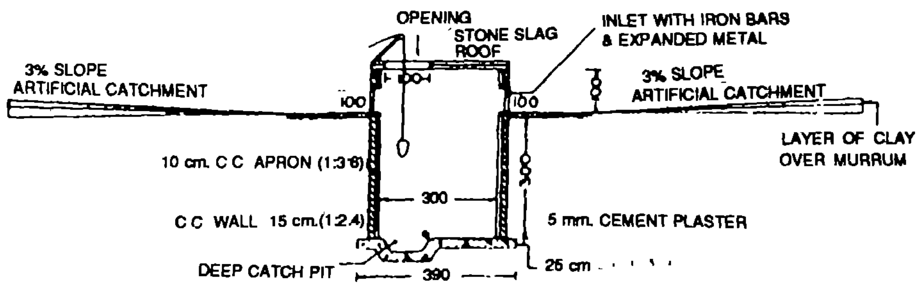
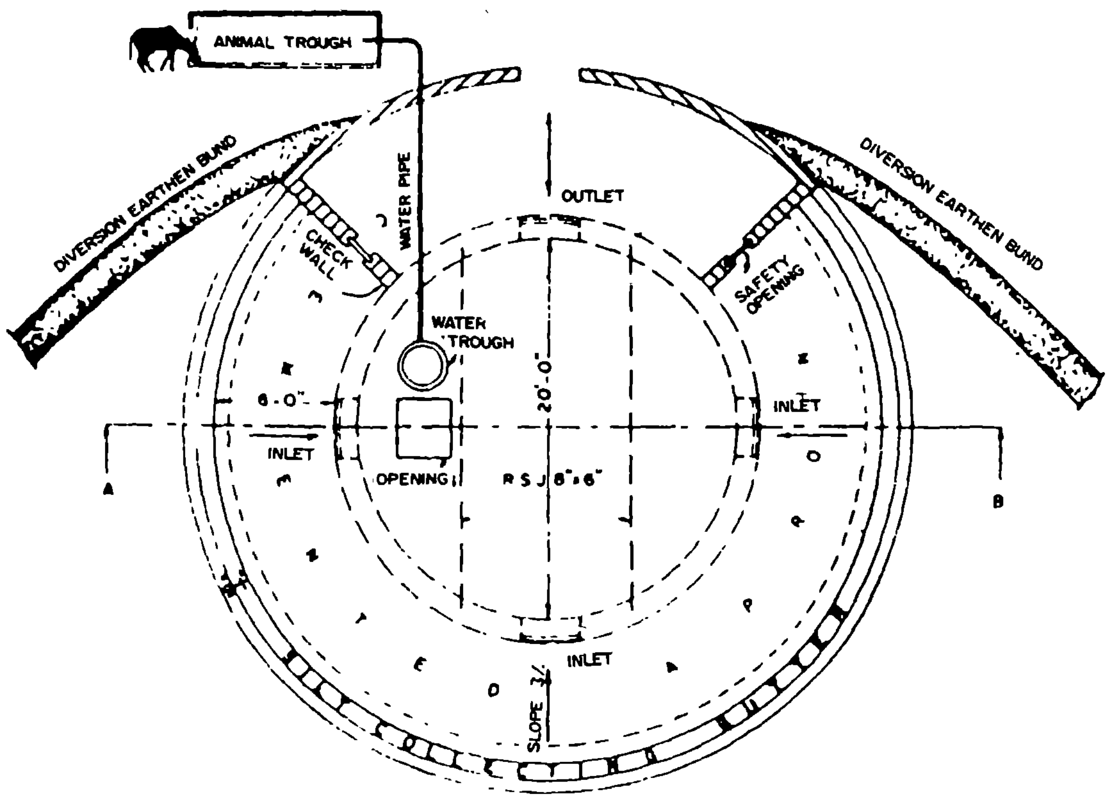


SECTION AB

NOTE ALL DIMENSIONS IN CMS

CONSTRUCTIONAL DETAILS OF A WATER TANKA

(CAPACITY 200 Cu m)



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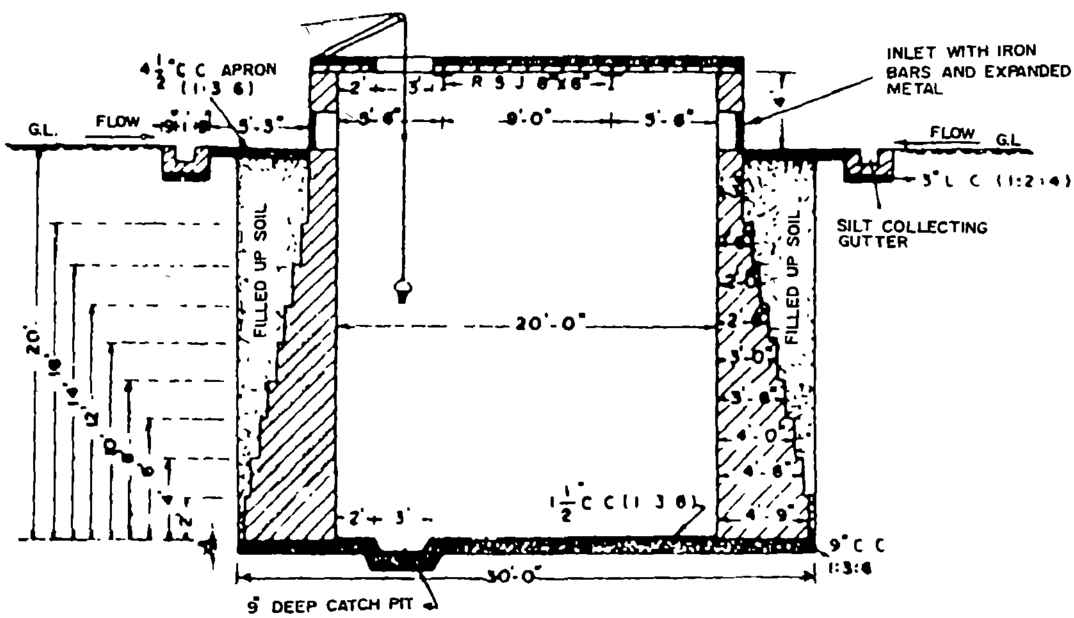


SECTION AB

ROOF WATER HARVESTING

Introduction

In many parts of the world, rain water continues to be the only source of domestic water supply. Rain-water may be harvested in remote hilly areas, having rainfall of considerable intensity, spread over the larger part of the year. This is an ideal solution to water problem where there is no groundwater and surface sources are very far. This is ideally suited from the economical point of view where the houses are scattered over a wide area and are located at different elevations. Rainwater is bacteriologically pure, free from organic matter and soft in nature. To meet out the drinking water demand during the critical dry period of 90-120 days in the N.E. India, roof water harvesting is being practiced since long.

Prevalence

The roof water harvesting is folloowed in Meghalaya, Mizoram and other hilly states in the northeast India and Himalayan State.

Details of the system

1. Estimation of yield : The maximum yield possible from a rain water catchment system is directly proportional to the catchment surface area, is runoff co-efficient and the amount of rainfall. Field measurements indicate that a portion of rainfall serves to wet the catchment, a portion is evaporated and a portion is wasted as 'foul flush' in case of roof catchment. The portion of the rainfall actually harvested ranges from 30% for pervious flat gorund catchment, over 90% for covered sloping ground catchment. Thus run off co-efficient factor 'f' ranges between 0.3 to 0.9 as shown in Table 1 assuming there is an adequate storage volume to accumulate any surplus of rainfall over consumption.

Table 1

Type of catchment	$f = \dfrac{\text{Harvestable rainfall}}{\text{Total rainfall}}$
Uncovered catchment surface	
Flat	0.3
Sloping 0-5%	0.4
Sloping 0-10%	0.5
Covered catchment	
Roof tiles	0.8 - 0.9
G.I. Sheets	0.7 - 0.9
Brick pavement	0.7 - 0.8
Compacted soil	0.4 - 0.5

The yield 'Y' of a catchment area 'A' m^2 receiving rainfall 'R' mm in a month is given by

$$Y = \frac{f \times A \times R}{1000} \quad m^3/month$$

If 'p' number of people is to be served with drinking water from a rain water system at a rate of 'q' litters per day, the amount of water 'Q' to be supplied per month will be

$$Q = \frac{P \times 30 \times q}{1000} \quad m^3/month$$

2. Storage capacity : The total storage capacity required depends on

Number of people to be served

- Daily per capita requirement in litres/day
- Number of consecutive days without rainfall
- (Usually 90 to 120 days in N.E. State & Himalayan Region)
- Amount of rainfall and its duration
- Size of catchment area
- Losses of water due to evaporation and leakage

On the basis of rainfall and critical dry period (90 to 120 days normally), the minimum storage volume can be computed from :

$$V = \frac{P \times q \times D}{1000} \quad m^3$$

Where P	=	number of persons
q	=	daily consumption rate in litres per day
D	=	number of critical dry days

3. Components of the system : Essential components of Roof top collection Rain Water Harvesting Scheme.

a) Roof catchment

b) Gutters for collection of roof water

c) Down pipe to convey rain water from gutter to storage tank

d) 'Foul Flush' system to divert the contaminated run off from roof

e) Filter/mesh

f) Storage tank above or under ground

g) Water withdrawal arrangement

h) Disinfection arrangement

Roof : Roofing may be either G.I. aluminium or A.C. Sheets or even tiles. Although thatch roof is not very suitable, the same can also be used by covering with Plastic or polythene sheet.

Gutter : Gutter of plain G.I. sheet or local materials such as wood, bamboo etc. may be used. All gutters should have adequate slope for free flow of water.

Down Pipe : The down pipe is used for feeding the water from the gutter to the storage tank. This pipe should be at least 100 mm dia. provided with a 20 mesh wire screen at the inlet to prevent dry leaves and other debris from clogging it.

Foul Flush : During the period of no rain, dust, bird droppings etc. accumulate on the roof. These are washed off with the first rains and enter the storage tank to contaminate the water. This can be prevented by two methods :

a) Simple diversion of foul water
b) Installation of foul flush system

Under method (a), the down pipe is moved away from the inlet of the storage tank during the rains until clean water flows. Under method (b), storage provision for initial rain is kept in a pipe or bozo. These are cleaned off after each heavy rain.

Filter : A filter is provided between down pipe and storage tank after foul flush. This filter may be of brick, R.C.C. or ferrocement. The filter is cleaned every three months.

Storage tank/cistern

This is the most important and costliest component of the scheme. The rain water collected from the roof catchment is stored in this tank. The tank or cistern may be brick, stone, R.C.C. or ferrocement. The tank is provided with :

- a manhole of 0.50 m x 0.50 m size with cover
- Vent pipe/over flow pipe (with screen) of 100 mm dia.
- drain pipe (100 mm dia.) at bottom

Choice of tank depends on locally available materials and space available. When the tank is constructed under-ground, at least 30 cm of the tank should remain above ground.

Water withdrawal arrangement :

If the tanks are constructed underground because of the low height of the houses in the rural areas, a shallow hand pump is required to be provided for withdrawal of water otherwise a bib-cock will suffice.

Disinfection arrangement

Before the tank is put to use, it shoud be thoroughly cleaned and disinfected with chlorine solution.

Design Considerations

In the design of the system, the main criteria is the most economical combination of the storage tank volume, systematic anlaysis of rainfall records and construction costs. The roof should be pucca like brick, RCC, GI Sheets/Asbestos sheets, etc so as to generate good runoff.

Suggestion for Improvement

It is only during collection, storage or handling, there is a possiblity of contamination. Therefore, utmost care has to be taken during these operations to maintain the water safe. People should be educated that the quality is important rather than the quantity.

A typical drawing of roof water harvesting is placed at Fig 1.

Economics, if any

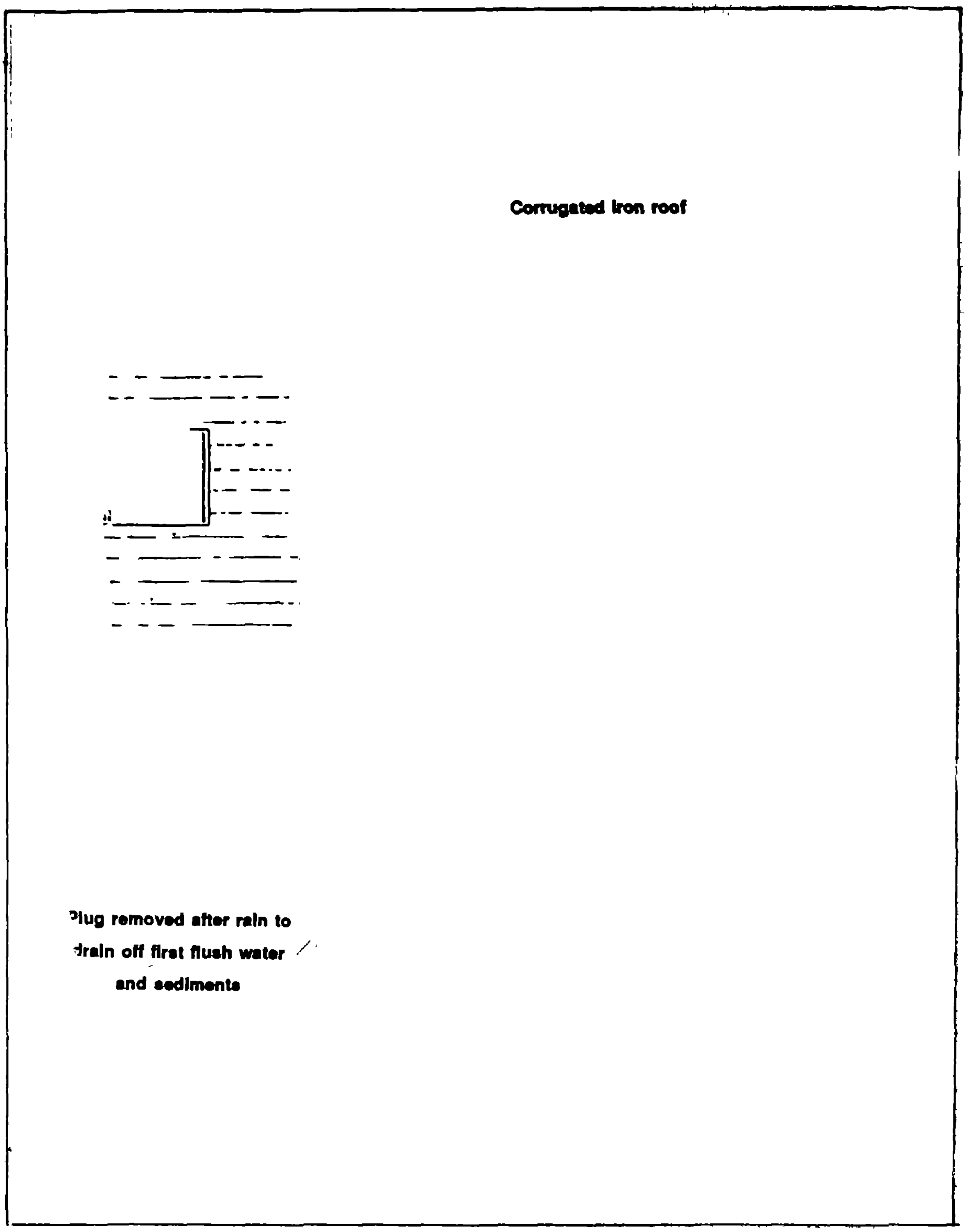
1. In the west Khasi hills of Meghalaya, the roof water harvesting schemes have been designed @ 10 litres per person per day for 90 days critical dry period. The average cost for a household of 8 persons are as under :

1.	Cost of storage tank	Rs.	7,000.00
2.	Cost of gutter, downflow pipe, polythene sheet cover, clamp etc. including carriage and labour for fitting.	Rs.	1,500.00
3.	Cost of handpump including carriage and fitting	Rs.	321.00
4.	Ferro cement filter	Rs.	695.00
	Total	Rs.	9516.00
	Cost per capita	Rs.	1,189.50

2. Per capita cost for 15000 litres capacity G.C.I. tank in Mizoram is :

(i) Rs. 235/- @ 3 litres per day per person.

(ii) Rs. 1000/- @ 10 litres per day person.



Corrugated iron roof
Plug removed after rain to
drain off first flush water
and sediments

SANITARY DIGGI

In the command area of major canal net works where gorund water is not potable, the local people depend on canal water for their drinking water requirement. The canals normally run for a fixed period called Barabandi. In this system water is released in the cananls for a period of say 7 days after every 28 days or 35 days. Thus water is required to be stored for the drinking water requirement of atleast 28 to 35 days.

In the command area of Indira Gandhi Canal in Rajasthan, which was scarcely populated with no drinking water facilities, new human settlements have been developed. These settlements provide residential facilities for a defined geographical area. These settlements have been designed for in-habiting 1000 people on ultimate basis.

To provide drinking water facilities to the people of these new settlements, a system has been developed which is now popularly called Sanitary Diggi. Earlier water from the canal system used to be collected in natural depressions or in dug out Diggies to meet the drinking water requirement for the closure period of the canal. However these natural depresssions or dug out ditches suffered with heavy seepage losses. These older system has other disadvantages of heavy silting and pollution. To over come these problems, system of Sanitary Diggies has been adopted.

A typical Diggi comprises of feeding a group of 1000 people. It consists of 2 storage tanks to store canal water for the requirement of 28 days including evaporation losses. These storage tanks are normally lined. The advantage of having two storage tanks is that in case of the requirement of desilting or repairs, the other storage tank may be utilised. The storage tanks each have a capacity of 800 Cums. to meet the drinking water reqirement for 28 days of canal closer. Water in these storage tanks is received from the canal through a water course and a chamber to trap silt. Water from these storage tanks is taken under gravity to slow sand filter having dia. of about 4 meters. The filteration rate in the slow sand filter iskept about 150 Lit/sq.m/hr. Water from Slow Sand Filter is taken under gravity to a closed underground reservoir, again circular in shape and 4 m. in diameter. At the top of the underground C.W.R., 4 shallow well hand pumps are installed to enable people to take out water. This arrangement avoids physical contact of human beings and cattle from the filtered water. The waste water from the hand pmps is diverted to a Cattle Water Trough where cattle can drink water. About 200 such Diggie systems are presently working in Indira Gandhi Canal command area in Rajasthan.

The lining of the storage tanks has been done in the following ways :-

1. **Double brick tile lining**

In this system the prepared surface of the storage tank which are normally circular in shape, a cement mortor layer is laid which is over laid by 2 layers of bricks sand witching a rich cement mortor mix. This rich cement mortor mix (1:3) acts as an impervious medium.

2. **Stone Slab Lining**

In this case, on the prepared surface of the storage tanks an impervious layer of rich cement mortor mix (1:3) is laid over a sub-grade of poor cement sand mortor mix (1:6) over which stone slabs measuring around 30 cms x 60 cms jointed by cement sand mortor are laid.

3. **LDPE Film Lining**

This type of lining is widely used in these storage tanks. In this case the surface is first treated with antitermite and anti-weed chemicals and then a plaster of poor cement sand mortor mix (1:6) is applied in a thickness of 2 cms. On this surface, LDPE film of 250 microne thickness is spread and then covered with a brick lining duly jointed with cement sand mortor. This type of lining has shown very good results in the storage tanks constructed for the sanitary Diggi system.

The storage tanks on the above pattern with slow sand filter and Clear Water Reservoirs may also be adopted in other areas even with rain water catchments.

KHADIN

Hitory

Water harvesting and runoff farming has been an ancient practice in various parts of arid zone of India. 'Khadin' is one such system basically innovated for runoff farming by the Paliwal Brahmin Community in Jaisalmer area in former Jaisalmer State, in 15th. Century. It has quite a similarity with method practiced by people of Ur in trag 4500 B.C. or later by Nabateans in the middle east. Similar system is also reported to have been practiced 4000 years ago in Negev desert, as also till 500 years back in USA by ancient people in south western Colorado, particuarly at site now known as Mesa Varde National Park.

In arid Rajasthan, though it was started in 15th. Century, the idea slowly spread over other parts too. In Jaisalmer, the ruler used to encourage people to develop this system on suitable sites, grow and develop agriculture and share the 'part of it with ruler, who would remain the owner of it. However, later Paliwal community was either driven out or left the region and for long period no new Khadins could be made but old Khadins continued to be used. However, their proper management got neglected. Still, there are as many as 500 big and small khadins in present Jaisalmer district which are still productive with even zero to 40 mm rainfall.

Present Status

The systems is site specific needing a large natural, high runoff potential catchment in proximity of plain valley land with deep soils. The ratio of Khadin to catchment area, depending on type of catchment is minimum 1:12 or 15. Thus site needs to be confinedly selected and bund Khadin area is to be properly marked or taken out.

Recently, since a decade, irrigation department of State has started making many new Khadins at various locations. Under Desert Development Programme also new Khadins are being made. However, successful system is not seen every where. Old Khadins also need proper management.

Constructional Details

Khadin is constructed in a valley of rocky hilly area or low lying area of stony gravelly wasteland. First of all the detailed contour surveyof propsoed Khadin land is done and contour plan prepared. Khadin bund is fixed on the down stream side of the catchment. The size of khadin bund is designed on the basis of rainfall pattern, catchment characteristics, wave length and soil type. Height of bund usually varied from 1 m. to 3m.. to submerge 3/4th. of the catchment area. Top width of khadin bund varies with height of bund. For bund height of 1m, 1.6m, 1.9m, and more than 2.1m, the top width will be 1m, 1.3m, 1.5m and 1.8m, respectively. Bund side slope (U/S & D/S) varies from 2:1 for light soil to 1:1 for heavy soil.

Before starting the construction of Khadin, bund position is aligned and then about 15 cm. layer of natural ground surface is scrapped out. The earth work is done in layers of 30 cm depth and then compacted by ramming with hand hammer, sheep foot roller or road roller. For providing proper shape to the bund a profile at every 20 m. length of bund is erected. Over flow provision is made by providing cement-concrete spill-over structure and stone pitching in down stream to check erosion. Pipe outlet is also provided in centre of bund to drain out standing water before cultivating khadin land. After completion of Khadin, levelling of land near bund is done for uniform spreading of water. Seeding of grass on bund during rainy season is done for its stabilization.

Draw Back

a) **Old Khadins** : Centuries old Khadins have not properly been managed. At places, very coarse sediments like coarse land gravels etc. get involved in plain lands as result of high intensity rains or cloud bursts. These need to be removed.

No regular levelling inside Khadin seems to have bene practiced, making Khadins very uneven.

Most of the Khadin bunds - are earthen bunds. At places, due to lack of their management they are eroding.

b) **New Khadins** : It seems, Rainfall-runoff relationship as also the catchment Khadin ratio have not been properly taken into account while selecting sites, as also making Khadin bunds at many places. As a result, at some places, not enough runoff water could be generated even with average rain fall receipts while at other places, the bunds could not withstand the water present and get broken and eroded.

At some sites in small size Khadins, spillways have not been provided.

In big Khadins, making small dug wells outside Khadin bunds is an innovative method developed by ancient people to have conjunctive use of water as also to encourage seeping out of water and salts so as to prevent salinity, development in Khadin in course of time. No such small dug well have been provided in new Khadins. These are the wells which should be used for human and stock drinking as this is some what filtered and better water than open inundated water.

No planting of trees etc. seems to have been planned or adopted around new Khadins.

no proper treatment is given to catchment areas nor any channelisation of all runoff water towards only Khadin area is planned or adopted.

Proposed Modifications

No basic modification needed in this ancient system. But suggestion for making new Khandins and their management are as follow :-

1. Site should be selected on physiography of land taking into account proximity of catchment area and farm land or khadin area.

2. Depending on size of catchment, its runoff potential should be worked out on the basis of land features, like nature of profile, infiltration rate, slope of land etc., of, catchment and rainfall of the region. The size of farm land or Khadin area is to be worked out to be enclosed by earthen bund while developing new khadins.

3. In rocky gravelly catchments, minimum khadin areas to catchment area ratio is 1:12 to 1:15 (i.e. one ha Khadin to 12 to 15 ha catchment), in other catchment with more infiltration and less runoff, ratio may still be larger.

4. Low valley where hwere farm is to be developed as khadin area for water inundation, soil profile should be very deep without rocky strata at least 1.5 m dug. This land should be absolutely level for uniform spread of water, with ditches and gullies. Often flash floods bring in coarse sand/gravels on surface as sediments which should be removed and levelling done regularly.

5. Soil salinity should regularly be checked inside Khadin and if found accumulating, it should be flushed out during first or second rain, through use of sluice.

6. Seeping out of inundated water also helps to keep salinity in check inside Khadin. During inundation period small shallow well should be dug out side Khadin bund to encourage it For human and stock drinking water from such wells should be used rather than inundated open water in Khadin.

7. Good grasses and other plant cover should be developed and maintained in the catchment area and controlled grazing practice should be adopted in catchment.

8. With the help of small bunds of soil or small stone walls, made at appropriate slopes, water running of in all directions and going waste could be properly channelised to Khadin spots to have better and efficient harvest of water from complete catchment.

9. Big trees could be planted properly inside Khadin, on the bund and out side the Khadin bund to improve environment around it.

Limitations

1. It is only a site specific system, that can not be developed every where.

2. It is large scale scheme where a large community is invovled of diverse attitude, to its development and subsequent management. Government may once develop it but diverse community with part of its ownership of land has to manage it.

In ancient time all khadins were built up by the Darbar (King), through those who would cultivate and utilise it giving Darbar a part or share in the harvest, with total ownership of Darbar.

Research required for further improvements

1. Khadin is bsically a runoff agricultural system though site specific with good management, it can make arid wasteland productive. Modern experience is however, limited to few isolated projects. Intensive techno-economic evaluation in several regions with different climates, soils, and crops are needed to identify its potential for the future.

2. To make run off agriculture more effective, there is a need to develop crops better suited to it.

3. Though it is primarily runoff agriculture, a lot of water gets inundated on the land, partly going down deep, side ways and much is lost through evaporation. For conservation and conjunctive use of such collected water, research work on models for suppression of evaporative losses, monitoring the water use for drinking purposes through dug well around Khadins etc. is needed.

PERCOLATION TANK

Technological developments in the pumping method and well construction have resulted in large scale exploitation of groundwater. In many countries, which have to face the vagaries of monsoon, dependability of groundwater has increased tremendously. In arid or semiarid regions availability of surface water is either lacking or is inadequate and storage of surface water is also uneconomical on acocunt of high evaporation losses. Proper storage and management of available ground water, resources, therefore, is very essential. The replenishment of groundwater reservoirs in the arid and the semi-arid regions is necessary because the intensity of normal rainfall is grossely inadequate to produce any moisture surplus under normal infiltration conditions. Although artificial groundwater recharge methods have been familiar in the developed nations over the past several decades, their importance was felt in the developing nations like India, only during past two or three decades. Methods like nala bunding, percolation tanks, trenching along the hill slopes and around the hills, etc., are being practiced in many parts of the country but advantage of such projects could not be obtained for want of scientific orientation of the programmes. A thorough and detailed knowledge of the geological, hydrological and morphological features of the area are necessary for selecting the sites for recharge structures.

Percolation tanks are constructed for impounding Surface runoff to create small storage and for inducing recharge to groundwater through percolation. Construction of this structure takes into account the catchment area, likely runoff, designed storage at the site as well as the area of benefit from the structure. The construction of such structure is considered to be very useful as means of water conservation and to strengthen the drinking water and irrigation water sources.

Studies have been carried-out on artificial recharge through percolation tanks in the Sina and the Man river basins, Maharashtra. Both these basins comprise mainly basaltic flows with narrow and shallow alluvial patches. Seven percolation tanks were cosntructed to find out their effectiveness and suggest methods for improving their utility. The average recharge was 50% of the capacity of tank provided, the tanks bottom was renovated by scrapping the surface every year before monsoon. The location was selected in such a way that reservoir area is covered by vesicular or fractured basalts. Nala (Stream) bunding, where the entire storage of surface was restricted to the course of nala, was found to be more effective and economical as the surface exposed to evaporation was on an average 10% of that of normal percolation tank. The rate of infiltration varied from 50 to 70% of the capacity. Further studies in central Maharashtra revealed that the recharge from percolation tanks in basaltic formation having the area of influence about 1.5 sq.km boosted in average rise in SWL of 2.05 m. i.e. nearly 0.15 mcm.

Similar studies on nine percolation tanks in the Noyil Ponani and Vattamalai river basins of Tamilnadu and Kerala revealed that the rate of percolation was as high as 163 mm/day at the beginning of rainy season but reduced to hardly 15 mm/day after few months. This reduction in infiltration rate was mainly due to accumulation of silt at bottom. Periodic desilting was therefore, found to be essential.

Another set of seven tanks having an average storage capacity of 0.13 mcm were studied. The area under influence of tanks was 1.7 sq.km. Due to the storage, rise in SWL was recorded to 2.5 m which reflects the variable recharge from 0.032 mcm to 0.112 mcm with mean 0.079 mcm which is about 60% of the tank capacity. This additional water could be utilised for the beneficial use by constructing 6 new wells giving a discharge of 0.012 mcm every year. Water level was generally found to be higher in wells nearer to the tank and the same was gradually reducing away from tanks.

Economic percolation tank schemes

Initial cost of structure per 1000 lit. per year recharge was found to be Rs. 45.00 in alluvial areas and operational cost per 1000 lit. of recharged water was Rs. 0.045.

ANICUTS/CHECK DAMS

Introduction

The anicut is a structure which intercepts the water from local catchment and store it for optimum utilisation. Such structures not only reduce the erosive velocity of runoff but also prevent the gullies from further enlargement. The retained water behind the structure can be used for lift irrigation and as drinking water for the human, cattle and wild animals. The anicuts recharge the downstream wells and the submergence area can be used for cultivation during the dry season. In a case study, the groundwater recharge was enhanced upto 35% during a period of three years by the construction of an anicut on an ephemeral stream near Jodhpur, Rajasthan.

In Gujrat, on the Saurashtra coast the anicuts not only recharge the sweet water into the surrounding area but also prevent the saline ingress towards the fertile and the valuable coastal areas.

Prevalence

The anicuts, check dams, Nala Bundig and Bundharas are similar structures and have been widely adopted in south-east Rajasthan, Gujrat, Maharashtra, Madhya Pradesh and in hard rock areas of deccan plateau. These structures have been in vogue since the old days and are very popular.

Details of system

a) **Design rainfall** : The anicuts are desinged on the basis of 50 years recurrence intervals i.e. the maximum rain fall occuring once in 50 years.

b) **Design runoff** : The design runoff is estimated by any suitable runoff formula applicable in a given region. The normally used runoff formula are :

Dickens formula

$$Q = CM^{3/4} \qquad (1)$$

where Q is maximum flood discharge (cumec), C is constant and equal to 11.40 and M is catchment area (Km^2)

Inglish formula

$$Q = \frac{10500A}{\sqrt{A + C}} \qquad (2)$$

where Q is maximum flood discharge (cusec), A is catchment area ($mile^2$) and C is constant which can be taken as zero in arid to semi-arid regions.

Rational formula

$$Q = \frac{C.I.A.}{30} \qquad (3)$$

Here Q is maximum flood discharge (cumec), C is coefficient, I is rainfall intensity (cm/hr) and A is catchment area.

c) **Anicut design**

An anicut is essentially consisting of two components viz. earthen embankments and masonry spillway. Local guidelines and design parameters have been developed for their construction by the soil conservation/irrigation Departments. These guidelines are region specific and to be consulted as per the site conditions. **Normally, an anicut is considered to be feasible when it is able to store 5 million cubic feet of water.**

Adaptability/Limitation

1. The anicuts are suitable in hilly and uneven topography where ephemeral streams are available and good catchments are present.

2. The subsurface formations must be receptive to the enhanced ground water recharge.

3. Good agricultural lands should be available on the banks, so as to make full use of the project, by providing irrigation.

4. The subsurface water must not be highly saline.

Recommendations

Each anicut must be provided with adequate overflow arrangement, absence of which is the main cause of their failure. The structure must be safe against sliding and overturning.

GULLY PLUGGING

Introduction

Gullies are a symptom of a functional disorder of the land, improper land use, and are the most spectacular type of soil erosion. As per the recent estimates 4 m ha affected by such problems in about 12 States. While another 4 to 6 m ha of table land, including some of the command areas, are threatened. However, with proper management the run off through gullies can be harvested for ground water recharge and human and livestock drinking. In western countries the gully plugging works started as back as 1900. However, in India such works were taken up on extensive scale since 1960 in Gujrat, Maharashtra Madhya Pradesh and Rajasthan.

Prevalence

Gullies and ravines (a system of gullies) are found along the rivers of Chambal, Jamuna, Mahi, Sabarmati, etc. and are mainly located in Utter Pradesh, Madhya Pradesh, Rajasthan and Gujrat. Gullies are also seen in the plateau region of Eastern India, along the foot hills of Himalayas and in Deccan plateau. All these areas require gully control and water conservation measures in the form of gully plugs, check dams and drop structures. Such works have already been taken up on a wider scale in these areas.

Details of system

The specifications and spacing are given in Table 1. Brick masonry gully plugs are constructed at the confluence of all gully branches of a compound gully. For gullies where no runoff is expected from the top, earthen gully plugs of 1.1 m^2 cross section with a grassed ramp of 22.5 cm below the top level and spaced at 45-60 m horizontal interval are suitable, for gullies in which excess runoff from the top is expected, an earthen gully plug of 2.2 m^2 cross section with a pipe outlet is to be provided. The diameter of the pipe shall depend on the catchment area (15 cm diameter R.C.C. spun pipe upto 0.03 to 0.09 cumec discharge from an effective catchment of 1.6 ha is suitable). A composite check dam of earth and brick masonry is necessary for larger catchments (more than 1.6 ha) which is located at the confluence of big compound gullies with the main drainage system or in the bed of the main drainage system at 1.2 m vertical interval or 120 m horizontal interval. These plugs should be taken into hard foundation and the flanks of the gully plug should be taken about 1.2 m inside the natural ground to prevent flood water outflanking the work. The surface runoff collected in th upstream of these plugs not only recharges the groundwater but also act as source for human and livestock drinking and for other domestic use.

Table 1
Specifications for materials and location of gully plugs in the gullies

Slope of gully bed (%)	Width of gully bed (m)	Location	Type of gully plug	Vertical interval (m)
0 - 5	4.5	Gully bed	Brush wood	3.0
	4.5 - 10.5	Gully bed and side branch	Earthen	2.25 - 3.0
	7.5 - 15.0	At the confluence of 2 gullies	Sand bag	-
	7.5 - 15.0	At the confluence of all branches of a compound gully	Brick masonry	-
5 - 10	4.5	Gully bed	Brush wood	3.0
	4.5 - 6.0	Gully bed and side branch	Earthen	1.5 - 3.0

Limitations/adaptability

The gully plugging is a site and location specific structure. Hence, general guidelines are to be modified as per the need for each such structure.

Preference of firm foundation below the gully bed is necessary to prevent structure from wash out.

Since these are smaller structures, no particular attention has been paid to them and hence these are neglected. In fact, the gully plugging structures involve a good knowledge of hydraulic engineering as these are fairly costly works.

Suggestions/Recommendations

1. Research work on small gully plugging structures using locally available materials like lime mortor etc. needs to be worked out.

2. Field manual for easy adoption need to be developed for use by the Soil Conservation Departments.

SUB SURFACE BARRIERS FOR ARTIFICIAL RECHARGE

In many of the dry regions in the world, adequate supply of water for irrigation as well as for drinking during dry seasons constitute a problem of paramount importance. Such supplies will depend on the storage in the form of surface reservoir or groundwater. The availability of groundwater invariably sustain on the recharge from various sources. Recharge of ground-water may take place directly from rainfall or from aquifer with intake outside the area or from sandy floors of ephemeral drainage channels. The second case is rare under arid climatic conditions. Recharge from direct rainfall is relatively less important in arid region because of high evaporation losses. The most estimates place it below 5 percent of rainfall. Moreover in sandy plains this recharged water seldom reaches the water table and likely it may be limited to the years of exceptional high rainfall.

The creation of surface storage reservoirs is often restricted by lack of suitable storage sites. Moreover the runoff drained by streams in these reservoirs is heavily loaded with suspended sediments which ultimately reduce the useful life period of the reservoir. Also the stored water is subjected to high rate of evaporation.

The rivers flowing ephemrerally often have wide beds and low banks. These wide beds, constituting the upper boundary of the previous deposits, form an excellent surface for infiltration during river surface flow. It has been reported that the infiltered water will penetrate the under lying rocks through suitable fissures, the outstanding example being in limestone areas. Recharge into alluvial fill is particularly important in pediment zones where it is favoured by the greater frequency and volume of flow and by coarseness of alluvium.

Recharge in desert areas, whether direct from rainfall or through stream flow will be irregular and discontinuous, reflecting the variable nature of rainfall and runoff. Wells located along the banks of streams show immediate response of recharge during the runoff in the streams but ceases during dry period with insufficient replenishment of the aquifer. The meagre recharge during runoff period does not sustain a sufficient long period due to which scarcity of water is felt. To some extent the yield of such wells could be improved by abstracting the sub-surface flow of Sandy bed streams, by sub-surface Semi-permeable barriers.

Description

Depending on geological history, many valleys in dry regions are filled with large deposit of coarse sands and gravels. In cross section these deposits are often bounded by impervious layers consiting of clay deposits and/or bed rock. During short duration of river surface flow through coarse sands and gravels, excellent infiltration takes place which in many cases replenish completely the coarse valley deposits.

The influent water from bank storage into the stream is, in general, negligible due to low banks. Once the surface flow ceases, the groundwater aquifer below the river bed could be considered as an entity, independent from river itself. Hence the sub-surface storage in sandy beds could be imagined as a long shaped aquifer under certain slope, yearly replenished and partly naturally depleted by evaporation and evapotranspiration by vegetation. In dry season the depletion due to these losses often not more than 1.5-2 m below river bed level. Hence for a sutained water supply of potable quality of water by improving the recharge conditions, the construction of sub-surface barrier across the stream section with infiltration galleries may be the most suitable and economical proposition.

The sub-surface barrier may be constructed with angular rock pieces arranged in the form of dry masonry wall having less interspaces and of one metre width and 5-7 m high and should be placed 1.5 m below the sand surface in the river bed. Such barrier should be extended 1 to 1.5 m below the summer static water level in the river bed. The height of barrier is site specific only, it may be increased or decreased as per the site conditions. The construction of sub-surface barriers could only be considered where topography, and slope of groundwater table and water bearing capacity of the aquifer render suitable conditions.

Investigation required

It is essential to undertake the following investigations before construction of the barrier.

1. Drilling of three exploratory bore holes along the proposed sub-surface barrier site. Proper lithological logs and samples should be obtained.

2. Electrical or Seismic profile survey along the site i.e. across the river section.

3. Calculation of existing draft from the area by actual field survey. These would help in proper designing and location of barrier and infiltration galleries.

Moreover after construction of barrier and wells the following investigations should be periodically under-taken.

1. Reduced level Survey of the area
2. Periodical changes in the quality of water
3. Changes in the draft pattern

Advantages

- Reliable source of water as a result of the yearly replenishment of the aquifer.

- In many cases the sub-surface flow will supply the basic needs for drinking water for human and livestock in the form of shallow holes dug in the river bed.

ABANDONED QUARRIES FOR WATER RESOURCES DEVELOPMENT

Introduction

Nearly 5000 km2 area in Rajasthan is under mining activity. The quarrying for building stones like sandstone, limestone, phyllite, slates, etc. are generally undertaken on hill slopes and most of the quarry pits are abandoned after surface mining. These pits can be used to develop additional water resources both as surface storage and enhanced ground water recharge.

Prevalence

Quarrying of building stones is prevailing in and around the Aravalli mountain system and in the western Rajasthan. These areas also have the abandoned pits and mine spoils which can be developed into water bodies.

Details of the system

Development of water bodies depend on the quality and quantity of water available in nearby area, if the mine has not reached a depth of ground water level. Also on the magnitude of the excavation, rainwater could be harvested to fill up these pits. These water bodies provide additional drinking water source and augment the ground water resources. It may be necessary to reduce the seepage losses, if recharge to aquifer has not been envisaged within the plan. This could best be achieved by using low cost material like pond silt and clay etc.

Likewise reduction of evaporative losses from the pits converted into ponds will be essential. Use of monomolecular films/wax blocks/concrete blocks/plastic sheets, etc. should be tried. the quarry pits could also be filled with rock debris and sand to create an artificial ground water resource. Development of water resources through use of abandoned quarry pits will not only rehabilitate the mining area but also provide the water for drinking and other domestic use.

Limitation/adaptability

This system of water harvesting has potential to be adopted in abandoned quarrying pits and mines throughout the country. However, the system is site specific and needs few corrective measures before put to the use.

CONTOUR BUNDS

Countour bunding is one of the Soil and Water Conservation measures, carried-out for watershed management programme. The term contour bunding used in India is same as level terraces and 'ridge type terraces'. Mainly contour bunds act as a barrier to the flow of water and at the same time impounding water increases soil moisture. Selection of site for bunding should be done judiciously. For an example contour-bunding in deep black soils failed due to wide spread breaches and water stagnation for longer period due to poor infiltration etc. In such soils, it was recorded, the yield of every crop in contour bunded areas were lower than the unbunded areas. On the other hand contour bunding done in areas having rainfall less than 60 cm and soils were permeable, contour bunding assisted in intercepting the overland flow and made it to infilter into the soil. Hence it can be said that contour bunding has its adoptability and limitations, which should be given a due consideration. The maximum depth of impounding for contour bunds in permeable soils can be arbitrarily fixed as 30 cm where the depth is more than 30 cm. arrangements should be provided so that excess water can drain off safely.

Two types of contour bunds can be constructed i.e. (1) Narrow based bunds (2) Broad based bunds. Narrow based bunding in agriculture lands is normally not prefered due to considerable hinderance in farming and transportation of equipment from one terraced field to another. Moreover the narrow based bunding waste more than 6% of area from cultivation. Broad based contour bundign has advantage of causing no hinderance in farming as well as entire area remains under crop production. Therefore narrow based bunding should be carried-out in grazing lands/westelands, so as to control damaging runoff and to utilize the same for useful purposes.

Specification of contour bunding

1 **Spacing** : The main criteria for spacing of bunds, is to intercept the water before it attains the erosive velocity. This will depend on many factors, important of them are slope, soil, rainfall, cropping programme and conservation practice adopted. Based on the field observations and experiments, C.E. Ramsar, established the general equation for sub-humid areas of united states.

$$VI = 0.3 \left(\frac{S}{3} + 2 \right)$$

where

VI = Vertical interval in metres in between two consecutive bunds
S = degree of slope in percent

In the above formula no consideration was given to other factors than slope. To take into account some other factors, the following adjustments were suggested.

a) **Adjustment for soil infiltration & permeability**

25% extra spacing can be provided above the mean VI' in soils having high infiltration and permeability and good follow on consrvation practices are adopted which include contour farming, frequent use of legume in rotation.

15% decrease in spacing where soils are of low rates of infiltration or permeability. Practically when used with unfavourable cropping conditions.

b) **Adjustment for rainfall** : Rainfall intensity and its erosive power is more important than the annual rainfall. Based on USDA-SGS recommendation for level terraces, vertical interval can be determined by equation.

$$VI = 0.3\,(0.8S + Y)$$

where,

VI = Vertical interval in metres
S = Slope of ground in percent
Y = A variable with value from 1.0 - 2.0 depend upon the soil erodibility, cropping system and crop management practices.

Vertical spacing by any method can be increased by 10 cm or by 15 cm to provide better location, alignment or to miss the obstacle. In case small strip is left in between the last bund and field boundary, the vertical fall may be distributed in all the bunds rather than in only last bund. Moreover in the field, having undulations, some deviation has to be made. These deviations causes uneven impounding of water which may result the potential danger of breach. It is always desirable to remove these local ridges and depressions by levelling prior to alignment of contour bunding. If levelling of local ridges and depression is not possible due to cost factor, the limit of deviation can be adopted as 10 cm higher elevation side and 20 cm for crossing the depressions In field, having narrow gullies, may also be checked by providing one or two earthen gully checks for effective bunding.

c) **Cross sections** : Normally cross section is designed (i) 30 cm depth impounding near the bund (ii) height to store 24 hours rainfall of particular frequency (i) with 30 cm depth of impunding : the dpeth of impounding is designed as 30 cm; 30 cm is provided as depth of flow over the outlet and 20 cm is provided as free board. This makes overall height of 80 cm. With top width of 0.50, side slope 1:1, and bottom width of 2.10, cross section works out to be nearly 1 sq.m. Contour bund of cross section of 1 sq.m. is suitable for low rainfall areas with permeable soils.

The broad based bund shuld have settled height more than 30 cm (preferable 50 cm). The easeness in farming increases with decrease in side slope which may be taken upto 8:1. Normally a triangular section is assumed and under cultivation the shape will become parabolic.

Cross sectional area in sq. metres of broad based contour bunding with different height and side slope.

Height of bund	Side slope				
(m)	4 : 1	5 : 1	6 : 1	7 : 1	8 : 1
0.30	0.36	0.45	0.54	0.61	0.72
0.40	0.64	0.80	0.96	1.12	1.28
0.50	1.00	1.25	1.50	1.75	2.00

d) **Design of cross section of contour bund to store runoff from 24 hours rainstorm of particular frequency** : The design of cross section of contour bund which can store runoff excess from 24 hrs. rainstorm can be done with the help of the following equation.

$$h = \frac{Re \times VI}{50}$$

Where,

h = depth of impounding in metres near the bund

Re = 24 hours rainfall excess in cm.

VI = Vertical interval in metres

Using the above equation, height of impounding required for 10 years frequency (or any other frequency) can be obtained which will not cause any spill over. In depth of impounding 'h' the free board of 25 to 30% may be added. Once the height is fixed, then using the minimum top width of 0.50 m and side slopes 1:1, the cross section of narrow base contour bund can be obtained.

SAND-FILLED RESERVOIRS

In many arid and semi-arid lands, harvesting and storing rainwater in surface reservoir or village tanks, being practiced over centuries is still the major source of water supplies in remote areas for human and livestock consumption. A large share of this precious water gets lost through evaporation from free water surface of tanks leaving people to struggle for water during lean period.

Sand-filled reservoir system of water harvesting is being practiced for storing water in pores between the particles of material below ground surface level to shield it from the evaporation. In arid environments such as Indian desert where rainfall is scanty, annual average evaporation far exceeds the annual average rainfall and most of the rivers are ephemeral with abandoned sand and gravel, sand filled reservoir may be an additional source of water supply.

Historical background

Sand filled reservoir system of water harvesting is an old practice in many African and South American countries. In South West Africa this system has been developed on a large scale for fresh water supply in sustained manner for reasonable period.

Water use from rived bed was first initiated in 1849 in South West Africa but first sand-filled dam was constructed in 1886. In Namib desert sand filled dams have been used since 1907 for supplying drinking water to livestock. Sand filled water storage tanks developed in Sudan are in use for rain water harvesting from an early time. Recently plastic lined rockfilled tanks were built in Arizona, U.S.A. for evaporation control. In India, this technology is yet to be tested.

Constructional details

(A) Sand/Rock-filled tank

Sand/rock-filled tank is constructed in lower valley of rocky hilly area or lower part of stoney/gravelly or rock out cropped catchment area. The size of tank depends upon rainfall pattern, catchment characteristics and water requirement.

The tank is first excavated in desired shape and size and surface is made smooth. The sides and bottom of tank are lined either with stone masonry and cement plaster or polyethylene sheet or any other materials for seepage control. Polyethylene lining if properly covered, offers positive method of seepage control. A wire mesh reinforced coat of cement mortar or tiles or a 30 to 45 cm layer of soil could be used to protect the polyethylene from getting punctured with rocks. A pukka silt trap at the inlet of the tank is provided to arrest silt load entering in the tank. The tank inlet and outlet are stone pitched to check soil erosion.

The tank is filled with sand and loose rocks. Rain water harnessed from the catchment area is collected and stored in the tank between the particles. Water level in tank is kept 30 cm below the surface to shield it from evaporation. The rocks reduce the tank volume by about 55% but they reduce evaporation by 90 percent. Water supply from the tank is maintained by installing shallow tube well, or hand pump or by constructing small diameter exploitation well in the tank with withdrawal arrangements.

Sand-filled tank can provide good quality water for a logner period than conventional open storage.

(B) Sand-filled dam

Sandy river beds with no surface flow, except in flood seasons, are a common feature of arid and semi-arid regions. The creation of water supplies by conserving surface run off in sand is an equally important aid to development.

Sand-filled dam is basically a sub-surface barrier used for storing water in sand bed, for water supply and for ground water recharge in the near vicinity. The dam is built across the river bed during the dry period. The river bed is filled with sand and gravel depsoits carried by river flood during monsoon seasons. Flood water is stored in the basin between the sand particles. Initially the dam height is kept few centimeters above the stream bed and as the reservoir get filled up with sand and gravel the height is raised gradually in stages. The basic principle involved in raising dam height in stages is to allow velocities of flood through the basin to transport most of the fine sediments over the dam crest which otherwise get deposited in the reservoir, thus, its storage capacity is reduced. In certain cases provision of siphon in dam helps during large flood period in scouring and flushing off silt deposit in the basin area.

To increase effectiveness of storage, water stored in upper reaches of the reservoir is guided and drained to a common draw off point. The sand body from which the pump station draws its supply is deprived of the replenishment by natural seepage which occurs at a comparatively steady rate.

Storage efficiency of sand-filled reservoir

Storage efficiency of sand-filled reservoir depends largely upon porosity of material (sand and rock) in tank, rate of useful draw off, depletion time etc.

$$\text{Efficiency of storage} = \frac{\text{Useful draw off}}{\text{Volume of water absorbed}}$$

The porosity depends on the size and shape of grains, uniformity of grain size and compaction. Higher porosity are available in freshly deposited silt. Silt deposits become consolidated in time through weight of overlying material alternate drying out and inundation, wave action etc.

The specific yield also depends upon grain size of the material. Central Arid Zone Research Institute, Jodhpur has studied in laboratory, the specific yield of different combination of materials. The following values were obtained :

Diameter of grain (mm)	Specific yield (%)
1. ≤ 1.17 (47%) 6.35 - 12.70 (53%)	39
2. ≤ 1.17 (50%) 12.70(50%)	43
3. ≤ 1.17 (10%) 12.70(20%) 25.40(70%)	48

Higher specific yield was obtained with bigger grain size of material.

Limitations of sand-filled reservoir

1. Deposition of fine sediment load in the reservoir transported by run off water reduces its storage capacity. Evaporation losses from the reservoir are also increased as a result of favourable capillary action of the deposited material.

2. Run off water received from salt affected catchment area deteriorate the quality of stored water as well as ground water.

3. Construction of sand-filled dam reduces recharge of aquifer in down stream of river.

Suggestions for improvement

1. The catchment area of sand-filled reservoir should be rocky hills with eroded channel or stoney gravelly waste land with sufficient slope for generating run off to be stored in the reservoir.

2. Run off from the salt affected area should not be allowed to enter in the reservoir so that good quality water is available for water supply.

3. Industrial waste or sewage water should not be allowed to enter in the reservoir to save water from contamination.

4. Movement of livestock should be restricted from reservoir site to control water pollution in the reservoir.

5. In case of sand-filled dam, the dam should be built on streams with deep courses and heavy discharges for flushing out fine sediment which otherwise get deposited in basin and reduces its storage capacity.

6. Water in the upper reaches of basin should be guided and drained to a common draw off point to increase the effectiveness of storage reservoir.

7. Provision of siphon at the dam wall will increase the transporting power of the floods passing through the basin.

8. Plantation of trees and grasses in the catchment area of sand-filled reservoir will check erosion and also environment around it will be improved.

9. Open wells in near vicinity of the storage reservoir should be dug out for additional supply of good quality water as a result or recharge of aquifer.

Future of sand filled reservoir

In arid environments such as Indian desert where numerous small but dependable water supplies are required, sand filled reservoir system of water harvesting is worth encouraging.

FLAT BATTER TANKS

History

Flat batter tank system of water harvesting is relatively new technique, developed in mid sixties by farmers and contractors in the Esperance district, Australia. The technique has similarities with the "dew pond "system" in East Yokshene, England, and have since been rendered obsolete by reticulation.

Flat-batter tanks are yet to be tested in this country.

Details of the System

The flat batter tank is the standard water harvesting technique where the catchment is an integral part of the storage. The tank is excavated in the centre of the field. Top light-textured soil is removed and placed around the outer extremity of the flat batter in a wedge shape. The clay from the lower in the excavation is then taken out and spread over the whole surface and faced so as to form a clay smooth blanket 5 to 15 cm. thick. The grade on the batter is about 1 percent with relatively impervious surface which drains back into the tank. A raised wall around the lip of excavation is made to guide the run-off entry into the tank by means of pipe or chute. This reduces erosion developed at the point of entry. Above ground storage can sometimes be gained by fixing a stopcock in the pipe. This can be achieved by closing the cock and pumping over the wall.

Flat batter tanks are either square (four way) or circular type. In square batter tanks, common catchment batter sizes are 30 m and 40 m from the edges of excavation and storage capacity of tank are in the range of 2,000 to 3,000 m³.

Circular batter tanks are being constructed with a radius of 100 m from the centre of excavation to the outer edge of the catchment - a total area of approximately 3.2 ha. The area of flat batters surface are approximately 3.0 ha and 8.0 ha for storing 5,000 m³ and 1,500 m³ water, respectively. Run-off in the tank, comes solely from the batters. Run-off from near by natural catchment or additional improved catchment, such as roaded catchment is also possible to divert or pump into the tank.

Advantages of Flat Batter Tanks

The main advantage of flat batter tank is that the catchment, being an integral part of the tank, comparatively little space in required. They can be developed on sites that lack sufficient size to accomodate conventional tank and catchment. The other advantage is availability of good quality water as run off is received only from the treated catchment.

Limitations

1. The capacity of storage is large relatively to the size of catchment; consequently, water level rarely reaches full supply level.

2. There is no provision of arresting silt at tank inlet, therefore siltation in tank takes place and need regular cleaning.

3. In absence of protective measures for seepage and evaporation control, water losses from the tanks are high.

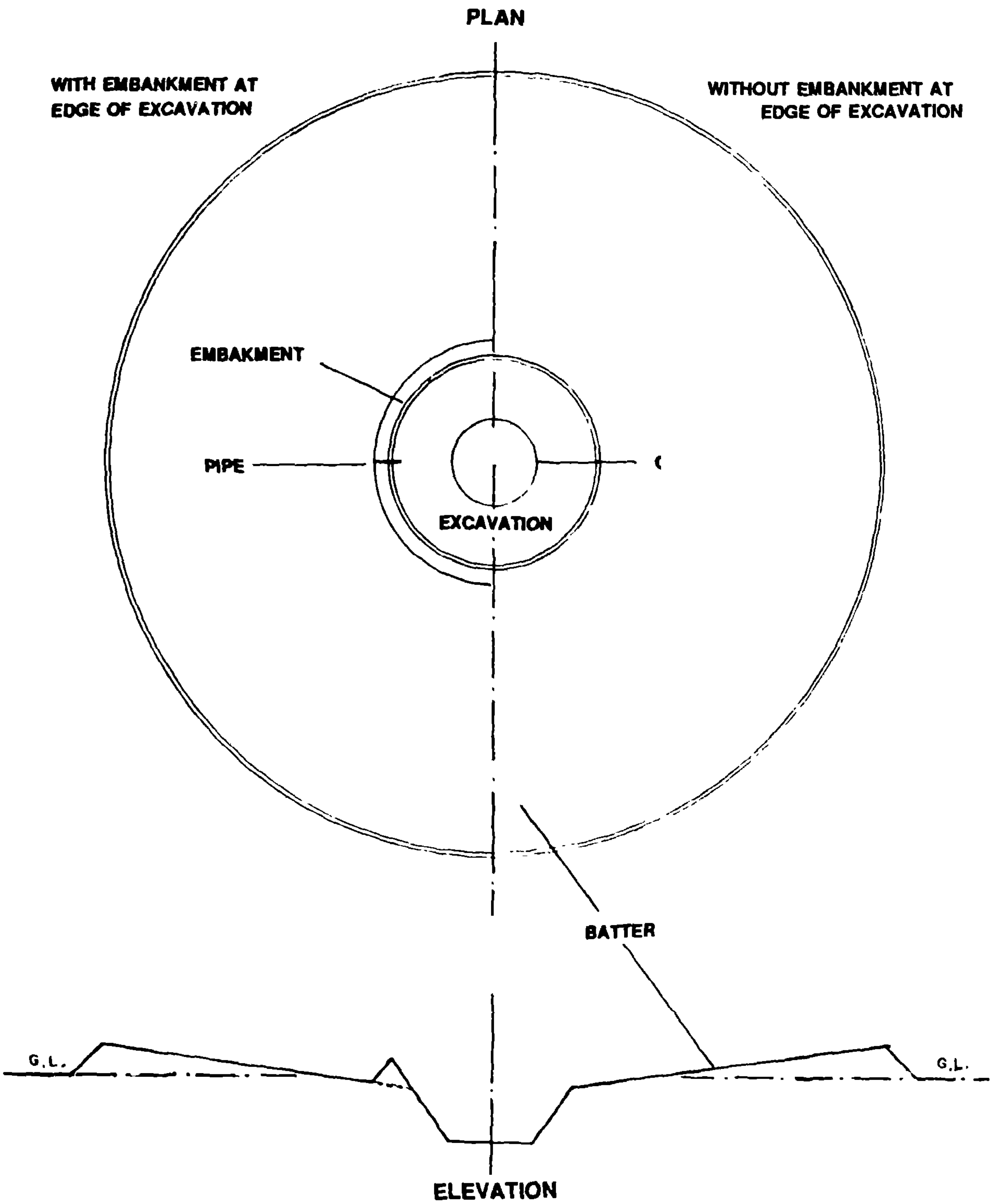
Suggestions

1. The system should be developed on a fallow waste land with sufficient clay material available from the excavation for preparing semi-impervious catchment. Catchment treatment with Janta emulsion or sodium carbonate or any other suitable sealant will help in generating more runoff from the same area.

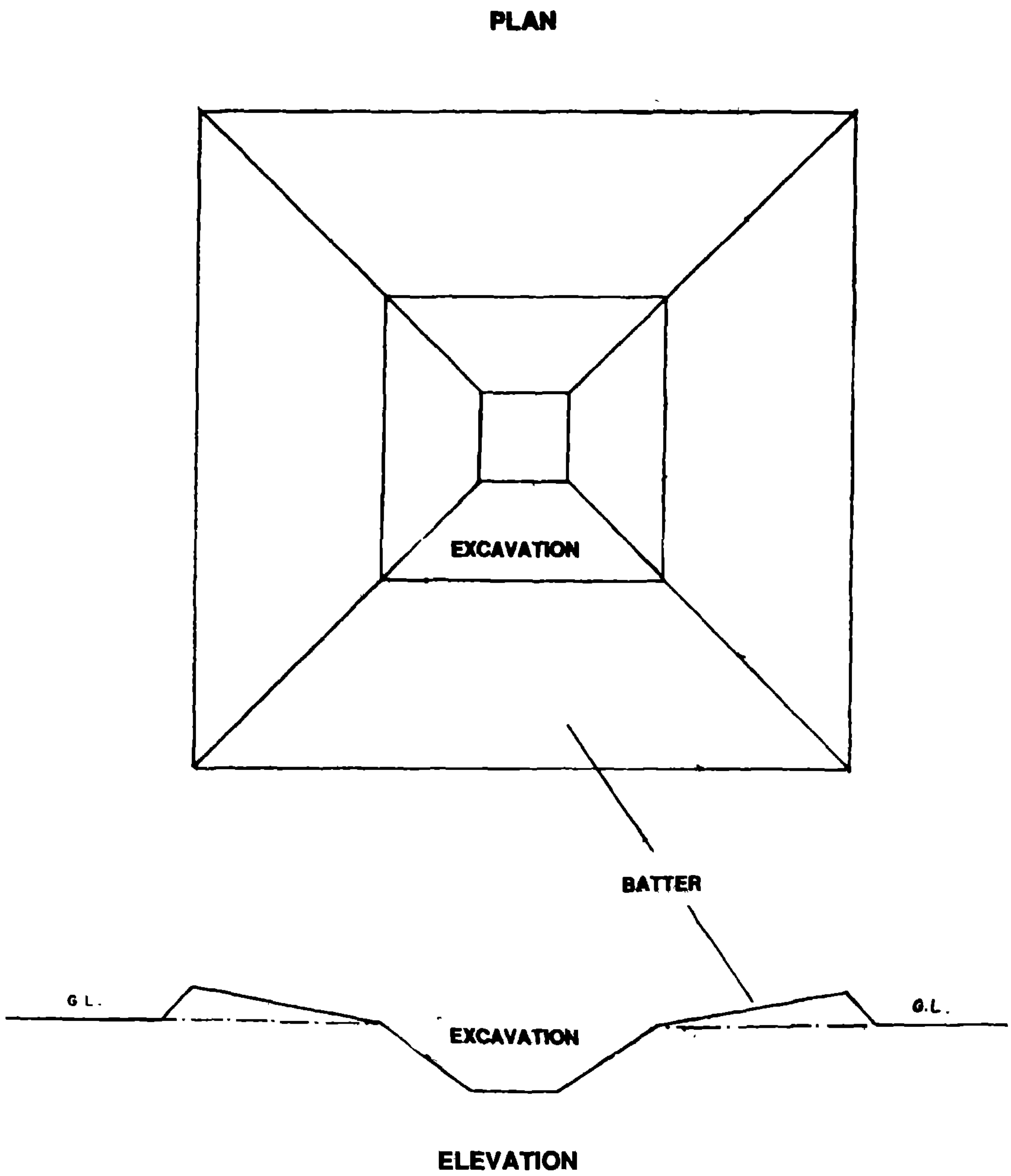
2. In case runoff available from the flat-batters is not sufficient to fill the tank, runoff from additonal adjoining area should be guided or pumped over in the tank.

3. silt-trap at the inlet of tank should be constructed to arrest the silt load which otherwise will be deposited in the tank.

4. Tank walls and bottom should be lined for controlling seepage and percolation losses from the tank.



CIRCULAR FLAT BATTER TANK



SQUARE OR FOUR WAY FLAT BATTER TANK

5. Movement of animals in the catchment area should be restricted for controlling water pollution.

Research Required

Flat batter tank system of water harvesting is a new technique to this country and therefore, there is need for intensive evaluation of the system for establishment of catchment and storage ratio in different agro-climatic zones, storage efficiency, techno-economics etc.

ROADED CATCHMENTS FOR MAXIMUM RUN OFF

To provide reliable run off, a water harvesting catchment needs to be impermeable, smooth and have little depression storage. However, sealing the soil surface is expensive and some infiltration losses must frequently be accepted. In these cases, ground forming can increase the run off yield by improving the hydraulic efficiency of the catchments and thus reduce the time available for infiltration to take place.

One type of formed catchment that is widely used in western australia and to a lesser extent in other States, is so called roaded catchment. This consist of a series of parallel formed and comapcted roads with exaggerated camber that adjoin to make approximately V-shaped channels which discharge into a collecting drain at their lower end. Cambered steepy road surface is made as smooth and impervious as possible. Drains between the roads are on grades that permit water to reach the storage structure expeditiously with minimum erosion.

Site selected should not be more than 400 m far away from the water storage structure and also should consist of clay soil or clay subsoil within not more than 1 m of the surface (loose sands and gravels, loams and friable self mulching clays are unsuitable materials for surfacing catchments). Also the surface slope that allows the catchment drains to be aligned on correct grade.

Individual roads may vary from 5 to 12 m wide (crest to crest) and from 50 to 300 m long. Where ground slope is little more than the grade of road drains, roads can discharge directly infront of storage structure. If number of roads are constructed as per the size of catchment requirement, they can be provided with a collecting drain.

On slopes of more than 3 percent, collecting drains of the required grade would meet the road drains at an angle too acute to be conveniently constructed. On steeper slopes, roads are usually discharged on a grass water way leading to the storage structure.

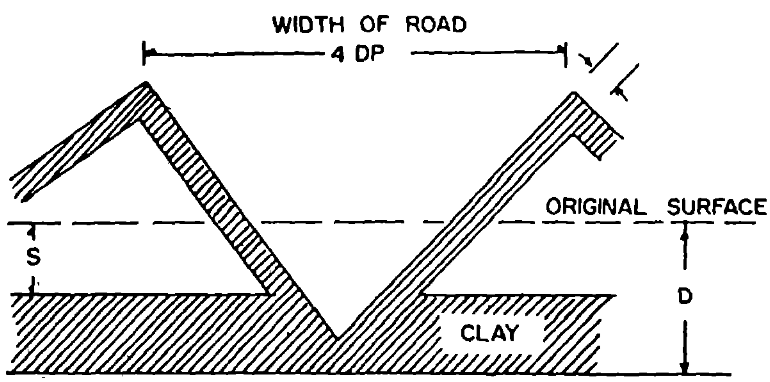
The above specifications will further be influenced by considerations of ground conformation, depth and availability of clay sub-soil, distance and height difference between the storage structure and catchment and thickness of clay cover desired.

Frith and Nulsen related depth of road drains to depth of top soil and thickness of clay required to cover graded top soil, as follows :

$$2\,C = \frac{D^2 - 2\,DS + S^2}{D + S}$$

Where

C = thickness of clay cover
D = depth of road drain below original ground surface
S = depth of top soil
P = reciprocal of the side slope of road surface



Frith and Nulsen suggested that an effective cover thickness of 7.5 cm might be required where a power grader was used for construction. It has since been found that mixing of top soil and subsoil clay during construction is increased when larger depths of top soil are present. Current practice is, therefore, to design for an effective 15 cm thickness of cover where depth of top soil exceeds 20 cm.

Road side slope is made as steep as possible. It can approach 25 percent, but limitations of rollers used for compaction often reduce it to 20 percent or less. If a steel roller is used and a smooth hard surface results, side slope of 10 percent are probably quite satisfactory.

Water harvesting system with roaded catchment in India

In Banni area of Kachchh district where rainfall is meagre, surface slopes are negligible, soils are saline (silty loam to silty clay loam - calcareous) construction of conventional water harvesting structures does not appear to be feasible. For such areas, providing of roaded catchment has been considered to be technically possible. The structure could be planned to have storage for 2-3 years, keeping in view the water supply requirement and evaporation losses. The proposed work in Banni area is at conceptual stage. The available cost estimates indicates a roaded catchment of 0.17 million sq. m and required water supply source works could cost about Rs. 9.11 lakhs. The likely storage water is estimated to be nearly 9000 m^3 which brings the cost of nearly Rs. 1 per cubic metre of water.

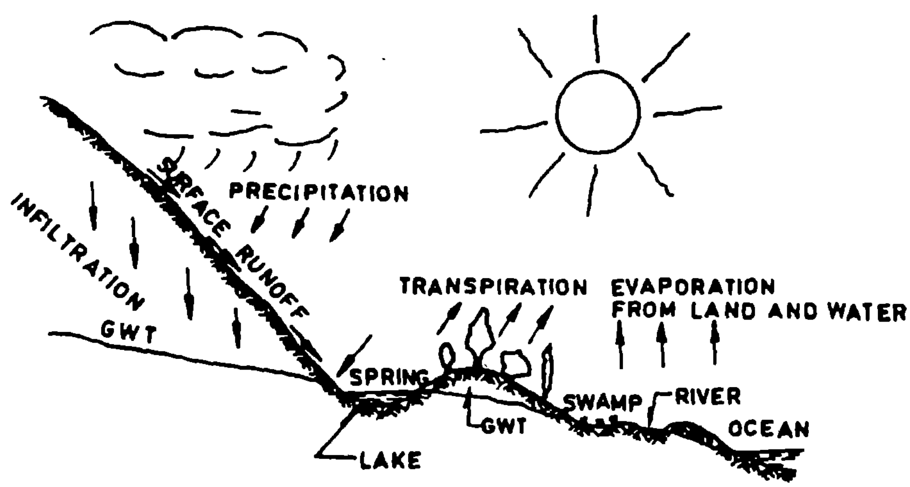


Fig. 1 : HYDROLOGICAL CYCLE

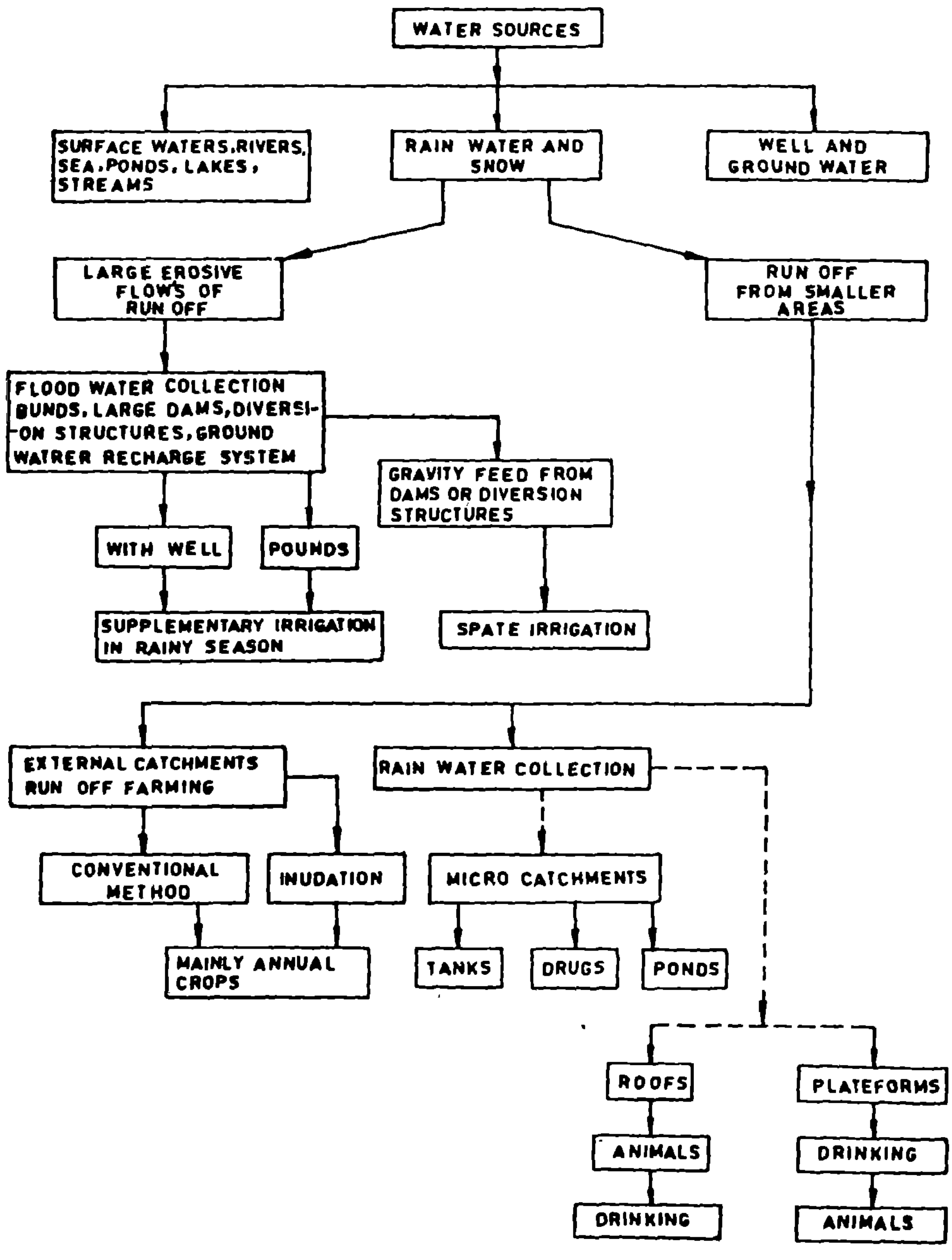


Fig. 2 : WATER SOURCE AND CONSUMPTION

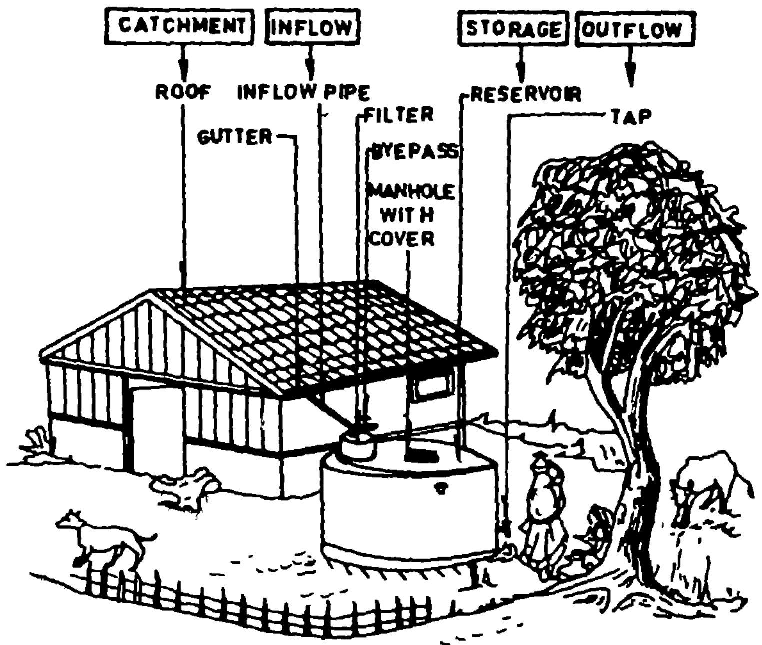


Fig. 4 : RAIN WATER COLLECTION THROUGH ROOFS

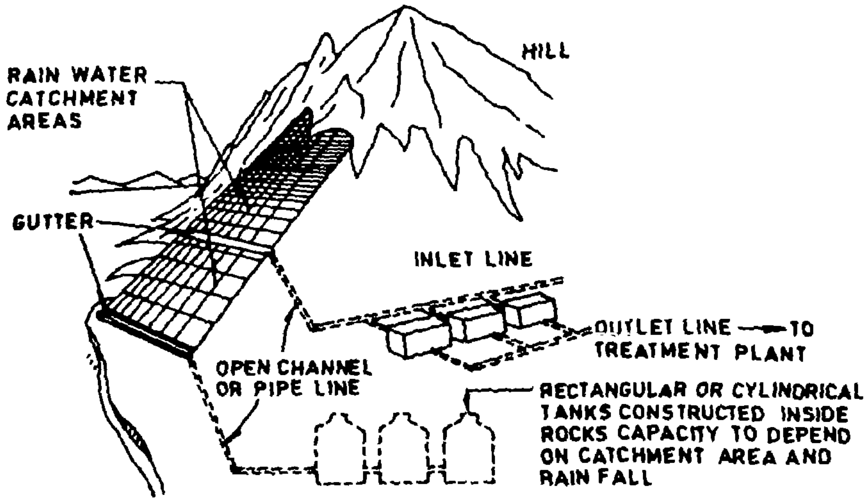


Fig. 6 : RAIN WATER COLLECTION THROUGH HILL SLOPES

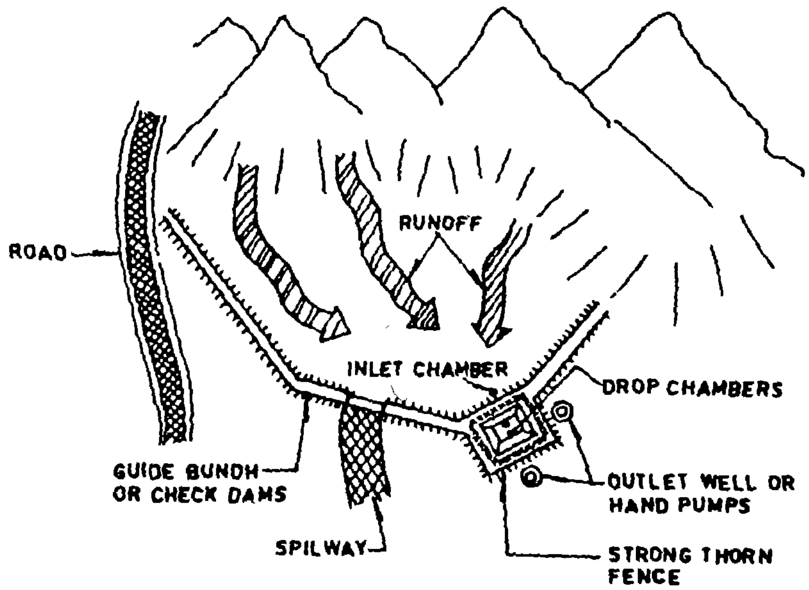


Fig. 5 : RAIN WATER COLLECTION THROUGH WATER SHED MANAGEMENT

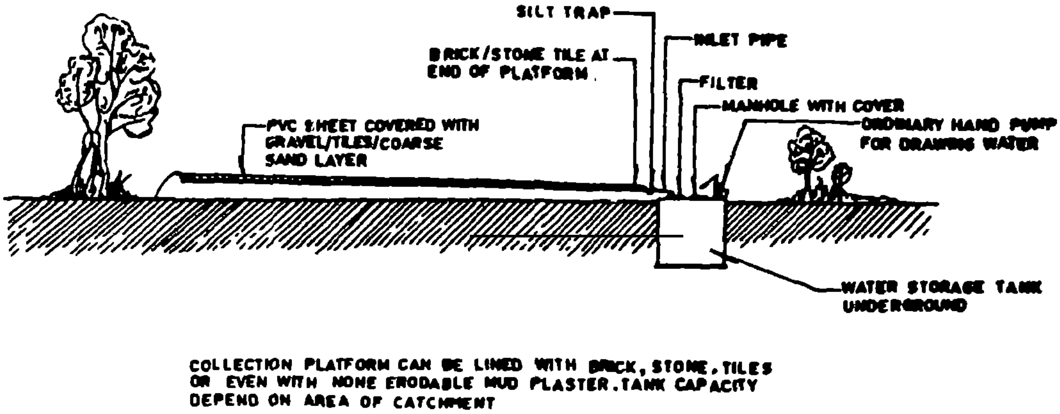


Fig. 7 : RAIN WATER COLLECTION SYSTEM PLATFORM CATCHMENT

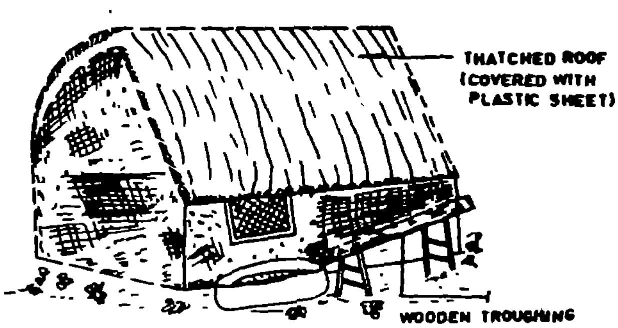


Fig. 8 : ALTERNATIVES TO GUTTERING-GLIDES AND LOW LEVEL TROUGHING

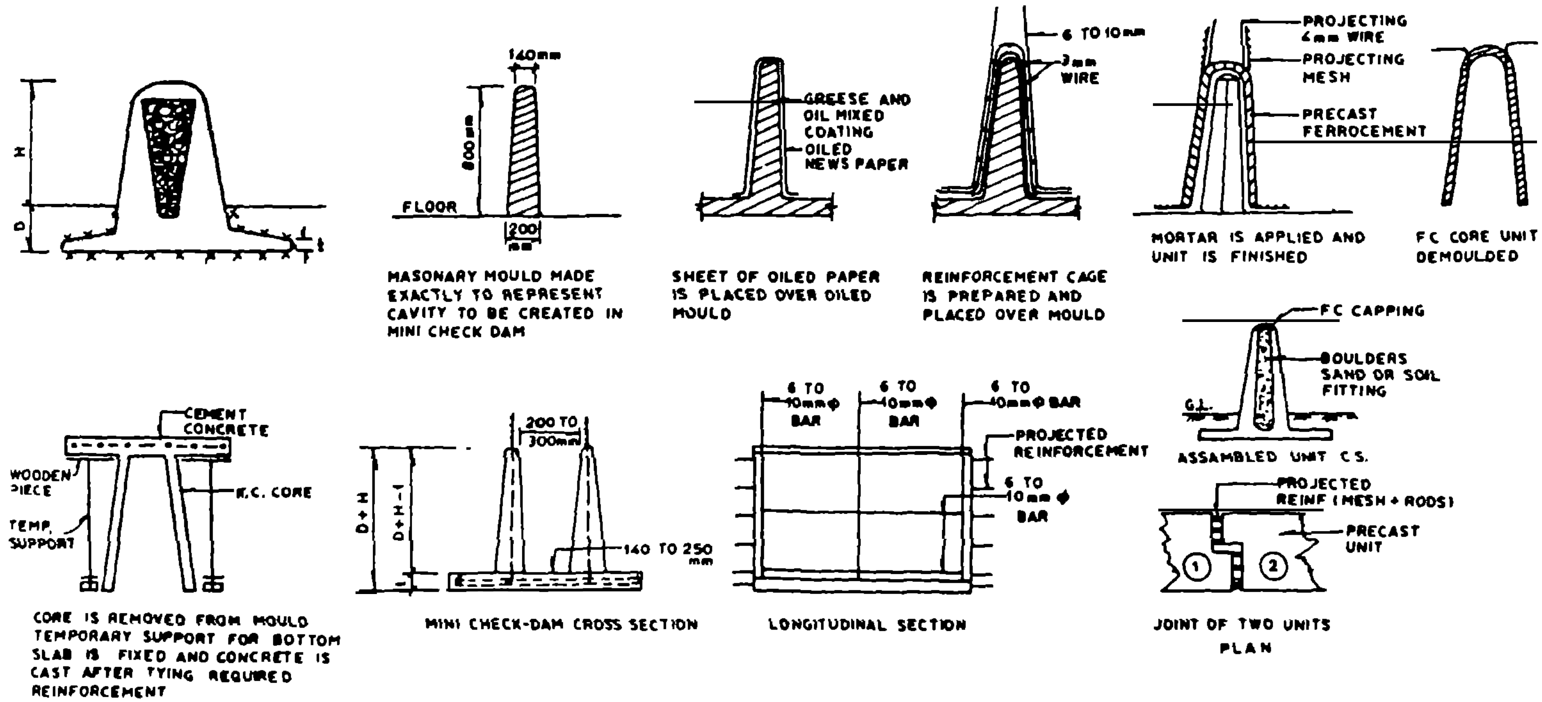


Fig. 9 : FERROCEMENT MINI CHECK-DAMS DEVELOPED AT S.E.R.C.

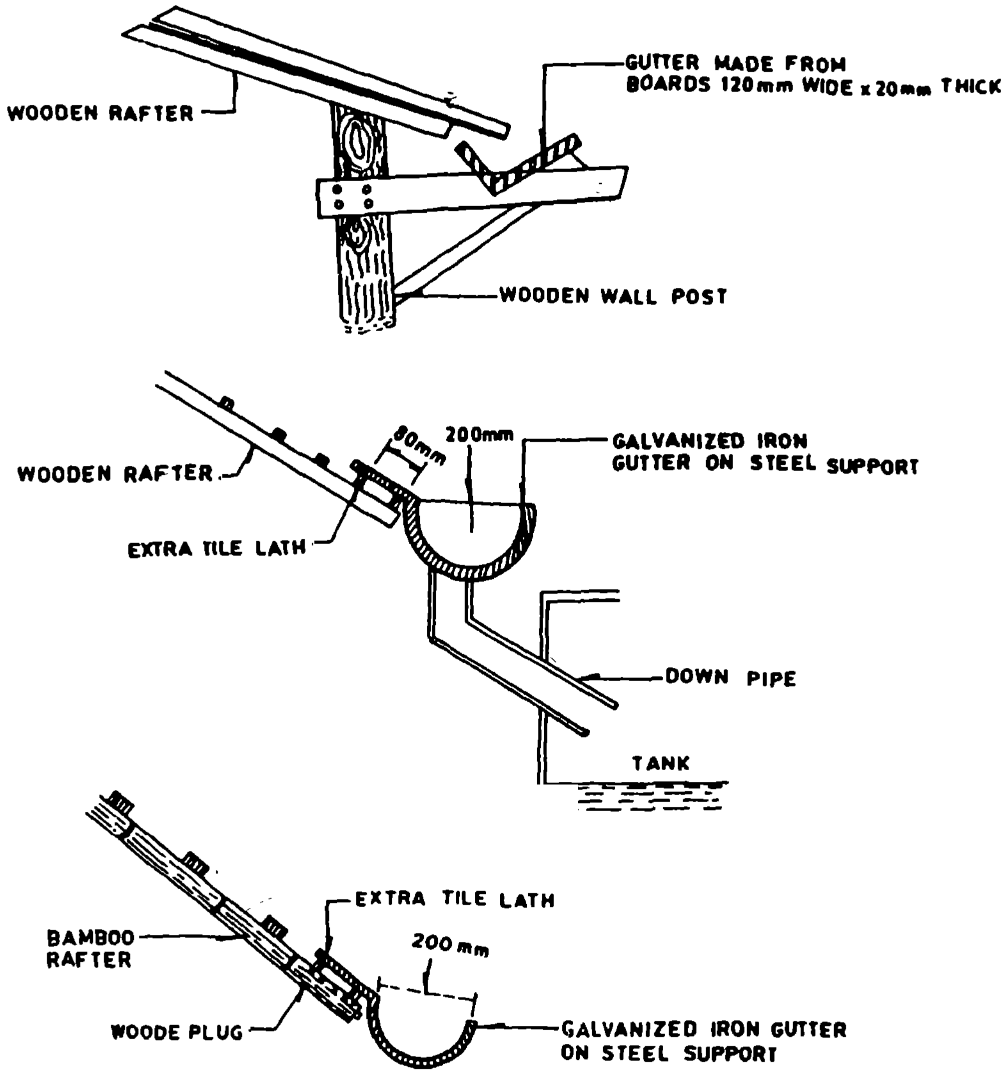


Fig. 10 : METHOD OF FIXING METAL GUTTERS AND TO WOODEN GUTTERS TO WALL POSTS. WHERE RAFTERS ARE MADE OF BAMBOO, THE HOLLOW ENDS OF THE RAFTERS NEED TO BE PLUGGED WITH WOOD BEFORE LATHS ARE ATTACHED TO CARRY THE GUTTER

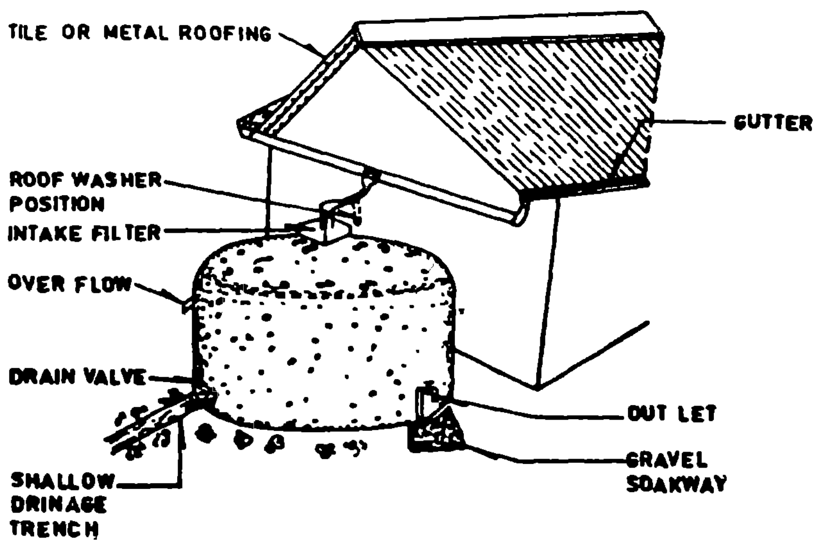


Fig. 11 : DOWN-PIPES FOR COLLECTING WATER FROM BOTH SIDES OF PITCHED ROOFS

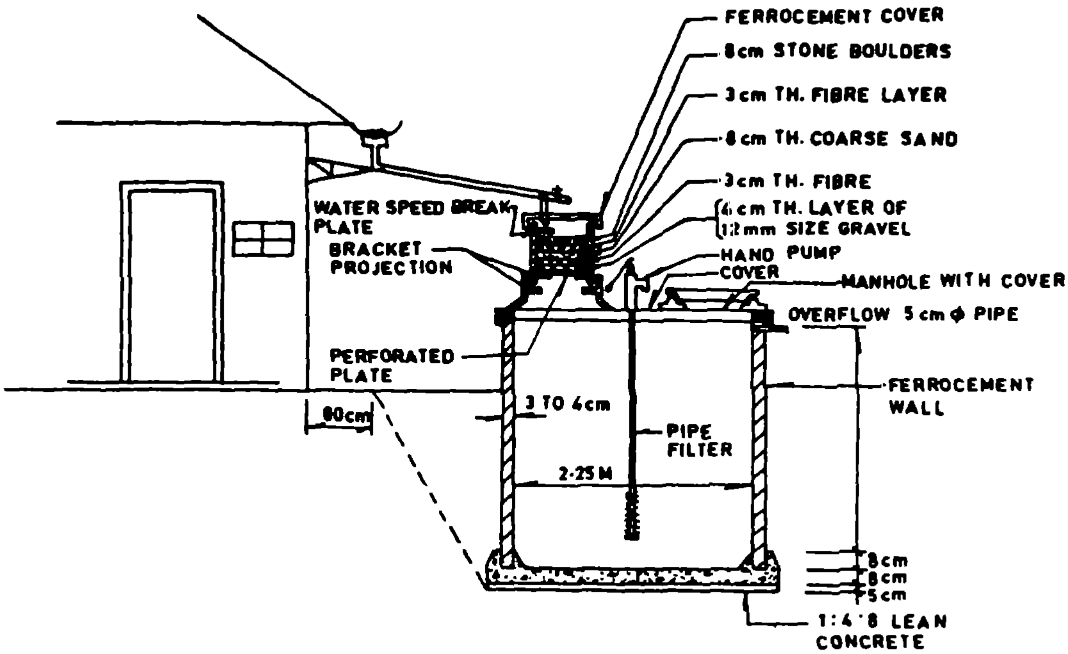


Fig. 12 : BYEPASS SYSTEM & FILTER

RAIN WATER HARVESTING

Rain water collection is also practical since ancient time on 'Microcatchment Principles' that is the runoff from :

(a) roofs;

(b) artificial surfaces at ground level and

(c) land surface with slopes less than 50 to 150 m in length.

The collection of rainwater from Microcatchments for water supply involves not only the collection of rainwater, but also its safe storage in a reservoir.

A rainwater harvesting system (RHS) consists of the following components :

1. **Catchment areas — It is the collection surface**

   (a) Roof
   (b) Rainwater platforms
   (b.1) Raised platforms
   (b.2) Ground catchment with underground cisterns (Tankas)
   (c) Hill slopes
   (d) Watershed management

2. **Inflow Structures**

   (a) Gutter - For collection of rainwater
   (b) Inflow Pipe - For transferring rainwater to reservoir
   (c) Filter - For filtration to remove pollutants

3. **Storage Tanks — For storage during periods of insufficient rainfall**

   (a) Above ground
   (b) Under ground

4. **Outflow**

   (a) Tap for the over ground tanks
   (b) Hand pump or bucket pulley system for underground tanks

Since safe drinking water supply method will be required by large number of people, its designs has to be geared towards mass production which means that it should be simple and economical so that people can afford.

1. RAIN WATER HARVESTING PLATFORMS

Platforms or high level earth deposits sloping to one side provide a good surface for collection of the rain water. The following precautions need to be strictly followed :

(1) Area used is kept away from the approach of animals.

(2) It is kept completely free from faecal contact — the area may be prohibited for easing of human beings which is common practice in our villages.

(3) Platforms are cleaned and maintained properly by the owners.

(4) Inlet levels of tanks installed for these systems is kept sufficiently above the ground level so that surface runoff do not enter the tank inlet.

Platforms are provided with some lining or top surface covering for preventing turbidity in the water collected. Plastic sheet lining with bamboo strip frame for keeping it in position, soil cement lining, brick lining, covering with a layer of grit or coarse sand or covering with bamboo mats are some of the methods which could be adopted depending upon area. Plastic sheet covering with a bamboo or any other local wood strips or tree branches is preferred due to easy to carry out method. Normal plastic sheet may serve only for two to three years if left exposed to sun specially during summer. Soil cement lining will be suitable as it may work for very long periods and will not have any maintenance problem though its initial cost may be higher.

2. INFLOW STRUCTURES

i) Gutters

This is a type of hanging or supported drain in which the rain water enters after flowing over the catchment area. Number of gutters will depend upon the type of roof. In one slope roof system, only one gutter will be needed. The water from roof is collected into a gutter, of size suitable for carrying the full quantity of rainwater coming over the surface of the roof, and conveyed to the pipe connecting the gutter to the tank. The size of the gutter is selected according to the flow of water during higher intensity of rain. It is advisable to provide gutter of 10 to 15 percent additional capacity.

The gutter could be made using :

(a) Plain galvanised iron sheet of 18 to 22 gauge thickness. Thin sheets are not used as the number of the gutter supports will have to be increased in such a case. The gutter edges should be reinforced by bending the edge and fixing G.I. wire in it.

(b) Half cut PVC rigid pipe, provided the skill for PVC pipe jointing is available.

(c) Half cut bamboo, cleaned from inside.

(ii) **Inflow Pipe**

Inflow pipe is the pipe which connects the gutter to the water tank/reservoir, G.I. sheet fabricated pipe, rigid PVC pipe or galvanised iron pipes of class 'A' may be used as inflow pipe. The size of pipe is to be selected in such a manner that it can carry the water collected. The minimum diameter of pipe is kept as of 100 mm. The distance between the roof gutter and reservoir is kept minimum by adjusting the position of the tank/reservoir. M.S. Pipes are not used for this purpose to avoid corrosion.

A bye_pass arrangement (Fig. 4, 11 & 12) is necessary to be provided at the point where this pipe is connected to the filter. This is needed for removing out water received during first 15 to 20 minutes rain from the roof. This can be done using two methods :

1. By providing a removable canvas pipe connection between two sections of the inflow pipe.

2. By making an inbuilt stopper for stopping water entry in the filter and conveying the water into a byepass pipe carrying water outside the system. For preventing entry of first rain for few minutes, the stopper at filter end is closed and the stopper at byepass end is opened. After few minutes of rain, the byepass stopper is closed and stopper at filter is opened.

By operating the byepass system, the water bringing dust and other undesired matters from the catchment area is made to flow out of system and its entry in the tank is prevented.

Fig. 10 provide details of fixing for Gutters in various roofs.

The point, where the gutter is joined to the inflow pipe is kept enlarged for preventing overflow as at this point water flowing with speed has to change its flow direction and may splash out (Fig. 11).

The pipe leading from the gutter to the reservoir is raised about 1 cm above the bottom level of the gutter for enabling sediments to settle in gutter itself rather than entering into the tank. Raising the pipe by 1 cm is for preventing mosquito breeding in accumulated water. A galvanised or plastic jali (net having a tight fitting over pipe) with square openings of 1 cm x 1 cm be fixed over the pipe for preventing entry of large leaves, birds etc.

For avoiding rust mixing with water, M.S. sheet is not used for making gutter structure. For keeping gutter in position, suitable steel or wooden brackets may be used keeping spacing in such a way that the gutter does not sag with full water load (Fig. 12).

iii) **Filter**

Filter is an important part of the inflow structure of a RHS and it is used to remove pollutants from water. Fig. 12 presents details for a filter developed at SERC (G) for use in rain water harvesting schemes. The filter can be divided into following three parts :

Container : Container for filter can be made with 18-20 gauge G.I. sheet, or with ferrocement. It is, generally circular in shape and is fixed over an opening provided in the roof of the reservoir. A bracket projection is cast around in the opening of the roof which provides support to the filter unit. In the container unit also another bracket projection is cast for supporting the perforated plate which supports the filter media.

A cover for the filter is also cast with ferrocement using an earth deposit mould and G.I. wire skeletal steel cage with two layers of Hexa mesh fixed over it and mortar is applied. A pipe nipple is cast in the cover of the filter for receiving the inflow pipe connection.

Perforated Plate : A ferrocement or a non-corroding material perforated plate with 1 cm dia circular perforations is cast and provided in the bottom of the filter. The outer dia of plate is kept 1.5 cm less than the filter dia.

For making such a plate, a reinforcement cage made of 4 mm dia G.I. wires, spaced at 80 mm centres in both directions and connected to an outer ring, is used. This cage is placed on a levelled surface over a PVC sheet piece. After packigng these with cotton waste (oil mixed) 150 to 200 Nos. of 2 cm long rigid PVC conduit pipe pieces are placed in the cage vertically and mortar is applied and compacted in the gaps.

The top and botom surfaces are finished with thick cement slurry. The cotton waste is removed after 24 hours from the P.V.C. pipes and the plate is cured.

Ferrocement containers are better because they require least maintenance and can be easily cast using waste wiremesh and mortar obtained while casting the water reservoir. For casting the container of the filter with ferrocement, a skeletal cage is made using G.I. wire rings connected to vertical wires. The dia. of the cage may be selected depending upon the inflow rate.

Reinforcement for brackets for water speed break plate and the support for perforated plate is fixed. A layer of mesh is fixed on the outer surface of the skeletal cage and extra mesh is fixed for bracket. Cement Sand Mortar of Mix 1:2 is applied over the surface carefully by placing the cage on a levelled platform and finished smooth. The thickness of the container is kept as 15 mm. The bracket thickness is kept as 2 cm.

Filtering Media : It is the main part of the filter which separates the pollutants from the collected water. The materials such as sand, gravel, coconut/palm/betalnut fibre, boulders etc. used as filtering media should be thoroughly washed for removing foreign matters or contaminations before these are packed in the filter.

The filtering material consists of the following layers :

First layer : 40 mm thick layer of natural gravel of sand stone. Gravel size should not be less than 12 mm or more than 14 mm. Flaky or kachcha stone ballast should not be used.

Second layer : 30 mm thick layer of natural fibres of coconut/palm/betalnut, preferably 6 to 8 cm in length.

Third layer : 80 mm thick layer of natural coarse river bed washed sand or pit sand retained over 1 mm size sieve but passed through 3 mm sieve. (Graded sand between these two sizes is used)., Sand should be free from organic/chemical impurities and should be washed and dried before use.

Fourth layer : 30 mm thick layer of natural fibres as provided in 2nd layer.

Fifth and top layer : A layer of 80 mm size round boulders is placed at the top. The main function of this layer is to keep the fibres in position, breaking the intensity of water and making it's flow smooth without disturbing the filter media.

The filter must be kept free from contamination and in good condition. During off season, when filter is not in use, it is advisable to remove the filteration media, wash it, dry it and repack it in the filter.

3. STORAGE TANK RESERVOIRS

Stored rain water is used in dry seasons. In areas with long dry periods, a large storage capacity tanks will be required and cost of the tanks will also be high. The cost of the scheme can be reduced by using cheaper construction materials and techniques. This is very important for a developing country. The following types of tanks could be used for storing drinking water :

i) Galvanised iron sheet tanks

Fabrication facility including skilled brazing/gas welding etc. are required for the production of these tanks in villages itself as transporting bulky tanks to rural areas is very difficult. Creation of these facilities in villages and transporting filled gas cylinders to the site and back to the town is also a difficult job. G.I. sheet tanks made with standard thickness sheet are costly and will need regular maintenance. These tanks will also need replacement after 5 to 7 years due to corrosion. The rate per litre for standard G.I. tank comes to about Rs. 2.50 per litre.

ii) Reinforced concrete tanks

Construction of Rectangular or Cylindrical R.C.C. tanks need skilled labour and expensive and accurate formwork. If the tank start leaking repairing of RCC tanks is very expensive, difficult and success of the repair work is always doubtful. Construction of the R.C.C. tank is expensive and the rate per litre of storage comes to about Rs. 2.25 to 2.75. Due to difficulties in construction, larger requirement of materials, costly and difficult formwork, requirement of skilled technicians, adoption of these tanks for rainwater collection system or other rural water supply system for storing drinking water becomes difficult job.

iii) Plastic/HDPE Tanks

These tanks are available as finished factory product and have to be transported from factory to the site. The cost of the tank is very high and at times, these can get easily damaged during transportation and cannot be locally repaired. The cost of the tank comes to Rs. 3.50 per litre of stored water.

iv) **Ferrocement Tanks**

Ferrocement is a thin walled type of reinforced cement concrete, in which the mortar is reinforced with many layers of wire meshes woven or welded with small diameter steel wires. The mechanical-physical properties of ferrocement make this material particularly suitable for construction of cylindrical reservoirs at much lower cost than those constructed in R.C.C., plastic or steel. The method of construction is simple, easy to learn and can be carried out without the help of heavy or sophisticated equipment and electricity.

Some of the significant characteristics which distinguish ferrocement from ordinary RCC are :

1. It's thin section and reinforcement, provided in the form of thin wire meshes, create a high specific surface (cm^2/cm^3) of the reinforcement. Due to this high specific surface, ferrocement acts as a homogeneous material within wider limits than ordinary RCC and therefore, resist higher tension before cracking occurs.

2. Ferrocement has a higher impact resistance than ordinary RCC because of its high energic absorption capacity. Any damage occuring in a F.C. surface is localised to a small area and can be easily repaired by exposing the meshes and replastering the surface.

3. Ferrocement reinforcement is assembled over a light frame work into any desired shape without need for formwork. After the shape is reproduced in cage, the plastering is done directly over the cage.

4. The basic materials such as cement, sand, pore sealing compound, steel bars, G.I. wire, wire mesh etc. are mostly locally available in most of the areas.

5. Construction method is easy to learn by local labour. Structures can be constructed on self-help basis by the family of user thus saving expenses on labour.

The above properties make the application of ferrocement particularly suitable for use in rural areas. Because of its high resistance to cracking and ease in repairs use of ferrocement is highly advantageous.

Ferrocement structures are in use since last more than 50 years and their performance has been found to be satisfactory. Water storage structures developed at SERC(G), as thin as 10 to 12 mm, are in use since last 12 years in many parts of the country. Some of the units are under test since 1974 at SERC, Roorkee and their behaviour during these years have proved that ferrocement is a trust worthy construction material for water storage tanks in rural areas. Very large number of F.C. tanks have already been used in India, Thailand, Malaysia, Indonesia for storing drinking water and the experience about their behaviour is good. These tanks could be erected as above ground, under ground or as overhead tanks without any problem. Several types of construction techniques have been developed for ferrocement at SERC and Asian Institute of Technology, Bangkok. Annexure provide detailed information of F.C. tanks.

4. OUTFLOW

The water from the reservoir is to be taken out for consumption and for this, taps preferably with locking arrangements are provided in the above ground tanks. The tanks are installed at a slightly higher level so that the tap is fitted in such a manner that a bucket could be placed below it.

For underground tanks, drawing of water is done by using a simple hand pump for larger tanks. For smaller tanks with a plastic bellow pump or a pump used for drawing oil from drums can be used. If use of such pumps is difficult, the water can be pulled out through manhole using a clean bucket. Care should be taken in such a cases, that dirty buckets or mud stuck to the bucket do not reach inside the tank and water.

5. TREATMENT

If the water is stored in tank for long period as a precautionary measure the water drawn in a plastic bucket is added with chlorine tablets and is covered and kept for about 1 hour before consumption.

LIMITATIONS OR RAINWATER COLLECTION SYSTEM

Collection of rainwater has limitations also. Reliability of a system dependent on erratic rainfall can be questioned. As regards reliability stored rainwater cannot be considered as the sole source of supply. At various times and for various purposes such as for cloth washing, irrigation in gardens and other sources of water will have to be used. But for (1) individual household which wants convenience of its own water supply under its own control, and (2) often for the whole communities where the area lacks rivers or ground water, the possibility of developing rainwater collection systems can be very attractive.

DESIGN CHARACTERISTICS OF FERROCEMENT WATER TANK USING SKELETAL CAGE HAND PLASTERING SYSTEM

Ferrocement water storage tank of 12 M^3 capacity using traditional casting system with skeletal steel cage is presented in this note. The design, based on the acceptability by villagers or both construction techniques and cost, has been included. The same design can be adopted for construction of 15 M^3 capacity tank by increasing the height of the tank with the same diameter, reinforcement, and thickness of wall, base and roof.

MATERIALS NEEDED FOR FERROCEMENT TANK CONSTRUCTION

The specifications for cement, sand, wiremesh and admixtures have been covered in Part-I but these are being explained here once again for revision :

Cement

Three types of cement are available in Indian market and all the three can be used for ferrocement tank construction :

1. Ordinary portland cement (O.P.C.) may be used in normal conditions.
2. Portland Pozolona Cement (P.P.C.) may be used in normal conditions but with care and after checking the mortar setting.
3. High-early-strength cement (Quick setting cement) - may be used in cold climatic zones and also in places where early setting and strength gaining is desired.

USE OF ORDINARY PORTLAND CEMENT IS BETTER AND PREFERRED BECAUSE OF SURETY IN OBTAINING THE DESIRED STRENGTH OF MORTAR.

Sand

Sand from all local sources may be checked/tested and depending upon their properties, select a sand which meets most of requirements in terms of silt contents, freedom from chemical pollution and trading. Medium coarse sand with grading may be used for ferrocement jobs.

In order to find the strength of mortar for designing the tank mortar specimens may be made from these local sands. The ratio of cement : sand is 1:2 to 1:3 by volume and water : cement ratio is 0.45 by weight (recommended W:C is 0.4 but 0.45 may be tested to allow for the variation in the degree of control in the field). The strengths of the mortar desired are :

Tensile strength at 28 days (direct tension test ASTM, C190)	17 – 30 Kg/cm^2
Compressive strength at 28 days (2" cube)	200 Kg/cm^2

Wire Mesh

The most common wire meshes used for ferrocement are hexagonal wire mesh, square welded mesh and woven square mesh. Use of woven square mesh is preferred for F.C. Water Tanks.

Chemical Admixtures

Selected grade of poresealing compound and plasticizer may be added to the mortar to be used for construction of F.C. Tanks.

Table 1
Description, Properties of Hexagonal & Square Woven Wire Meshes

—	Ultimate strength	8740 Kg/cm^2
—	Yield strength	2100 $Kg./cm^2$
—	Modulus of elasticity	93.75 x 10^4 Kg/cm^2

Mesh Size mm (inch)	Wire diameter commonly available (mm)	Roll size generally available (feet)
19 (3/4)	0.5 to 1.2	0.91 to 1.2 m x 45.7 m (3 to 4 x 150) for hexagonal
12.5 (1/2)	0.5 to 1.2	
10 (3/8")	0.5 to 1.2	0.75 to 1.5 M x 15 to 30M (2.5 x 100) for square woven mesh

For water tanks construction without the aid of a formwork, the tank reinforcement must be strong enough to hold the weight of mortar applied on it and must also be stiff enough to prevent slumping of mortar during plastering. Hence the square woven mesh of grid size 12.5 mm (.91 x 30.5 m roll size) has been chosen because of its stiffness when compared to hexagonal mesh and cost advantage when compared to welded wire meshes.

Tank dimensions		12M^3 unit	15M^3 unit
Diameter	=	2.5 m	2.5 m
Area (in plain) of tank	=	4.90 Sq.M.	4.90 Sq.M.
Height	=	2.50 m	3.11 m
Wall thickness	=	30 mm	30 mm
Actual volume of container	=	12.27 M^3	15.19 M^3
Capacity for water storage	=	12 M^3 - 12000 lts.	15000 litres

The maximum hoop stresses obtained from an analysis fixed and hinged type connections between the wall and the base are 6.64 kg/cm^2 and 7.18 kg/cm^2 respectively. The maximum bending moment at the base of the wall is 34.20 kg-cm/cm width, which creates a maximum fibre stress of 12.83 kg/cm^2, if the wall is not reinforced.

DESIGN

The stresses occurring in the tank are small and do not exceed even the tensile strength of unreinforced mortar (17kg/cm^2) hence, in this case, the design of the tank is controlled partly by construction techniques and the sizes of materials available. For ease in construction, the tank reinforcement chosen consists of 6 mm skeletal steel rods sandwiched between two layers of 12.5 mm squares, woven 20 g (0.9 mm) wire G.I. mesh. The distance between the mesh layers is approximately 13 to 15 mm.

Details of tank dimensions are given in Fig. 1.1. A list of construction materials is presented in Table 1.3. Cutting steel bars are given in Table 1.4. Wire meshes and steel bars should be efficiently used. Unplanned cutting may result in extra requirement of materials due to wastage. A wire mesh lay out has been shown in Figure 1.2 which has been found to be economical.

Table 1.3

Materials and Cost

No.	Materials	Quantity	Price (Rs.)
1.	Cement @ Rs. 65/- per bag of 50 Kg.	16 bags	1040.00
2.	Sand @ Rs. 105/- M^3	2 M^3	210.00
3.	Stone aggregate 12 mm and down	0.76 M^3	150.00
4.	6 mm steel bars @ Rs. 6/- per kg.	47 kg.	282.00
5.	Square woven mesh 12.5 mm grid 20 g wire (0.91 x 30.5 m roll size) @ Rs. 350/- per roll	2 rolls	700.00
6.	Tying wires @ Rs.12.50 per kg.	2 kg.	25.00
7.	Pipe and fittings etc.		75.00
8.	PVC Sheet		100.00
9.	Chemicals, poresealent, plasticizer & drinking water paint		400.00
10.	4 mm wire		10.00
		Total (a)	2992.00

LABOUR

Category	Mandays	Rate	Amount Rs.
1. Barbender	2 days	@ 40.00	80.00
2. Mason	4 days	@ 40.00	160.00
3. Helpers	16 days	@ 18.00	288.00
		Total (b)	528.00

Add for T & P and unforeseen expenses (c) 300.00

Total (a) (b) & (c) = 2992.00 + 528.00 + 300.00 = **3820.00**

CONSTRUCTION TECHNIQUES

The construction stage of ferrocement water tanks are as follows :

Preparation of skeletal and Mesh Reinforcement

A skeletal steel cage is first built up and a layer of mesh is fixed at the inner face and another over the external face of the cage. The stiffness of the cage is very necessary in this type of construction.

Fig. 1.2, 1.3 and 1.4 show the arrangement of skeletal steel and the mesh. The verticality and the constant diameter of the tank are achieved by keeping the rods in their position by tying properly. Each joint of steel bars is tied. All vertical bar based reinforcement is first placed in position and tied. Wall rings are inserted and tied and Roof reinforcement is then put into place. The steel cage is gradually build up until it is completed. The distance between the inner and outer meshes is kept at approximately 16 mm. This distance might increase/change due to pressure applied and weight of mortar during the mortar application process. To prevent this increase, the meshes are tied together at intervals of approximately 150 to 200 mm for preventing any separation. All ends of tying wires should be bent and pushed inside the meshes for safety, ease and comfort in mortar plastering. It is also advisable to stagger the mesh position, in such a manner that the effective opening is reduced. Arrange the location of mesh over-laps both inside and outside so that an access can be achieved through the wall for mortar application. Wherever laps of meshes are fixed, provide a minimum overlap of 10 to 15 cm, depending upon size of tank.

Table 1.4
Details of Bar curring & configuration

Bar Designation	Dia	No. of Bars required	Length of Each bar	Shape
1	2	3	4	5
A	6 mm	2 nos. in Base & wall	7.62 M Total for 2 = 15.24 M	
B	6 mm	4 nos. Partly in Base and in wall	3.64 M Total for 4 = 14.56 M	
D	6 mm	8 nos. Partly in Base Roof and in wall	3.79 M Total for 8 = 30.32 M	

1	2	3	4	5
C	6 mm	14 Rings in wall	8.07 M Total for 14 = 113.06 M	
G	6 mm	Rings 2 nos. One in base & One in Roof	1.96 M Total for 2 = 3.93 M	
I	6 mm	1 no. in Base Ring	5.62 M Total for 1 = 5.62 M	
F	6 mm	1 no. in Roof Ring	4.29 M Total for 1 = 4.29 M	
B	6 mm	2 nos. in Roof	3.10 M Total for 2 = 6.20 M	
A	6 mm	4 nos. in Roof	1.47 M Total for 4 = 5.88 M	
H	6 mm	Ring Square 2 nos. for manhole opening frame	2.45 M Total for 2 = 4.90 M	
	6 mm	Pin for keeping frame rings in position	9 cm Total for 4 = 0.36 M	
W	4 mm wire	Cover for the manhole at top At top U shape bars W1 W2	0.80 M 4 Nos. = 3.20 M 76 cm 2 Nos. = 2.69 M Total 7.41 M	

Total quantity -

6 mm dia bars	=	209.96 M	=	46.19 kg
		Wastage	=	0.92 kg
				47.11 kg
4 mm wire	=		=	0.85 kg

Galv. Annealed Wire Mesh 20 g x 12.5 x 12.5 mm

G.I. Wire Mesh 0.91 x 30 M = 2 Rolls

Base Concreting

Concrete having a mixture of cement : sand : stone of 1:2:4 by volume is used for the base. The base thickness of 80mm is cast in two layers. The first 40 mm is laid and the steel cage is put into place then the other 40 mm of concrerte is poured on top. The compaction of concrete is done by a Jhurmut or concrete Rammer or by stepping on it. The base surface is finished with a thin layer of cement paste for water tightness. Add water proofing compound of approved make in base concrete.

Plastering of Mortar

Mortar having a cement : sand ratio of 1:2 by volume, and the water : cement ratio of 0.4 by weight, added with poresealing compound and plasticizer is recommended. Mortar is applied by hand and plastic gloves or bags are used for hand protection. Trowel and wooden Float can also be used for mortar application. One person stands outside the tank and pushes a handful of mortar through the reinforcement in a sweep motion to another man standing on the inside of the tank, who also moves his hand in the same manner. The mortar core of about 12 mm thickness, covering the central Reinforcement layer is left undisturbed for 24 hrs. to harden and 5-10 mm thick layer of mortar are trowelled on both outside and inside of the tank. A thin layer of cement paste is then trowelled on the inside surface for a smooth finish and an increase in water tightness. Plastering of the roof is done in the similar manner. Since water tightness is not required in the roof, plastering is carried out quickly. A piece of thin board such as 4 mm plywood board or a G.I. Sheet piece is used on the inside to receive the mortar and work as support. Thick cement slurry is applied to all construction joints such as the joints between the base and the wall, connection between the base concrete and the pipes. This will ensure a good watertight bond.

Curing of the Tank

Curing the tank can be carried out using several methods, such as water sprinkling, covering with wet sacks or by filling the tank but it is observed that any method which need a lot of water does not suit in rural situations as getting enough water is difficult. Hence curing the tank by covering it with thin PVC sheets is found to be most appropriate since no further attention is required during the curing period (14 days). The PVC sheet can be reused. This will need only once a day spraying of water in the morning and covering it again.

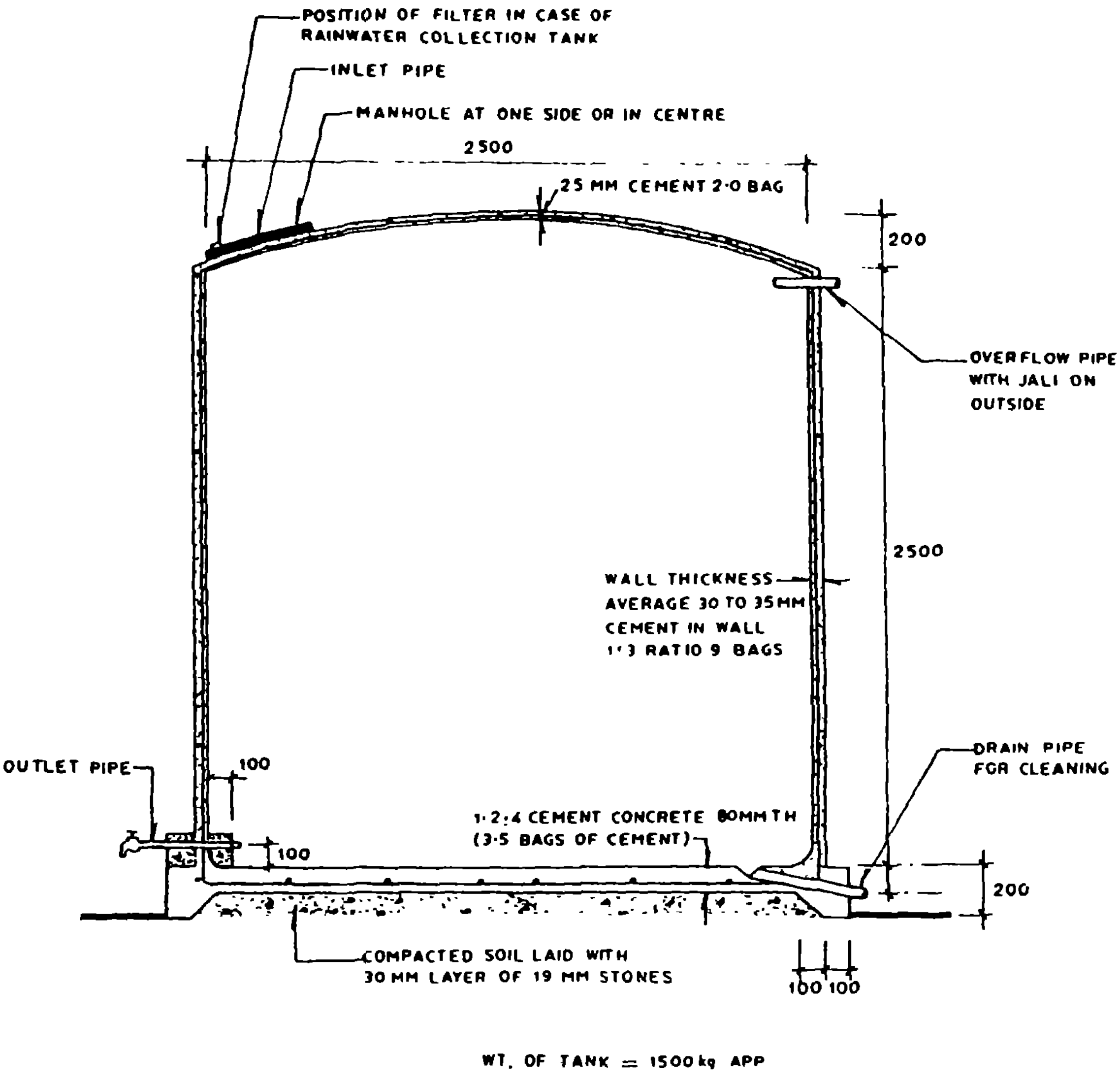


Fig. 1.1 : DETAILS AND DIMENSIONS OF FERROCEMENT TANK

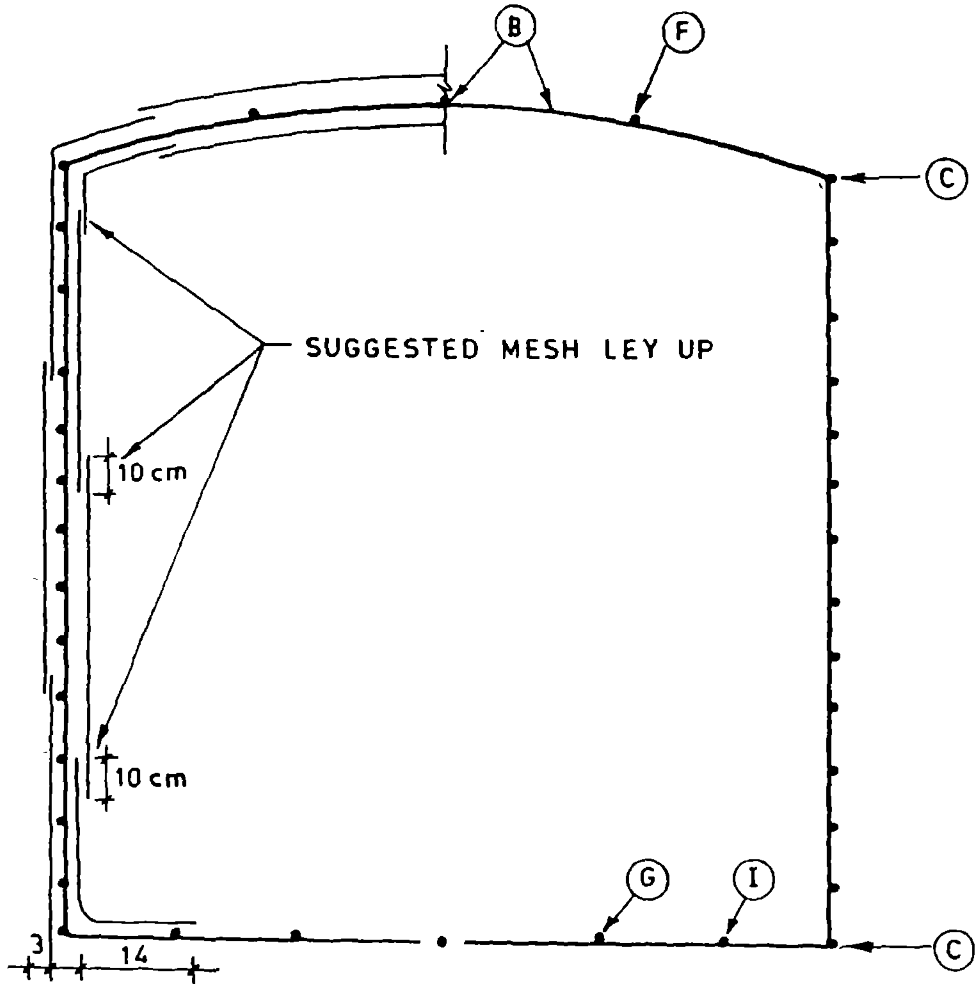


Fig. 1.2 : CROSS SECTION OF STEEL REINFORCEMENT

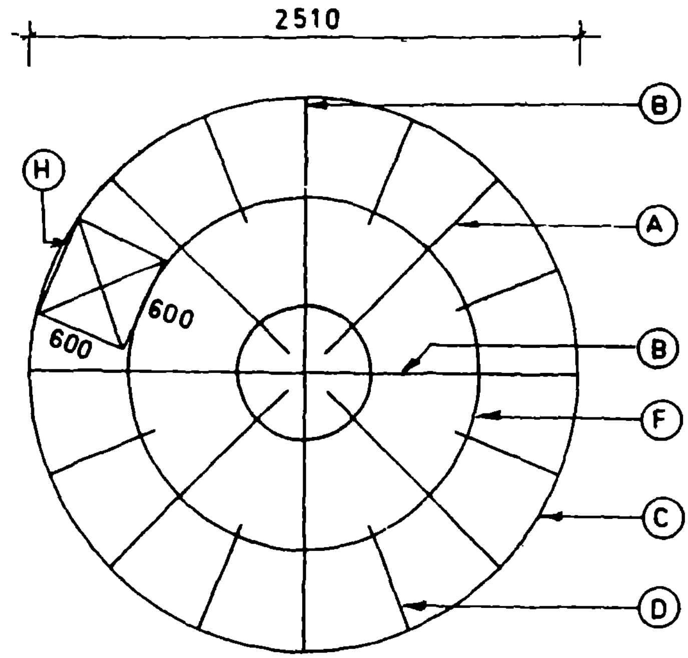
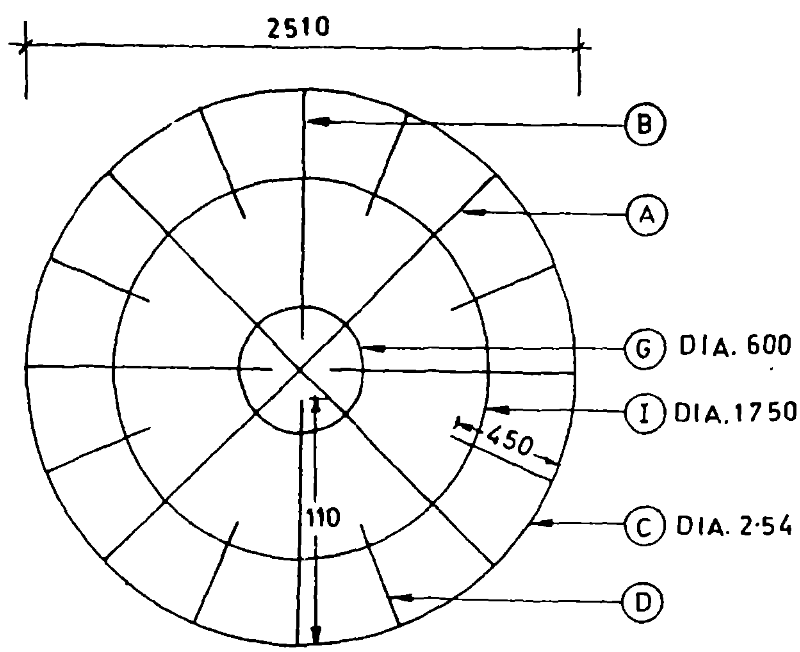


Fig. 1.3 : DETAILS OF SKELETAL STEEL FOR ROOF



NOTE: CIRCLED LETTERS ARE BAR DESIGNATIONS

Fig. 1.4 : DETAILS OF SKELETAL STEEL FOR BASE

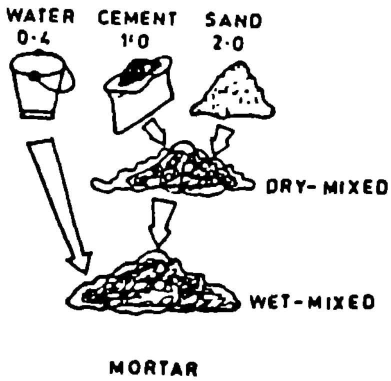


Fig. 1.5.1 : MIX PROPORTIONS BY WEIGHT FOR MORTAR MIXES THAT A ARE REQUIRED TO BE PREPARED

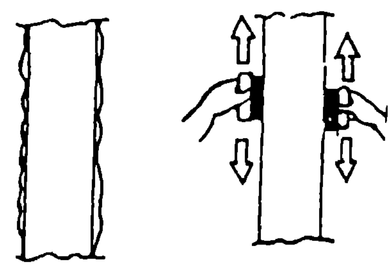


Fig. 1.5.2 : SCRAPING OUT EXCESSIVE MORTAR BUILD-UP THIS ALSO IMPROVES ADHESION OF FINISHING COAT

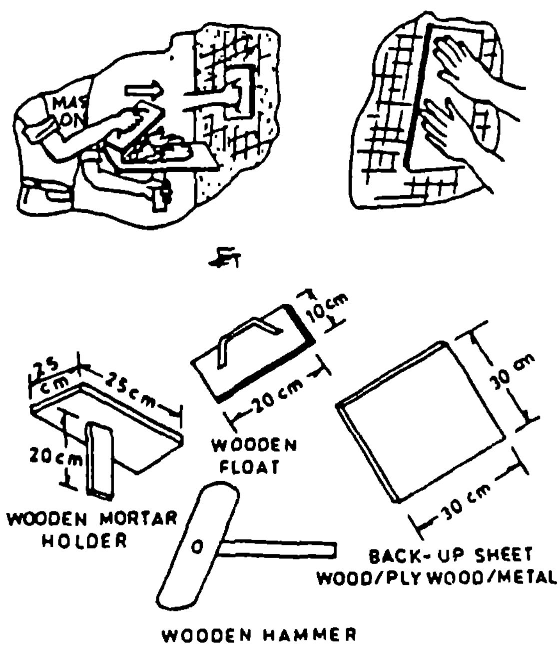


Fig. 1.5.2 : PLASTERING TECHNIQUE AND SIMPLE EQUIPMENTS THATMAKE PLASTERING AN EASY TASK. MASON IMPREGNATES MORTAR FROM THE INSIDE OF THE TANK WHILE THE HELPER HOLDS A BACK-UP SHEET ON THE OUTSIDE

Behaviour of the Tank

Large number of ferrocement tanks have been constructed, in the laboratories and in field and these tanks are in constant use for the past 15 years and no problem have been reported, in case any tank leaks at a particular area/point, the mortar can be chipped inside and outside and the mortar is applied again after applying cement slurry. This will make the tanks leak proof.

For each tank, the construction duration is four days. Tank construction can be carried out solely by unskilled labour if good finishing, plastering is not required. Water tightness of the tank is excellent. There is no seepage and no waterline, which is normally visible in a concrete tank when it is first filled with water. Villagers may at first be sceptical because of the thickness of the walls of the tank but this reaction, however, will change when the tank shows its remarkable strength.

SERC SEMI-MECHANISED PROCESS FOR PRODUCING CYLINDRICAL FERROCEMENT TANKS

Keeping in view that ferrocement units may be produced in rural or semi-urban areas, where power or advanced fabrication skills are not available, the Centre has developed a simple, easy to fabricate and transport process for producing ferrocement cylindrical units in 1970-74 period. Several laboratory and field trials were conducted for checking usefulness of process and tests were conducted of products produced with it. A patent was filed in January 1975. Ferrocement cylindrical units of thickness as small as 10 mm and as thick as 50 mm can be cast using this process. It does not require electricity or fuel oils for operation being manually operated system. The technique of casting units with this process can be acquired by rural artisans in a short period of about 5 days. Cylindrical units having diameter upto 2.0 m and height upto 1.2 m have been cast successfully with this process.

DESCRIPTION OF PROCESS EQUIPMENT

The process equipment has been so designed that it can be fabricated in rural workshops having facilities for drilling, cutting and welding. Materials required for fabrication of the process equipment which resembles with charkha are mild steel angle, flat pipe, wooden planks and M.S. or plain G.I. sheet. Most of these are available even in smaller towns. Process equipment is shown in Fig. 1a, 1b and 1c. The process facilitates continuous winding of wire mesh in a stretched condition from a wire mesh roll, onto a cylindrical mould and plastering of cement, sand mortar onto the mesh as and when it is wound on the mould (i.e. layer after layer). Stretching of wire mesh during winding and application of mortar with trowel over a firm mould backing, enables achieving of high degree of mortar campaction and good control for thickness. In case strong edges are required for any cylindrical unit for special reasons, steel edging with M.S. angle, flat or small channels can be provided during casting of the wall. Welded wire fabric cold drawn wires could also be wound on the mould along with the mesh during casting in case extra steel is desired to be provided (Fig. 1b). In Fig. 1, the dimensions of the equipment have not been given, as overall dimensions of the process equipment shall depend upon the largest diameter of the F.C. unit that are likely to be cast. The limitation of the size of casting is in terms of the handling capacity of weight manually. If mechanical handling equipment such as gantry and lifting derrik are used for removing the units from process stand then there is no limit to the size of unit whcih can be produced with this process. The components of the process equipment (ref. Fig. 2.1) can be listed as :

(a) **Base Frame** : Two long (or 4 jointed) mild steel channels are connected with two or four cross mild steel channel or angle pieces for making a rectangular base frame. If desired wheels can also be fitted at the frame bottom to facilitate movement of stand within the casting place.

(b) **A-Frames** : Four A-frames are fabricated using M.S. angles and vertically fitted over the base frame. The set of two A frames provided at front side support a pipe shaft which carries the cylindrical rotating mould (stand 2 Fig. 1). This shaft is connected to the rotating mould by a bolt connected to a 75 mm long half round pieces of pipe which is welded to side plate connected to the cross arms on both sides of the mould. The bolt passing through a hole in the shaft and in half round tubular segment connects the tubular shaft and the mould. The other pair of A-frame fixed vertically over base frame support three pipe shafts. Wire mesh roll for the wall portion reinforcement is wound on the top shaft. The second pipe shaft is provided on the rear side of A-frame to hold the wire mesh required for reinforcing the collar portion of the cylindrical unit. Second shaft is used only when wall units with collar are required to be cast. A-frame pairs are connected with mild steel angles on both sides for providing stability. The pipe shafts are fitted in bearing blocks at the A-frames for ensuring smooth movement. 40 mm diameter B class pipe is used for arresting the mould movement during stretching of mesh and plastering. Two 16 mm dia holes are drilled each of the shafts having reinforcing mesh rolls for wall and collar for stretching the mesh by putting a 14 mm dia rod and rotating the mesh shafts in reverse direction. For holding the mesh in stretched position the rod used for stretching is held in position by strucking it against the other shaft.

(c) **Cylindrical Mould** : The mould is a drum made in four or six segments. The frame of the mould segment is made of 2.5 cm thick wood covered with galvanised iron plain sheet. Segmental frames are assembled together with a joint filler batten inserted between every two segments. One of the battens is provided with 6 mm diameter holes of 5 cm centres through the depth for tying the wiremesh to the mould. In the case of collared unit, a separate solid wood collar mould piece is fabricated using hard wood and bolted or screwed to the main mould. Side frames made of M.S. flats of 65 to 80 mm x 6 to 8 mm are bolted on both sides of the mould for rotating it over the stand. Side plates are also fitted on each segment joint for making the joint rigid.

CASTING PROCEDURE

The process of casting consists of the following steps (refer to Fig. 1) :

(a) The wiremesh roll for reinforcing wall unit is mounted on spindle 'A' and the wire mesh for reinforcing collar portion of wall is mounted on spindle 'B'. The mesh is tightly wrapped over the tubular shafts (spindles) for connecting mesh to the spindle few holes are provided in the shaft The mesh end is tightened with tying wire to these holes.

(b) Mould for cylindrical unit is mounted on the rotating tubular shaft on stand 2.

(c) Wire mesh on spindle 'B' is passed under roller B1 and attached to the formwork in collar portion (only when collar is required). The wire mesh wrapped on spindle 'A' (for wall portion) is passed under roller 'A' and is attached to the formwork through the insert piece (with holes at 5 cm centres) provided between mould joint.

(d) In case welded wire fabric or mild steel wires, upto 5 mm dia, are to be provided as additional reinforcement in F.C. wall, these could be placed as shown in Fig. 1(b). M.S. flat or angle iron rings can also be provided for strengthening of edges of wall unit or for increasing stiffness of the edges for preventing edge breaking. In case of water tanks, pipe sockets for inlet, outlet, overflow and scouring are also fixed in position during casting of wall.

(e) Mild steel flat (20 x 3mm) pieces cut to a length - height of the wall portion of the mould are inserted between the mould surface and the mesh layer for maintaining 3 mm thick mortar cover to the inner most layer of reinforcement mesh.

(f) Mould is then rotated in forward direction (as marked by an arrow in Fig. 1) so that the mesh comes on to the front, where high strength cement sand mortar is manually applied and rubbed onto the wire mesh with a trowel and wooden float. Mason has to ensure that the penetration of the mortar in mesh is full before rotating the drum for further mortar application.

(g) For preventing the rotation of the mould drum during mortar application a steel pipe (B class - 40 mm dia and length 3.0 m) is inserted through the wall mould and supported over the connecting angles provided between both sets of 'A' frames. The pipe shaft carrying the reinforcing mesh is rotated in reverse direction for bringing the mild steel flat cross arms fitted on the mould sides to a position when it butts against the inserted stopper pipe which serves as a brake against the rotation of the mould.

(h) Care should be taken to see that the wire mesh rolls wound on the spindle 'A' and 'B' do not get loosened during this operation and also the wire mesh is wound tightly over the rotating mould. To achieve the above aims two 16 mm dia holes are provided in each of the pipe shafts (spindle) A and B. 14 mm dia steel bar handles are inserted through these holes. The spindles for carrying mesh for wall and collar portion are rotated manually with the help of these handles in such a way that the mesh rolls are tightened. This in turn ensures tight winding of mesh over the drum. These handles, after tightening the mesh rolls, are left butting other spindle itself so that they serve as brakes aginst the rotation of wire mesh rolls.

(i) The starting point of mesh is marked over the mould sides so that the number of wire mesh layers plastered can be counted.

(j) The mould is rotated and mortar is applied over the wire mesh in steps.

(k) In wall units, where collar is required, the diameter of the collar portion of wall unit is larger than that of the main portion of the wall. Hence the length of the mesh provided over the collar portion is longer than the length of the mesh provided over main portion of wall unit. As a result, when the collar portion mesh is lapped with wall portion mesh, the collar mesh can get distorted. This is rectified by providing a small cut in the collar mesh at every quarter point of the circumference over a width equal to little less than the overlap portion. The collar mesh is then straightened and tied to the wall portion mesh.

(l) The process of plastering, layer by layer, by rotating the cylindrical mould is continued till desired numbers of layers of wire mesh are wound on the drum and desired thickness is achieved.

(m) An extra mesh overlap of about 15 to 20 cms is provided at the end after winding the last layer and mesh is cut at this point after it is tied to mesh layer below the joint.

(n) The mortar layer over the last wire mesh layer is finished ensuring that no wire exposed and the minimum cover of mortar over last wire mesh layer is not less than 3 mm.

To repeat in brief semi-mechanised process high strength cement sand mortar mix (having 1 part of cement : 2 part of silt free medium coarse sand) mixed with poresealing and plasticizing compounds, is applied on the wire mesh wound over a mould placed over a stand. Winding of mesh and application of mortar goes on continuously in stages. When the desired thickness of ferrocement unit is obtained, the end of the wire mesh is anchored to the next below layer by stitching it with G.I. tying wire and the joint is covered by mortar layer.

The minimum number of mesh layers to be provided (as reinforcement for wall for tanks upto 120 cm dia) shall not be less than two layers of 20g x 1/2" x 1/2" in mortar thickness of 10mm. Wall units cast are demoulded after 24 hours of casting by (a) removing the rotating segmental mould and rotating shaft (b) placing it vertical on ground (c) opening of side frame and lap plates (d) pulling out of the sandwitch wooden battens fixed between every two segments of the mould after cutting of tying wire used for holding the mesh end over mould. Number of wire mesh layers and thickness of wall will depend upon the diameter and height of the wall unit.

The base unit (RCC) is cast over a levelled plate form. Reinforcement and thickness of the base will also depend upon the size of the tank and also on the supporting conditions.

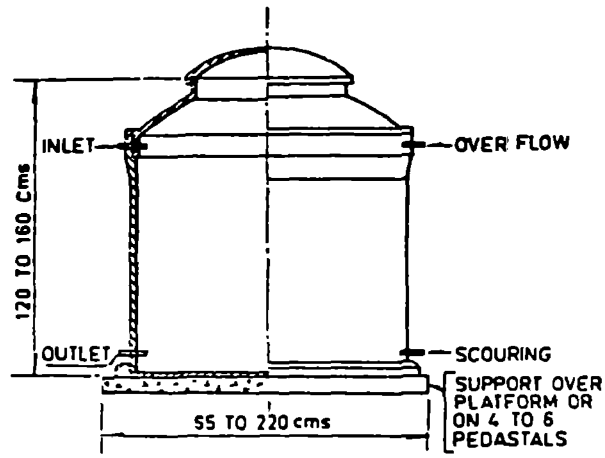
The roofing unit for cylindrical structures such as tanks, cover for the manhole provided in roof are cast using ferrocement over masonary or soil deposit mortar lined moulds.

Semi-mechanised process is suitable for production of tanks upto 2,500 litre capacity at centralised production units as the fully precast units of diameter upto 1.2 meter, can be easily handled and transported even on rural or hill roads manually. In case of tanks upto 5,000 litre capacity, it is desired that the casting process stand and the mould is shifted to site in place of transporting and shifting the cast units. Shifting of equipment will not pose any difficulty because it can be dismentalled into small and light weight pieces.

Finished precast tanks upto 600 litre capacity can be easily transported, lifted and erected manually upto 4 storey buildings. Tanks upto 2,500 litre capacity can be easily shifted but will need chain pully block and derrik arrangement for lifting over buildings but their components can be transported, erected and assembled manually or the wall units can be cast over roof by shifting the casting equipment to site.

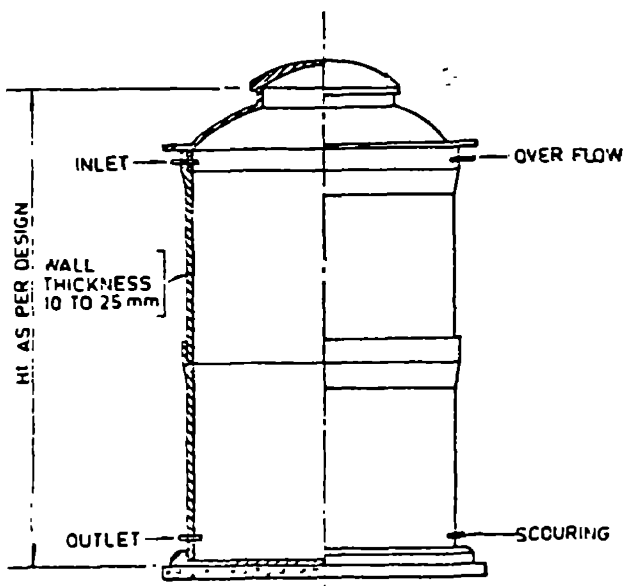
Cylindrical ferrocement tanks upto 10,000 litre capacity have been produced (using semi-mechanised process) and tested at SERC. 3 wall units of 2.0 m dia have been jointed by placing these one over other. An underground tank of 2,500 litre capacity has been under test since 1974 with water filled around this tank (upto 1984) for exerting external pressure and for testing leakage through the walls which are 10 mm thick. The inside of the tank has been kept empty. Since 1984 the outside cavity has been filled with coarse sand saturated with water. No deterioration or leakage has been observed. A 2,500 litre capacity O.H. tank installed in a factory at NOIDA (near Delhi) is being used for storing drinking water since last 11 years. Very large number of ferrocement tanks have been produced and marketed by SERC process licences all over India and these tanks have been received well by the public and the Government Departments.

Cylindrical ferrocement units, produced using SERC process, can also be used as walls for vertical cylindrical septic tanks, digesters, well lining rings, bins and circular shuttering/ formwork etc.



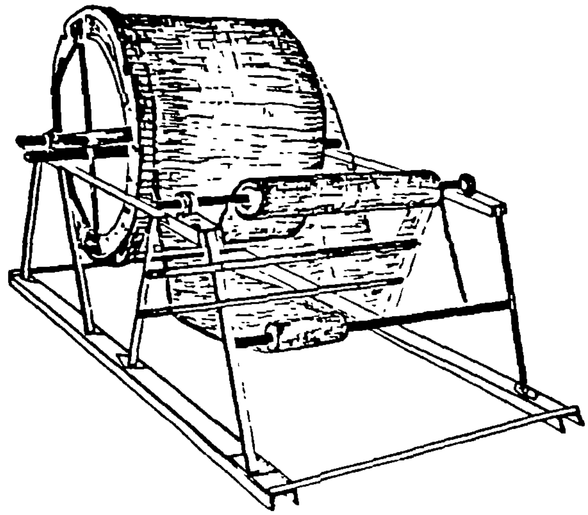
HALF SECTIONAL ELEVATION

FERROCEMENT WATER STORATE TANKS UPTO 5000 LIT. CAPACITY ASSEMBLED USING PRECAST UNIT PRODUCED WITH S.E.R.C. PROCESS



HALF SECTIONAL ELEVATION

FERROCEMENT WATER STORAGE TANK FOR 2500 TO 10000 LIT. CAPACITY PRODUCED USING S.E.R.C. SEMI-MECHANISED PROCESS



SEMI-MECHANISED PROCESS FOR PRODUCING FERROCEMENT CYLINDRICAL WALL UNITS FOR WATER TANKS DEVELOPED AT S.E.R.C. GHAZIABAD

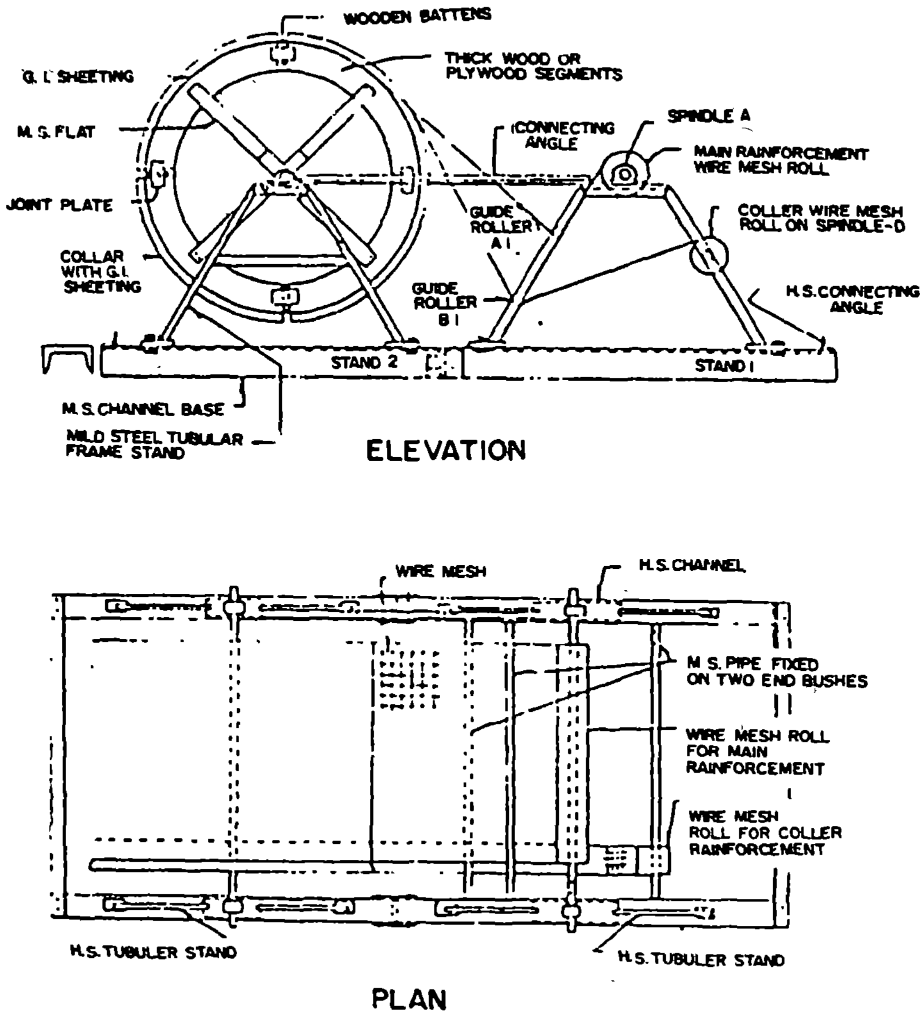


Fig. 2.1. SEMIMECHANISED CASTING PROCESS FOR PRODUCING CYLINDRICAL FERROCEMENT UNIT

SERC SEGMENTAL SHELL UNITS : CASTING AND JOINTING METHOD FOR CYLINDRICAL TANKS

During mass production, trials and transportation tests conducted on ferrocement tanks and bins, produced using SERC semi-mechanised process, it was observed that cylindrical units having larger diameter above 1.5 m need special care and effort during transportation and handling on rural roads and in hill areas. For solving this problem the technique of using vertical ferrocement segmental units for assembling of cylindrical walls for tanks and bins was developed at SERC, Ghaziabad, U.P. Vertical segments can be easily cast, transported, erected and joined to form cylindrical wall units. A complete system has been developed covering casting, handling and jointing of ferrocement segmental shell units. Precast ferrocement units are cast in the form of a segment of a cyinder. The circumferential surface of the cylinder is divided into 4, 6, 8, or even more number of parts. These segments of the cylinder are precast as individual units with meshes and cross reinforcement wires or bars projecting on both sides of unit. The projected reinforcement is used for jointing of segment with the adjacent segments on both sides. Thoese individual units have been termed as segmental shell units.

On special requirement for underground structures such as digesters (where extra excavation will have to be done in case joint filling has to be done from both sides), a method for providing a lip with projected reinforcement in it was developed for ferrocement segmental shell units. Unit in such a case is cast with the lip on one side and the reinforcement projection on the other side. Half of the reinforcement provided in segment is left unplastered which projects within the lip area. For joint such units the reinforcement projected at the other end is inserted in the lip area. The lap of this reinforcement is tied with the reinforcement projecting in lip area. Such a system saves extra earth work in case of underground tanks and cost of extra scafolding in case of above ground tanks as the joint finishing can be done from inside itself.

The ultimate crushing strength of the mortar used for casting and jointing of these precast segments should not be less than 200 kg/cm^2.

In case electricity is available at the casting site a surface vibrator may be used for improving the strength and performance of the precast units. A surface compaction device developed at SERC by fixing a steel disc with a slow speed portable drilling machine can also be used for surface compaction

In case vertical ribs or horizontal bands are to be provided in the tank, these could also be cast during the casting of wall segments.

For assembling tanks, digesters, bins etc. with segmental shell elements the following steps are followed :

(a) The base unit, with specified reinforcement and thickness (depending upon the supporting conditions), is cast with 1:2:4 cement concrete. Base reinforcement ends are projected out of the base in form of hooks for connecting the base concrete and the concrete to be placed at base to wall joint.

(b, Positions of all the joints are marked on the base concrete immediately after the initial setting of the concrete is over.

(c) The precast wall, segments are then shifted and placed at marked positions one by one.

(d) Temporary supports are fixed for holding the segments in position.

(e) Laps of projected reinforcement on both sides are fixed and tied with the projected reinforcement of the adjoining panels after adjusting the panel positions.

(f) Extra reinforcement, in form of vertical M.S. bars/wires and wire mesh layers on internal and external faces is fixed at all joints.

(g) Tying of laps of meshes is carried out carefully at intervals of 8 cms. in both directions using G.I. 24 gauge binding wire.

(h) The sockets or nipples for fixing inlet, outlet, scouring and overflow pipes at respective positions are fixed in the joints.

(i) The old mortar surface near joints is wetted with water and thick cement slurry is applied on all the joint areas.

(j) Mortar is then applied on all joints ensuring full impregnation of mortar into the reinforcement layers.

(k) The roofing unit is erected and joint of roof and wall is filled.

(l) Internal and external finishing is done over joints carried (1) curing for joints is done for 7 days.

(m) Tank surface is permitted to dry up and is painted with 2 coats/of drinking water tank paint on inside and with bituminous aluminium paint on outside.

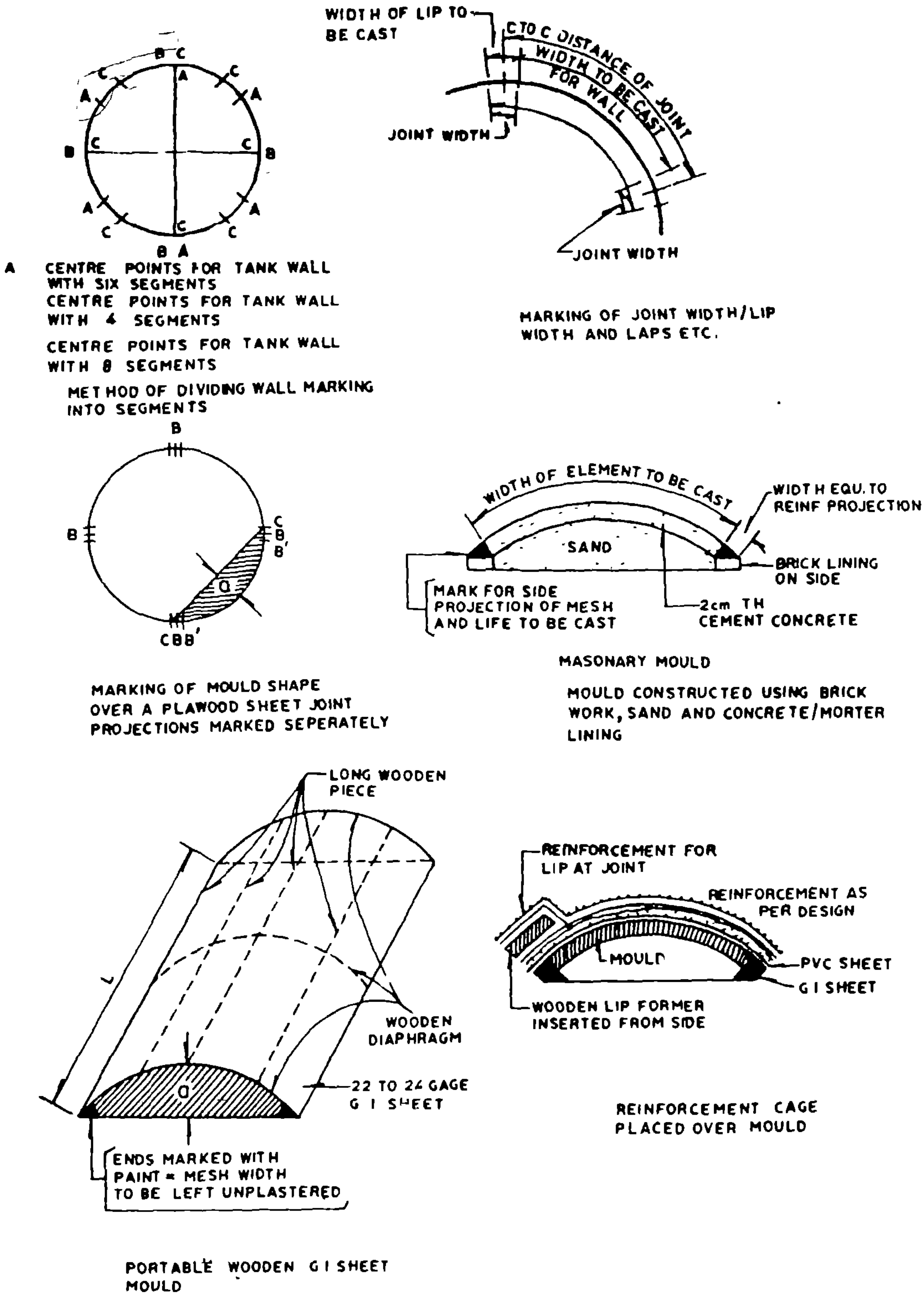
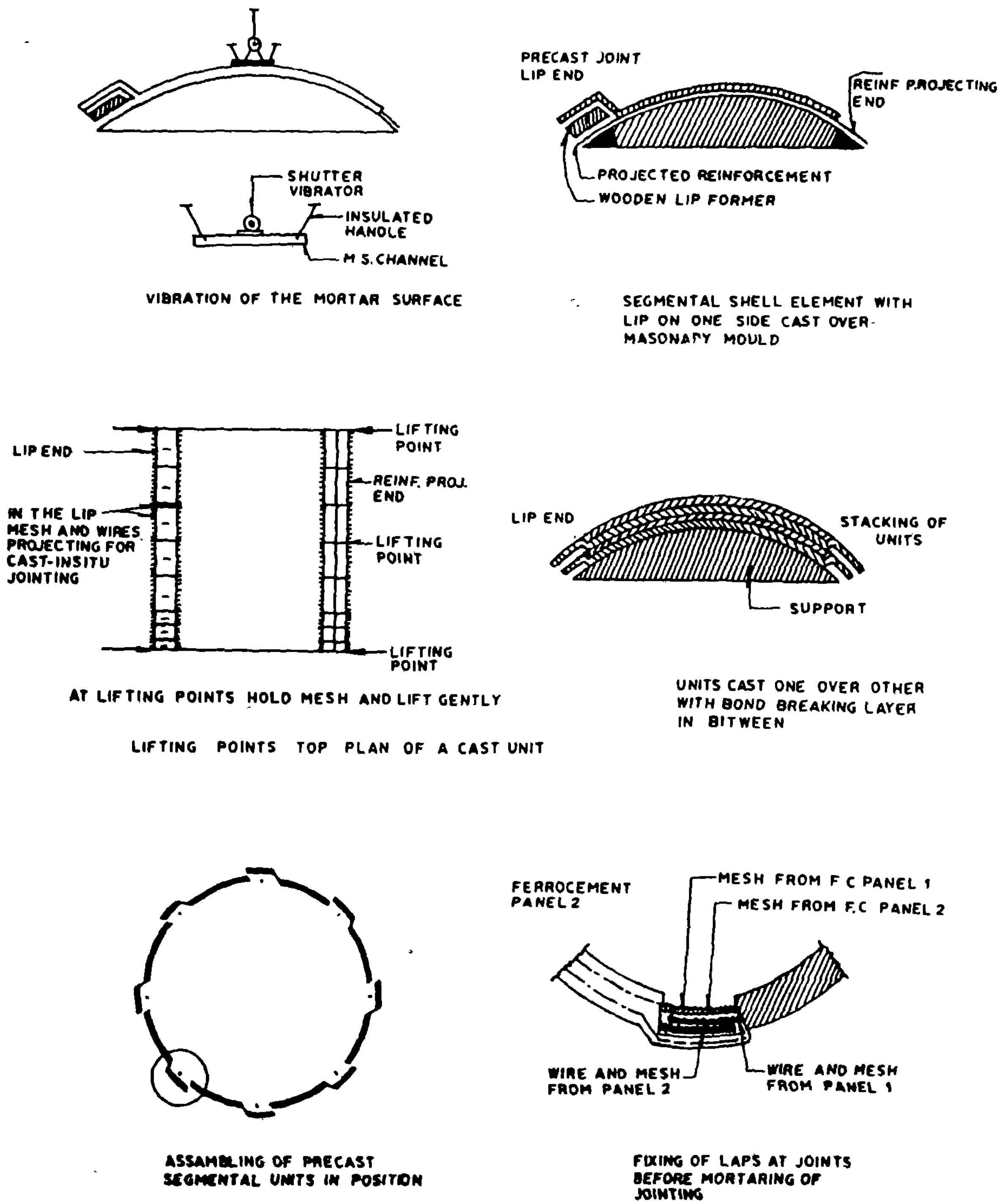
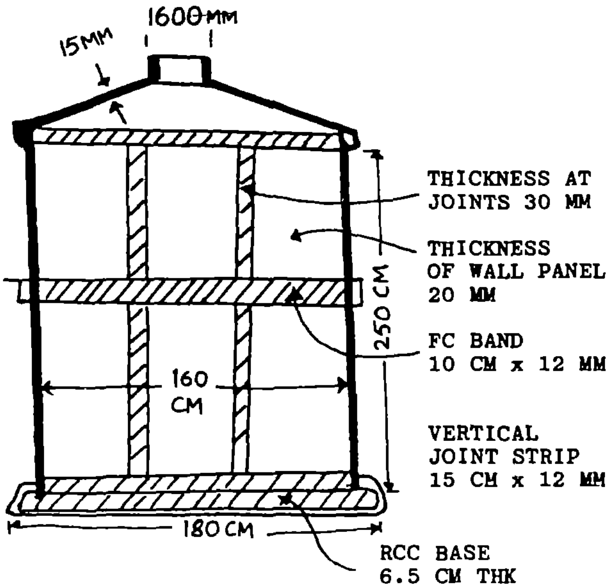


Fig. 3.1 : S.E.R.C. SEGMENTAL SHELL UNIT



S.E.R.C. SEGMENTAL SHELL CASTING AND ASSEMBLING METHOD

Fig. 3.1



DIAMETER OF TANK - 160 CMS
HEIGHT - 250 CMS
CIRCUMFERENCE ON
INNER LINE - 3.14 x 160 = 502.8 CMS

WALL CAST IN SIX SEGMENTS

cen

CENTRE TO CENTRE DISTANCE
BETWEEN JOINTS - $\frac{502.8}{6}$ = 83.8 CMS

WIDTH OF JOINT - 15 CMS

WIDTH OF REINF. CAGE FOR EACH SEGMENT
+ = 83.8 + 15 = 98.80 CMS

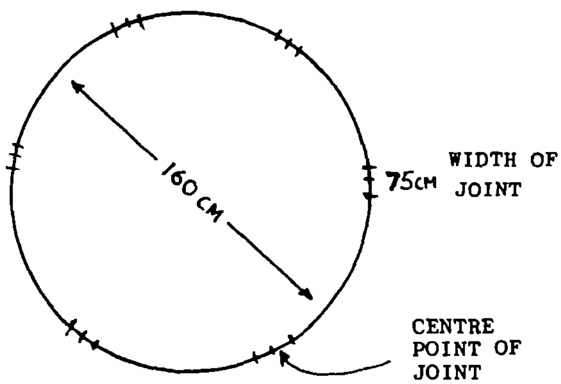
WIDTH OF WIRE MESH
= 98.80 CMS

MORTAR TO BE APPLIED ON
WIDTH OF WALL SEGMENT
= 83.8 - 15 CMS = 68.8 CMS

MORTAR THICKNESS APPLIED
OVER MOULD - 16 MM

MORTAR PLASTER AFTER
ASSAMBLING - 4 MM

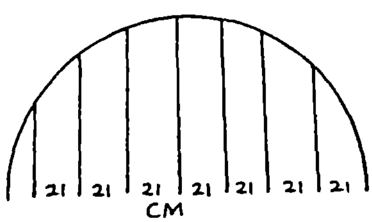
TOTAL THICKNESS - 20 MM



PLAN MARKED ON A
FLOOR FOR CALCULATING
BASE REINF & SEGMENT CAGE DIMENSIONS

MORTAR MATRIX USED FOR CASTING OF
SEGMENTS & JOINTING

CEMENT - 1 PART
SAND - 2 PARTS
PORESEALING - 0.5 Percentagex
PORESEALING - 0.5 Percent of wt. of cement
PLASTICIZER - 0.5 Percent of wt. of cement
WATER - 0.40 Parts



HALF PLAN FOR REINF.
OF BASE

DIAMETER FOR BASE - 180 CMS
REINF. - 6 MM DIA BARS AT
21 CMS CENTRES -
CENTRE BAR 8 MM DIA.
+ ONE 6 MM RING AT BOTTOM
AND ANOTHER 8 CM ABOVE

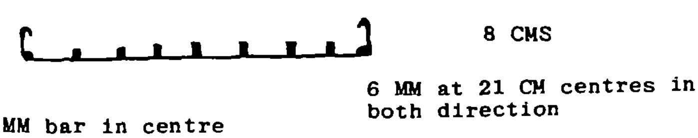
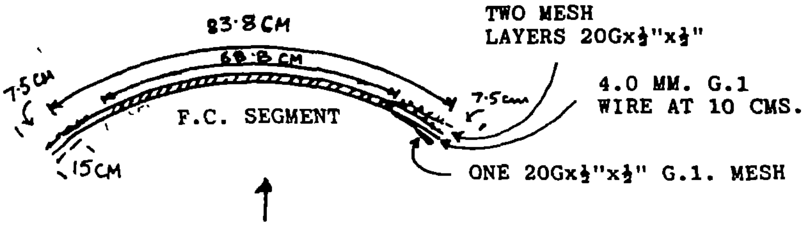
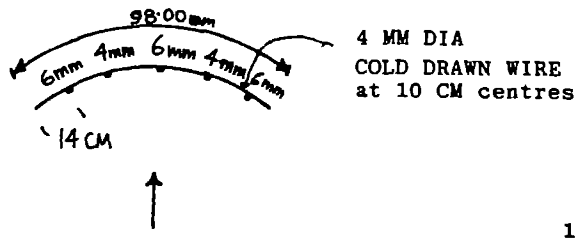


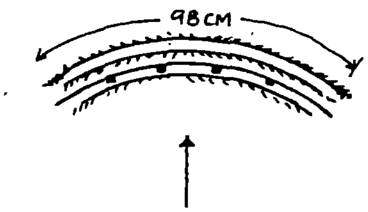
FIG. 3.2. F.C. WATER TANK WITH SERC SEGMENTALS WALL TECHNIQUE
CAP. 5000 LITRES



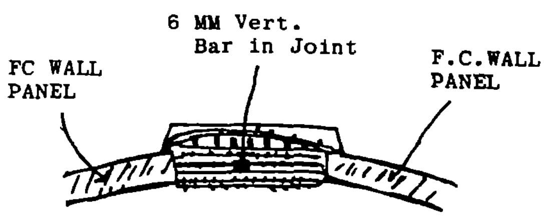
PRECAST WALL SEGMENT



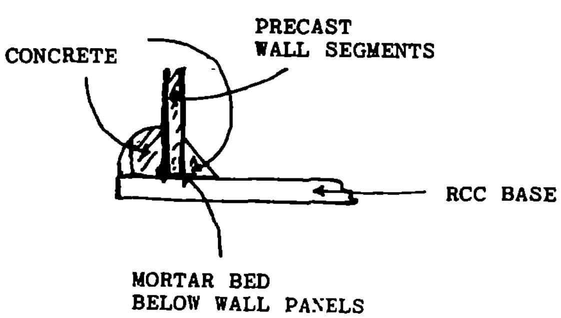
SKELETAL CAGE FOR SEGMENT



REINFORCEMENT CAGE
FOR SEGMENT



LAPPING OF
REINFORCEMENT
AT JOINT



SEQUENCE OF CONSTRUCTION

1. MARK A SKETCH FOR TANK WALL OVER FLOOR
2. MARK CENTRES FOR JOINTS - JOINT_WIDTH CALCULATE REINF. DIMENSIONS MARK TEMPLATE FOR MOULD
3. DEPOSIT SOIL IN SHAPE FOR CASTING OF SEGMENTS - SPREAD PLASTIC SHEET OVER IT. MAKE COLLER FOR TOP ON ONE END OF MOULD
4. FABRICATE CAGES FOR SEGMENTS WITH COLLER ON ONE END AND CAST OVER THE MOULD - ENSURE FULL PENETRATION OF MORTAR IN REINF. - DEMAN DEMOULD AFTER 2 to 3 DAYS - CAST REQUIRED NUMBER OF WALL SEGMENTS
5. FABRICATE BASE REINFORCEMENT
6. CAST THE BASE - MARK THE INNER CIRCLE & JOINT POSITIONS OVER GREEN CONCRETE ITSELF
7. PLACE SEGMENTS IN POSITION - ADJUST LAPS OF REINF. AT JOINTS - TIE AND STITCH WITH G.1.WIRE 18 gage -
8. CHECK DIMENSIONS - APPLY MORTAR ON JOINT
9. MAKE 45±
9. MAKE 45° EDGING ON WALL BASE JOINT ON INSIDE & OUTSIDE BOTH SIDES - PLASTER INSIDE ON WALL & BASE BOTH IN ONE Go.
10. PLATE THE PRECAST ROOF. REFER FIG. 7.1. & 7.2 FOR ROOF - FULL WALL ROOF JOINT
11. CAST LID AND PLACE OVER MANHOLE

FIG. 3.2. F.C. TANK WITH SEG. UNITS 5000 LITRE CAP

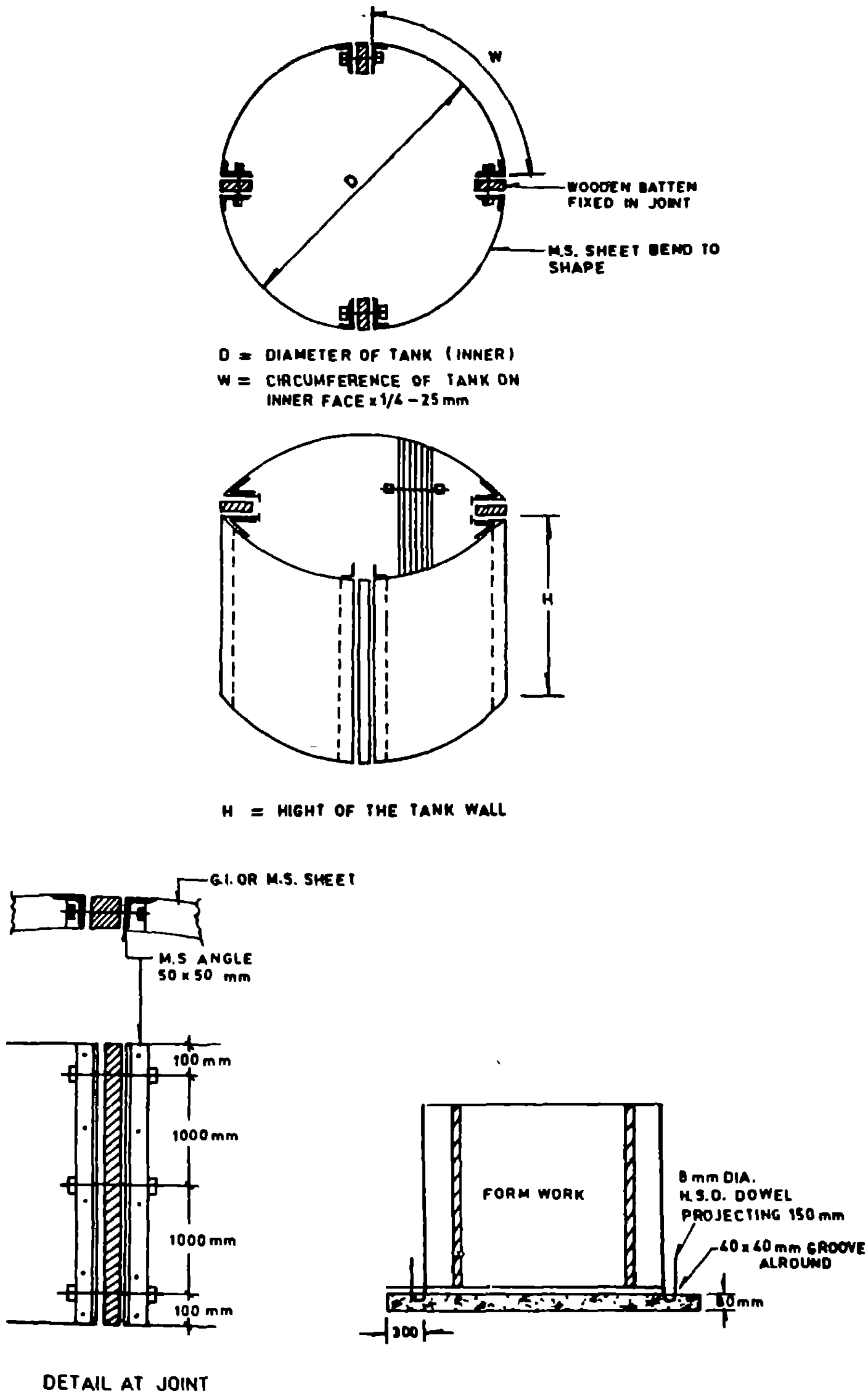


Fig. 4.2. DETAILS OF TEMPFORMER FOR E.C. TANKS

TEMPFORMER SYSTEM FOR CASTING OF F.C. CYLINDRICAL TANKS

Tempformer system, developed at SERC is a developed form of traditional casting method. In the system developed a temporary formwork is used for supporting the casting of the mid core of the ferrocement layer from inside. After the casting of mid core of the unit the tempformer is removed and the inner and outer surface are finished. The process can be divided into the following steps :

(a) The base unit for the tank/bin/septic tank/digester is cast in position.

(b) The tempformer is erected and reinforcement is fabricated and assembled around the tempformer.

(c) The sockets for inlets and outlet pipes are fixed in the wire mesh reinforcement.

(d) The mortar is applied over the cage upto the depth of the outer most mesh layer. The outer mesh is left unplastered.

(e) After 6 to 8 hours depending upon the setting period needed for cement sand mortar, the tempformer (which is made with segments and joint filler plates bolted together to form a cylindrical drum) is dismentalled and removed.

(f) The inner and outer surfaces are finished after 24 hours.

Roof is erected and tank is painted. Fig. 3 shows various stages of this method.

as they can brick up about 400 mm wall height per hour. Field experience shows that construction of base and brick wall can be completed in two days. Several methods can be used for keeping the brick wall in circular and vertical shape. Using the vertical line which is connected to wire fixed at base centre as a guide, and peridoically checking the distance between wall and line. A tape or thread can be used for checking.

3. **Fixing of hoop wire & plastering of external surface of wall of the tank**

Cement, sand mortar mixed in a ratio of 1:3 by volume is recommended for plastering of the wall. The base portion around the outside surface of the tank wall should be thoroughly cleaned and all uncompacted hardened mortar should be removed before starting the plastering of the wall. Thick cement slurry may then be applied at base wall junction for achieving good and water tight bond between mortar of the plaster and the base concrete. In the first step quick rough plastering is done over the external surface of the wall and then galvanised wires are wound around the tank wall. Three rounds of wire are fixed at the bottom for anchoring the wire. Spacing between wires in the beginning is kept at 40 mm and is increased to 60 mm and 100 mm when respective heights of 1.2 m and 2.0 m are reached at the end. Two rounds are fixed up for anchoring the wire at the top. Wires must be pulled very tightly over mortar surface so that these are embedded fully in the mortar. For achieving this goal plastering and winding of wire may be done either at the same time or alternately. Whichever procedure is adopted mortar plastering should not be done too far ahead of wire winding, otherwise the cement mortar will get stiffen and wires will not be able to penetrate into the mortar layer. If the plastering of wall for a height of 500 mm is done at a time and then wire winding is carried out it will make the work easy.

Unwinding of wires from coil of wire should be done gradually and smoothly so that the wire is free from twists and knots. Wire coils heavier than 10 kg. in weight should not be taken for winding. This is needed for easy working. Jointing of wires by tying knots with the end of other coil can be used for using short length wires. Diameter of the wire used for winding on outside wall has been taken as 2.7 mm dia (12 gauge). The wire selected should not be hard and should be of hot dip galvanised type. After the wire winding operation is completed, the external surface finish of the tank is carried out by plastering a layer of 8 mm thick cement mortar over the wound wires. This mortar layer acts as a protective cover to the wire winding done.

4. **Mortar Application on Inner Surface**

The inside base of the tank is cleaned and all unsound mortar and other undesired materials are removed. The 3 mm dia wires projecting from the base are nailed and held over the brick wall. On the inner surface of the tank wall, a layer of hexagonal wire mesh (24 g. x 1/2" size) is fixed using nails driven in joints. 3 rings of 3 mm dia are also fixed at top, centre and near bottom of the wall. Meshes can be placed in vertical or horizontal direction or in horizontal direction with 80 mm overlapping provided at all joints. Flathead nails are used for fixing wire meshes at intervals of about 300 to 400 mm. Bottom slab may also be lined with same mesh. After fixing of meshes entire surface is plastered after applying a thin layer of cement water mix (slurry) over brickwork. It is recommended that the mortar plastering of wall should be carried out by finishing the wall and base in one go. Soon after the plastering the inside surface is covered with neat cement coat for making it smooth.

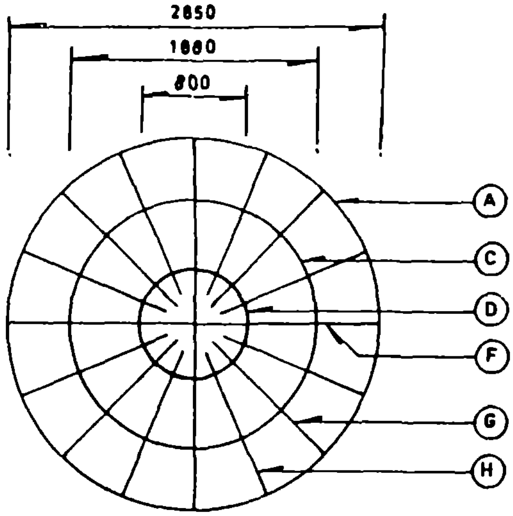
5. **Roof Construction**

Roof of the tank is construct using skeletal cage construction technique. 6 mm dia mild steel bars are provided with two layers of hexagonal wire mesh as reinforcement. Both meshes are fixed and tied together to the steel bars at a spacing of about 200 mm. The roof reinforcement cage is prepared at ground and placed on the top of the tank. Necessary adjustments are made in case the shape does not fit over the tank.

1 part of the cement : 3 part of sand (by volume) and 0.45 parts of water (by weight) are mixed and used for casting the roof. Plastering of mortar is performed by hand and trowel. A flexible plywood sheet or a G.I. sheet piece is held below the cage and the mortar is applied from top. The mortar application is done in these operations. The mid layer or core is cast using the ply/G.I. sheet backing. The thickness of this layer may be kept as 8 mm. The top layer and bottom layer can be applied next day after the mid layers become hard. A manhole is to be provided in the roof so that working become easy. For rain water collection system manhole is a must as the filter can be installed in the same opening.

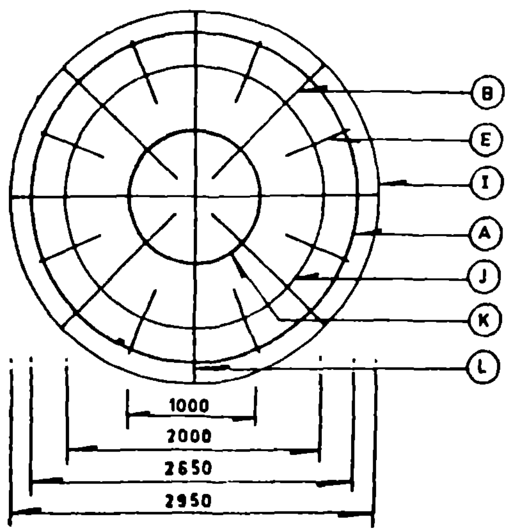
CURING OF THE TANK

For curing the entire tank surface is first saturated with water and then it is covered with a thin PVC sheet fully. The PVC sheet prevents evaporation of water from the tank surface. This method is suitable for rural areas where water is a scarce commodity. This method is very effective and no further attention is needed during the next 24 hours after wetting of the surface once a day. The PVC sheet is removed for curing and is wrapped back over the tank. The PVC sheets are reusable hence do not cost much.



NOTE: CIRCLED LETTERS ARE BAR DESIGNATIONS

Fig. 5.2 : ROOF REINFORCEMENT



NOTE: CIRCLED LETTERS ARE BAR DESIGNATIONS

Fig. 5.3 : BASE REINFORCEMENT

TABLE 5.1
DETAILS OF BAR CUTTING AND CONFIGURATION

Bar designation	No. of bars required	No. of 6 mm bars used	Details of bar cutting and Configuration (dimension in mm)
A	2	17.0 M	8500 → 2 of (2650)
B	2	3.0 M	1500 → 2 of (150, 1150, 100)
C	1	5.6 M	5600 → 1 of (1660)
D	1	2.85 M	2850 → 1 of (600)
E	3	1.55 M	1550 3 @ 510 → 3 of (450)
F	2	11.0 M	5500 2 @ 2750 → 1 of (2600, 200)
G	4	4.48 M	4500 4 @ 1120 → 4 of (1070)
E	4	1.88 M	1900 4 @ 470 → 4 of (400)
H	8	8.10 M	8100 8 @ 1010 → 8 of (9500)
I	1	9.40 M	9400 → 1 of (2950)
E	1	.60 M	600 → 1 of (540)
J	1	6.6 M	6600 → 1 of (2000)
K	1	3.4 M	3400 → 1 of (1000)
L	1	6.10	6100 2 @ 3050 → 2 of (150, 2900, 100)
B	2	3.90	3900 2 @ 1950 → 2 of (150, 1150, 100)

TOTAL 6 HM = 85.48M ADD 2% FOR WASTAGE 1.70 Kg = 85.18M x 0.22 = 19 Kg.

Table 5.2

Requirement of Construction Materials for Ferrocement Lined Brick Tanks

No.	Materials	12000 Lt. Capacity		14500 Lt. Capacity	
		Quantity	Cost Rs.	Quantity	Cost Rs.
1.	Portland cement (P.P.C.) @ Rs. 65/- per bag	22 bags	1430.00	24 bags	1500.00
2.	Bricks well burnt free from cracks @ Rs. 450/- per 1000 Nos.	2500	1125.00	3000	1350.00
3.	Stones 12 mm and down graded @ Rs. 175/- M^3	1 m^3	175.00	1 m^3	175.00
4.	Sand @ Rs. 140/- M^3	2.5 m^3	350.00	3 m^3	420.00
5.	Steel bars 6 mm @ Rs. 6/.- per Kg.	19 Kg.	114.00	19 Kfg.	114.00
6.	Hexagonal wire mesh 24gx1/2"x3" @ Rs. 300/- per 150 rft	1 roll	300.00	1 roll	300.00
7.	Galvanised wires 12 g (2.7 mm dia) @ Rs. 10/- Kg. 11g. (3.3 mm dia)	17 Kg.	170.00	25 Kg.	250.00
8.	Nails @ Rs. 9/- per Kg.	0.5 Kg.	4.50	0.5 Kg.	4.50
9.	Binding wire @ Rs. \10/- Kg.	0. 5 Kg.	5.00	0.5 Kg.	5.00
10.	Pipes & fittings etc.	—	150.00	—	150.00
11.	Drinking water tank paint @ Rs. 35/- per litre	2 litre	70.00	2.5 litre	87.50
12.	PVC sheet for curing (sheet cost divided on 4 tanks)	—	100.00	—	100.00
	Material Total :	Rs. 3993.50			Rs. 4456.00
Labour					
1.	Masons @ Rs. 40/- per day	10 m.d.	400.00	12 m.d.	480.00
2.	Barbender @ Rs. 40/- per day	2 m.d.	80.00	3 m.d.	120.00
3.	Helpers @ Rs. 15/-	24 m.d.	360.00	30 m.d.	450.00
		Total	Rs. 840.00		Rs. 1050.00
	Add for T&P and unforeseen items		100.00		100.00
	Total Cost :		**Rs. 4933.50**		**Rs. 5606.00**

Calculations based on 1987 rates in areas around Delhi.

SMALL CAPACITY FERROCEMENT WATER TANKS WITH SACKMOULD METHOD

In India and many Asian Countries the drinking water is bought from far-off distances within the village or from outside the village and is stored in water jars made with burnt clay. The production of large size burnt clay water jars of 50 to 150 litre capacities require high skill and large amount of fuel for their production. Such jars get damaged even with small accidental loads. The internal surface of these burnt clay jars remain semi-rough and after sometime it is difficult to clean the inner surface of the jar due to algae growth. Some designs of burnt clay jars have small mouth as in case of surahi type jars and their cleaning is very difficult. The village potters have started migrating to cities in search of better jobs or are not interested in producing water jars as these need large amount of firewood or cowdung cakes for firing (baking).

A cheap and easy method for making water jars using ferrocement (reinforced cement, sand and mortar) for large sizes or unreinforced mortar for capacities upto 300 litres has been developed. The shape is kept similar to burnt clay water jars. The method was originally developed in Thailand and further modifications have been made by various groups of researchers in the original method. In India the SERC(G) group has further simplified the technique for making it suitable for use in Indian villages. Large number of jars using this techniquehave been produced in Asian-African countries for storing rain water. Jars with ferrocement can be constructed upto 5.0 m^3 size. The water jar described in this note require very low level technology. SERC's experience during Drinking Water Mission Training Courses in North East States has proved that it can be adopted by unskilled persons without previous experience or knowledge of masonary work. They only need some training and demonstration of actual construction.

The construction technique does not require any equipment. The following items are needed for constructing a ferrocement reinforced/unreinforced jars :

1. Two pieces of Hesian cloth (tat)
2. One large needle and jute cord (sutli)
3. Measuring scale or tape and coloured chalk stick
4. A piece of waste craft paper, pencil and scissors.
5. Tools for mortar mixing - spade, tasla (tray), water bucket, jug etc.
6. One trowel, wooden gurmala and a paint brush.

7. Cement, sand, water and poresealing compounds.
8. Wire mesh (chicken or woven square mesh depending upon size).
9. Cold drawn/G.I. wire

The whole construction process can be divided into the following stages :

(a) Fixing of Dimensions - preparation of profile, selection of size and dimensions - preparation of a sketch for the profile.

(b) Preparation of the sack-mould jacket.

(c) Filling of sack-mould with light weight filling material.

(d) Preparation of base.

(e) Placing of mould over base.

(f) Application of mortar.

(g) Demoulding of jar by emptying the sackmould and pulling out of hesian cloth jacket.

(h) Finishing - covering and painting.

The construction of water jars, with unreinforced mortar or with ferrocement is carried out in the following steps :

1. **Selection of Size for the Jar**

For calculation of the volume, the water jar can be considered to be a combination of two cones kept one over the other. The volumes of both the cones when added will give the approximate volume of the water jar. For a decided volume of water desired to be stored in a cement/ferrocement jar the dimensions at base (the dia of the base), total heightof the jar, inlet (diameters of top opening) and height of top portion and height of bottom portion are decided.

The ratio of the height of top cone and height of the bottom cone is generally kept as 1/3 and 2/3rd respectively. This ratio gives a better look to the jar.

After deciding these dimensions for the jar a rough sketch is made giving all the dimensional details on a piece of waste craft paper. The circumference at top junction point and base are calculated as :

Circumference at the top (inlet)	=	$\pi \times d_1 = C1$
Circumference at the junction of top cone and bottom cone (at 2/3rd height from bottom)	=	$\pi \times d_2 = C2$
Circumference at the bottom/base	=	$\pi \times d_3 = C3$

A sketch of the outlines of jar is drawn over piece of craft paper as shown in Fig. 2. The sketch is cut and placed over two pieces of hesian cloth placed one over other.

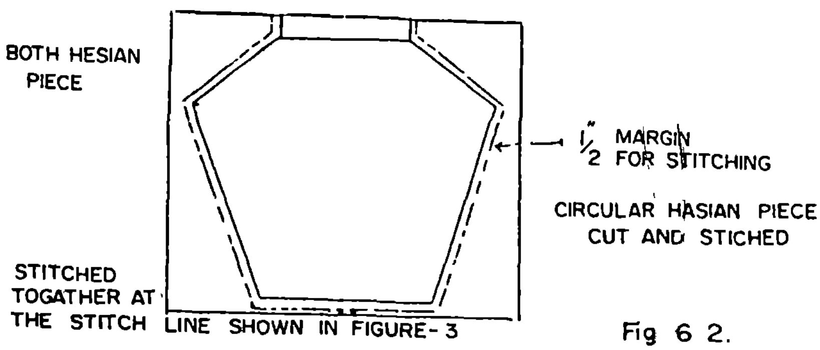


Fig 6 2.

The two hesian cloth pieces are stitched together using the needle and sutli at the stitch line shown in Figure 3. A bottom piece having a diameter = d_3 + 1" + 1" for stitching margin is cut and stitched at the bottom.

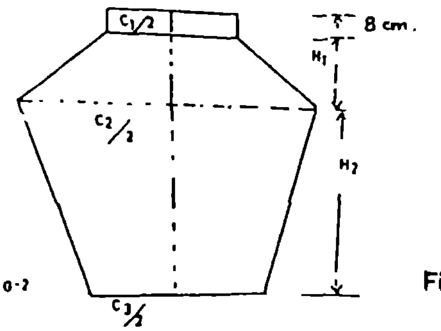


FIG-2

Fig. 6 3.

The hesian sack stitched in the manner, is inverted by turning the stitched surface inside. The sack mould for the tank is ready for use. This mould is filled with rich husk or saw dust or even with waste animal fodder or cut grass pieces, to a compacted form leaving no loose surface (Fig. 4). The top of the sack mould is also temporarily closed with a hesian piece so that the filled material does not splash out during casting.

The base of the jar is cast separately using 2.0 to 2.5 cm thick cement concrete or cement : sand mortar, six number wire pieces are provided as reinforcement as shown in Fig. 5. In case of ferrocement jars two number hexagonal mesh layer of 26 gauge x 1/2" opening are also provided as reinforcement in the base. The sack-mould is then placed over the cast base and the projected reinforcement is adjusted over the mould surface. The sack surface is made slightly moist by spraying water over it. A layer of mortar (cement sand mix of 1:2.5 to 1:3.0) is then applied over the sack surface in two layers making the thickness of mortar from 10 to 15 mm depending upon the size of the jar. After applying the first layer of mortar (thickness about 8 mm) the surface is made rough and the second layer of mortar is applied after 24 hours when the mortar of the 1st layer become hard. A coat of cement slurry is applied over the first layer before applying the second layer. Fig. 6 shows the mortar application for a water jar. A wooden ring or a steel flat ring is used for plastering the inlet opening or the mouth of the jar. This ring may be removed immediately after the casting. After 24 hours of the second layer mortar application after the mortar gets hardened the top of the sackmould is opened and the rice husk or saw dust is emptied. Once the entire infilled material is scooped out the sackmould is pulled out gently. The inner surface is cleaned with a plastic or steel wire brush with gentle strokes. The waste material is collected and disposed off. Two coats of thick cement slurry are applied on inside surface with a distamper brush. In case any wire mesh or wire ends is projecting, mortar is applied in that area before cement coating is applied. Similarly, the external surface may also be coated with cement slurry after wetting. In case any sockets or pipe fitting is to be provided in the jar, the same may be done during mortar application itself. These jars can be painted with cement paint of various shades.

Fig. 6.4 to 6.8 present various stages for casting of a F.C. Tank using sack mould method in Maran Khullen (Manipur) during a Demonstration for Technology Mission conducted by SERC Ghaziabad.

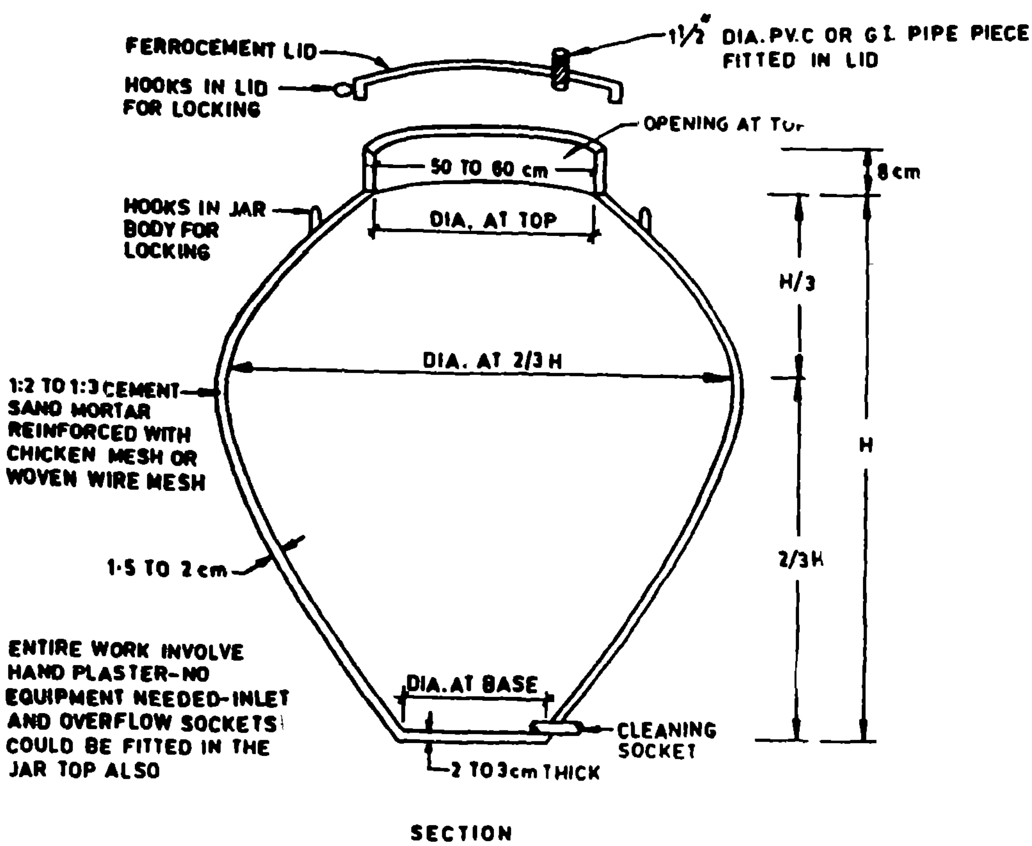


Fig. 6.4 : FERROCEMENT WATER JAR 200 TO 2000 LITRE CAPACITY

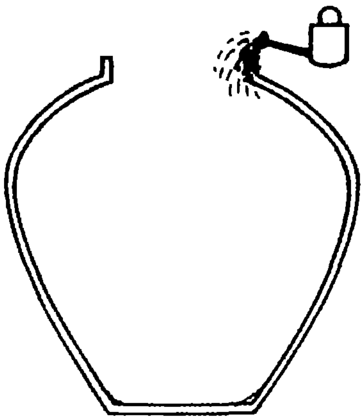


Fig. 6.9 : CURING-CURE THE CAST UNIT BY SPRAYING WATER FOR 3 DAYS AND THEN BY FILLING IT WITH AFTER 3 DAYS

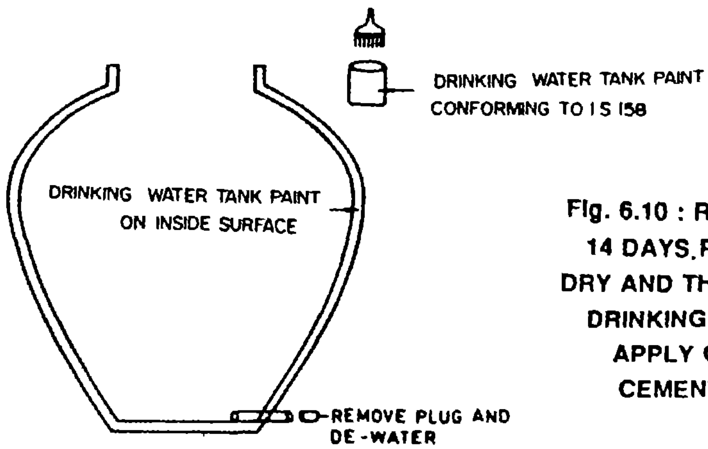
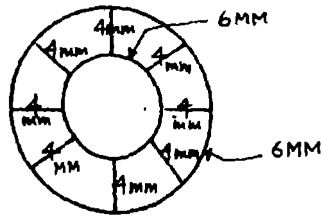
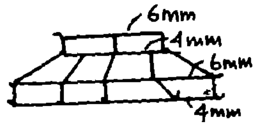


Fig. 6.10 : REMOVE WATER AFTER 14 DAYS.PERMIT THE TANK TO DRY AND THEN PAINT INSIDE WITH DRINKING WATER TANK PAINT APPLY CEMENT WASH OR CEMENT PAINT OUTSIDE.

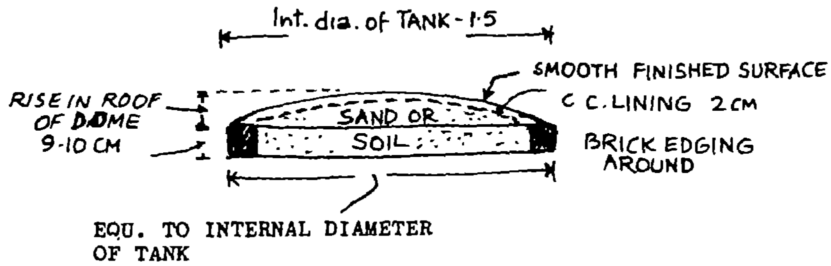


PLAN



SECTION

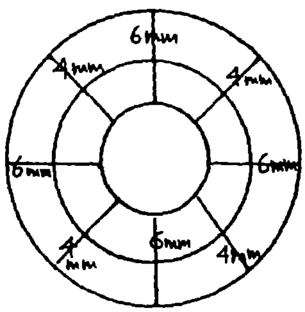
REINFORCEMENT CAGE FOR
60, 65, 75 & 90 CM DIAMETER
F.C. TANKS



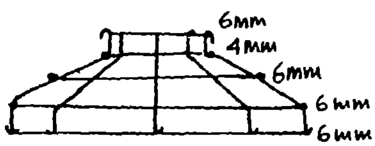
MOULD FOR F.C. TANK ROOF

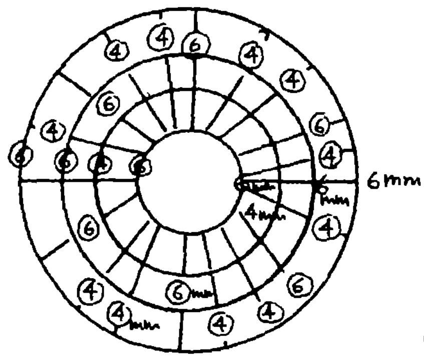
RISE OF ROOF DOME

DIA. OF TANK CMS	65	75/80	90	120	160	200	300
RISE IN ROOF DOME CMS	10	10	10	12	18	20	25



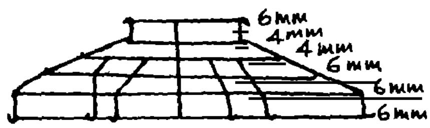
PLAN





CIRCLED NUMBER
REPRESENT DIA
OF BAR IN MM

PLAN



- REINF. CAGE FOR ROOF OF F.C. TANKS OF 120, 130, 140 & 160 CMS DIAMETERS
- WIRE MESH REINFORCEMENT 1 LAYER OF 22Gx½"x½" G.1 WOVEN MESH ON INSIDE & ON OUTSIDE SURFACES

- REINF. CAGE FOR ROOF OF F.C. TANKS OF DIAMETERS UPTO 2.25 M.
- WIRE MESH 2-22Gx½"x½" G.1 WOVEN MESH - ONE ON EACH SIDE

CASTING MATRIX - CEMENT - 1 PART
MEDIUM COARSE GRADED SAND - 2 PARTS
WATER 0.4 PARTS
PORESEALING COMPOUND 0.5 PERCENT OF CEMENT
PLASTICIZER 0.5 PERCENT OF CEMENT

FIG. 7.1 MOULD AND REINF. CAGE FOR ROOF OF F.C. WATER TANKS

CASTING OF FERROCEMENT ROOF FOR TANKS

Ferrocement roofs for these tanks are also precast over masonary moulds in one piece or in 4 to 6 pieces depending upon size and height of the tank. Jointing method for roof segments remain same as for wall segment. If the roof is case in pieces, the pieces are erected, placed in position at the top and supported temporarily. The laps of reinforcement for joints are fixed up and the joints are filled with mortar. Two type of joints between wall and roof can be adopted :

1. The edge beam cast around the roof is placed in the collar provided at the top of the wall (assembled with segments) and the mortar is filled in the wall roof paint.

2. The roof/roof segment edge beam cover the wall top edge like a cover.

Various stages of construction of Roofing Units for F.C. tanks have been shown in Fig. 7.1 to 7.6.

PIT LINING METHOD AND BAMBOO FERROCEMENT TANKS

PIT LINING METHOD

For underground storage of water in areas where soil strata is hard or rocky areas, tanks can be constructed using ferrocement lining applied over the soil directly. The main purpose of such lining is to prevent leakage/see page of stored water into the soil strata. Ferrocement being a high impermeably material, performs this duty very well. The experience of storing grains in Ethiopia in underground ferrocement lined pits has been very encouraging and the development of 'pit lined tanks' has been a result of this experience. A set of sketches provided in a small booklet (tilted pit lining method) included in the course material provides full details of the lining process in different stages.

Pit lining method of tank construction can be divided into the following steps :

(a) Determination of the soil characteristics and check if the soil can withstand of its own straight at it sides or on a small slope provided in both the vertical sides.

(b) Decide the dimensions of the tank to be constructed i.e. diameter, height, slopes in sides (if provided).

(c) Excavate the pit keeping the geometry and dimensions in view.

(d) Make the surface of the excavated pit moist by spraying water with very light spray.

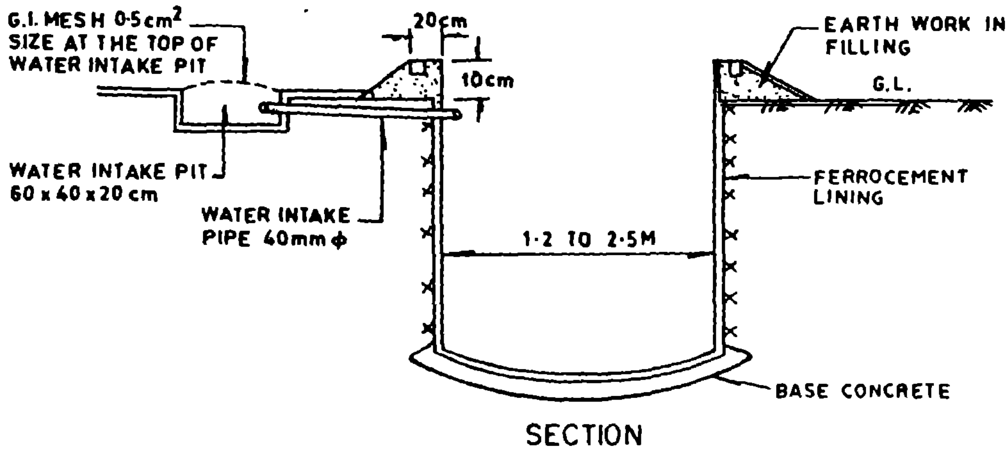
(e) Lay a layer of concrete in the base. Make the joint of the vertical wall and the base in slope (at 45° angle but in smooth curve).

(f) Apply a 6 mm thick plaster over the side walls using 1 part of cement and 3 parts of medium coarse silt free sand adopted with a pore sealing compound.

(g) Fix wire nails in this plaster layer at an distance of 20 cms apart. The wire nail may be fixed immediately after application of mortar. The side of the nails are pressed so that these become tight in mortar.

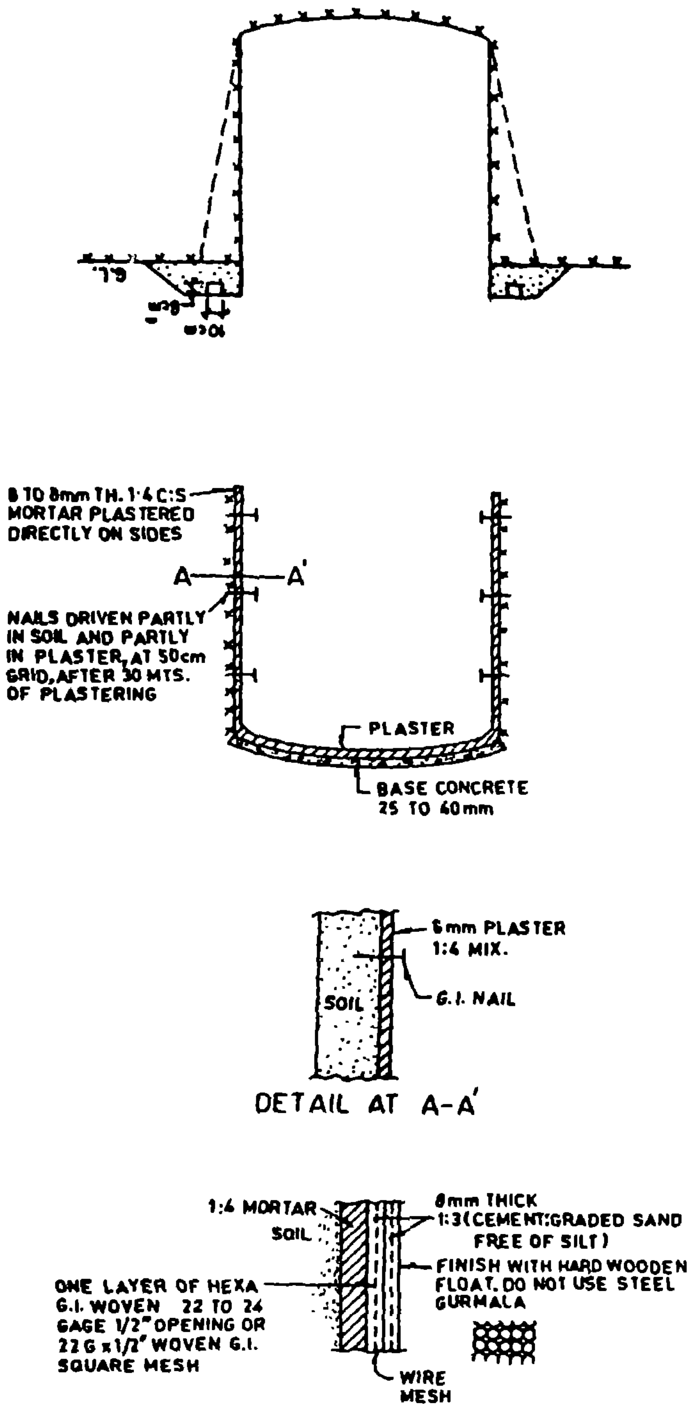
CONSTRUCTION OF UNDERGROUND FERROCEMENT RAIN WATER COLLECTION TANK BY PIT LINING

CONSTRUCTION STAGES



COMPLETED TANK

Fig. 8.1.



1. DECIDE THE SIZE, SHAPE AND DIMENSIONS OF THE TANK, DRAW A SKETCH. MARK ON GROUND, EXCAVATE THE PIT. COMPACT THE BASE AREA VERY WELL DEPOSIT EARTH AROUND THE PIT AND COMPACT IT AS SHOWN IN SKETCH.

MAKE A 10 x 8 cm PIT AROUND IN THE TOP SOIL DEPOSIT.

PROVIDE SUITABLE SLOPE IN SIDES IN CASE THE SOIL CAN NOT BE CUT IN VERTICAL OR NEAR VERTICAL ANGLE

PLACE A LAYER OF CEMENT CONC. 1:2·4 MIX IN THE BASE AND COMPACT IT.

MOIST THE VERTICAL SIDES SLIGHTLY AND APPLY 6 TO 8 mm THICK 1:4 MORTAR OVER THE VERTICAL SIDES MAKE THE SURFACE ROUGH WITH A BROOM OR COIR BRUSH.

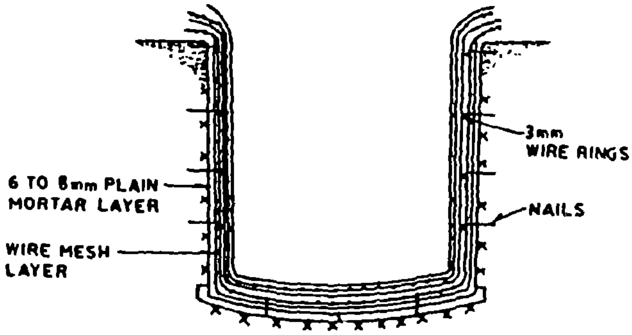
FIX HOT DIP GALVANISED NAILS IN MORTAR LAYER PARTLY IN MORTAR AND PARTLY IN THE SOIL. PROJECT-ION OF NAILS MAY BE KEPT 10 TO 12 mm

MAKE THE MORTAR SURFACE ROUGH WITH A BROOM OR COIR BRUSH SO SO THAT IT HAS GOOD BOND WITH NEXT LAYER.

NEXT WORKING DAY FIX ONE MORE LAYER OF MESH, APPLY A COAT OR CEMENT SLURRY AND APPLY 8mm THICK MORTAR LAYER FOR COVERING THE MESH.

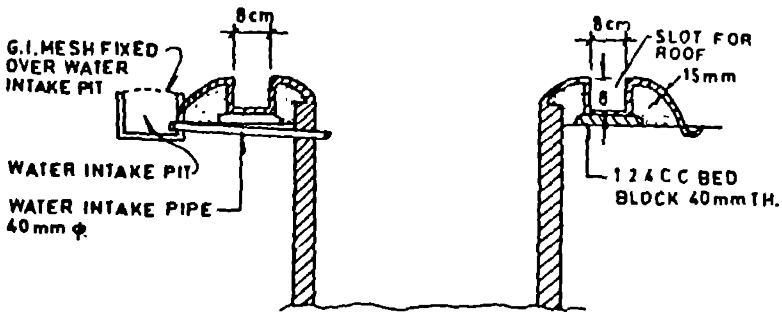
LEVEL THE SURFACE OF MORTAR, RUB HARD AND FINISH WITH WOODEN FLOAT.

Fig. 8.2.



FIX ONE LAYER OF WIRE MESH WITH THE HELP OF NAILS PROVIDE 3 mm⌀ GI/COLD DRAWN WIRE RINGS AT PLACES LIKE TOP, BOTTOM AND 2 OR 4 POINTS. THIS WILL FACILITATE TYING AND TIGHTNING OF WIRE MESH LAYERS-FIX WATER INTAKE PIPE AT THE DESIRED POINT.

SPRINKLE WATER FOR WETTING THE MORTAR LAYER. APPLY A COAT OF CEMENT SLURRY. APPLY 8 mm THICK 1:3 CEMENT · SAND MORTAR ENSURE THAT MORTAR IN PREGNATES IN MESH LAYER AND IS COMPACTED WELL



TAKE THE MESHES PROVIDED IN THE TANK LINING OVER THE SOIL DEPOSIT ON EDGE OF THE PIT AND FORM A SLOT FOR ROOF AS SHOWN

CONSTRUCT WATER INTAKE PIT AT A DESIRED LOCATION

COVER THE WATER INTAKE PIT WITH GI MESH COVER FRAME FOR AVOIDING ENTRY OF LEAVES, GRASS AND OTHER SUSPENDED OBJECTS INTO THE TANK

Fig. 8.3

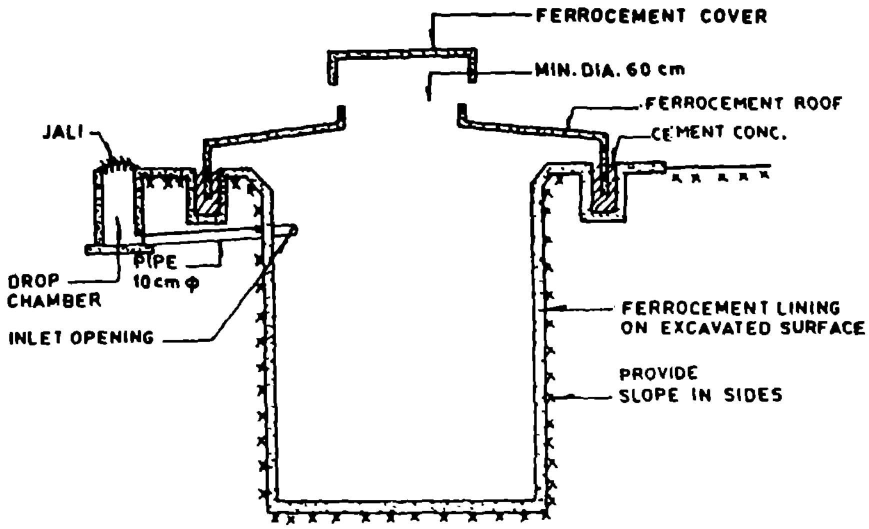
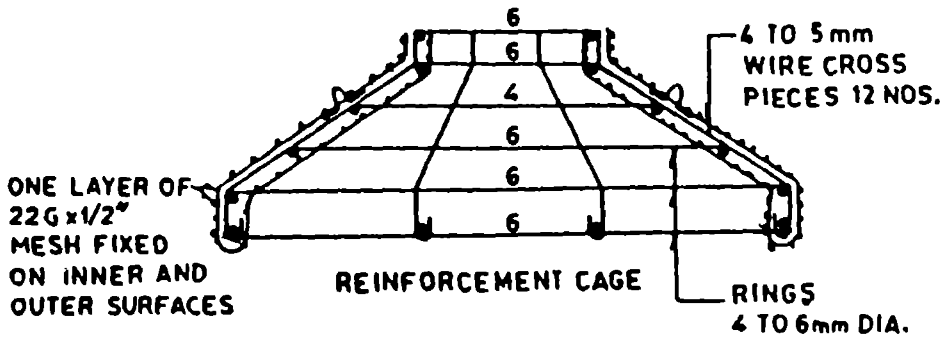
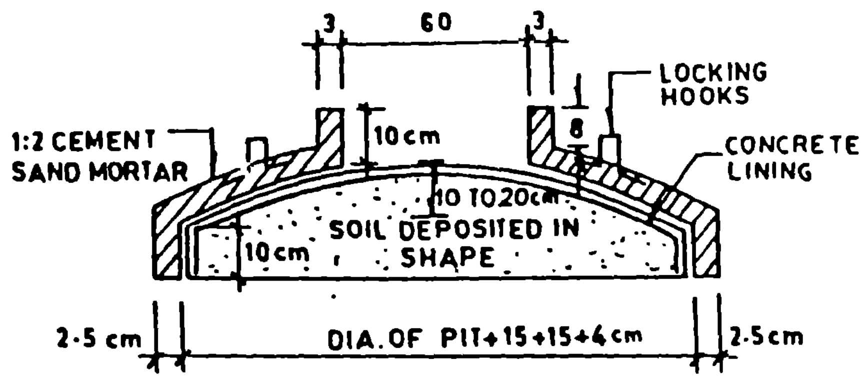


Fig. 8.4 : FERROCEMENT UNDERGROUND TANKS/CISTERNS FOR STORING RAIN WATER FROM GROUND CATCHMENT

PROCESS OF FERROCEMENT ROOF CASTING FOR U.G. TANKS





MOULD AND CASTING

1. MAKE A MOULD BY DEPOSITING SOIL IN INSIDE SHAPE OF ROOF.

2 PROVIDE 1cm SLOPE IN THE VERTICAL SIDES OF MOULD.

3. COVER THE MOULD WITH OILED PAPER

4. PLACE REINFORCEMENT OVER MOULD-CAGE OF 4 TO 5mm WIRE + 2 LAYERS OF MESH.

5. MIX CEMENT 1 PART + MEDIUM COARSE GRADED SAND 2 TO 3 PARTS + PORE SEALING COMPOUND + PLASTICIZER + WATER 0·4 TO 0·45 PARTS OF CEMENT. APPLY IN TO REINF. CAGE.

6. CURE FOR 3 TO 5 DAYS. DEPENDING ON CLIMATE.

7. LIFT OFF THE MOULD PLACE AT LAVEL PLACE.

8. FINISH FROM INSIDE

9. CURE FOR 10 DAYS. DRY TRANSPORT AND INSTALL.

Fig. 8.6.

(h) Fix a layer of G.I. mesh (24 gauge to 22 gauge with 3/0 to 1/2" mesh opening) over the base and wall surface and apply a layer of 6 to 8 mm mortar. The mesh may be held at wall with nails fixed in mortar. The surface of the mortar is made rough by a broom or a plastic brush.

The second layer of mesh is then fixed and cement mortar is plastered and finished. The thickness of each mortar layer can be about 8 mm. For fixing the roof and for anchoring of lining the ferrocement lining is carried over the horizontal surface of the tank top and a groove is formed around it for fixing the roof. In case of rain water collection units the water entry chamber (drop chamber) is also constructed by lining of the drop chamber pit with ferrocement. The roof is precast over soil deposit/masonary mould and is placed in the groove provided around the tank. The groove is then packed with rich cement and sand mortar for sealing the joint.

DO'S AND DONOT'S FOR FERROCEMENT TANKS

DO'S

1. Use the best quality materials for constructing the tank.

2. Take all cares to see that there are no loose pockets or honey-combed areas in the surface of wall or base of ferrocement tank. If such a defect is detected then repair it by chipping mortar on inside and outside surfaces (exposing the wire mesh in that area) and replastering.

3. Cure F.C. tanks for a minimum of 10 days.

4. Clean the tank from inside atleast twice a year when ever it is empty.

5. Keep the top of the tank clean for avoiding entry of waste material in the tank.

6. Construct the tank at a higher point so that drainage of water is proper or construct a soaking pit and connect it to the tank area by a drain.

7. Take all cares during mortar application and ensure that the mortar enters behind the steel rods and wires provided as skeletal steel and into the wire mesh layer reinforcement. Ensure that the cover over outer and inner mesh layer is not less than 3 mm.

DO NOT'S

1. Do not allow animals to come near the tank.

2. Do not allow children to climb over the tank. They open the lid and throw unwanted things inside or might jump in without knowing the consequences.

3. Do not use corroded steel or mesh for construction of the tank.

4. Do not use old stocks ot cement for tank construction.

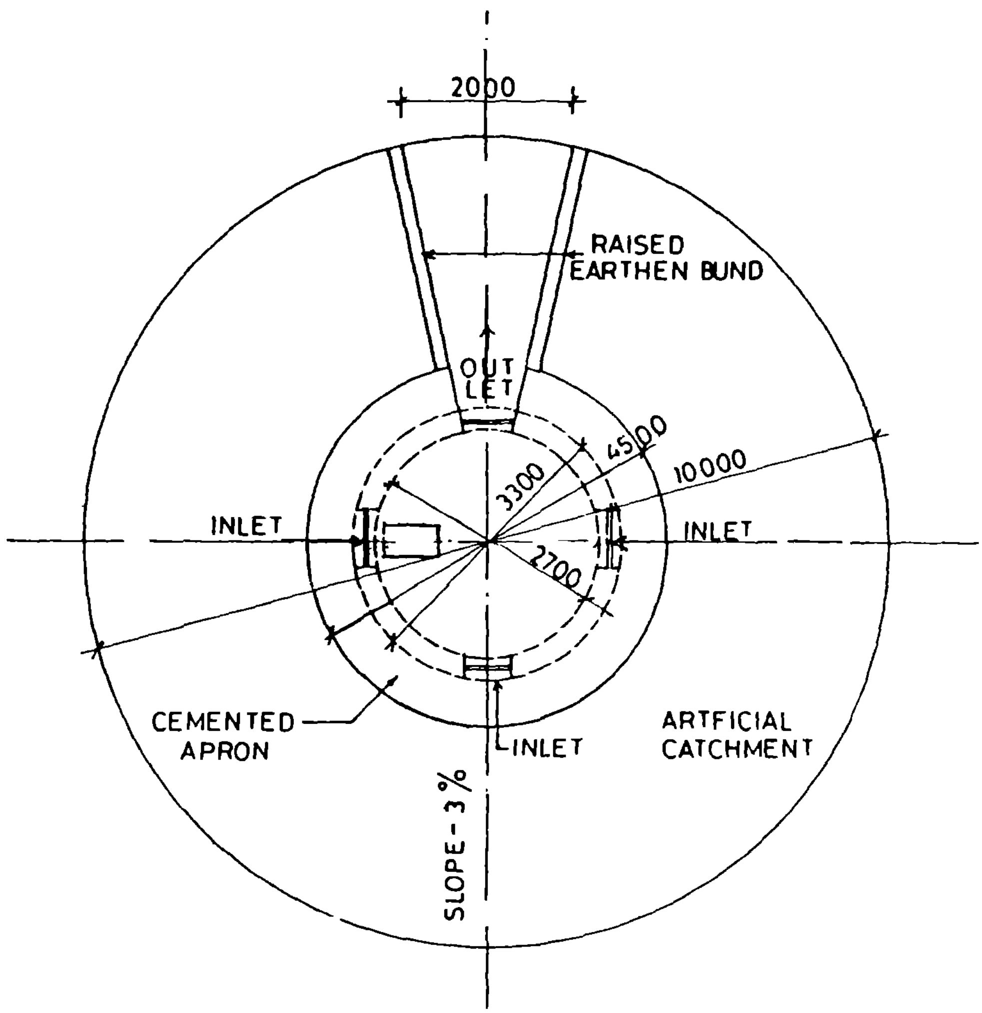
5. Do not use sand too fine or too coarse. Sand to be used should be graded and clean sand having silt contents within 3 per cent of the volume.

6. Do not allow water fittings fixed in the tank to leak, it will not only waste water but may also prove a base for algae growth on fitting joints or surface of the tank and development of bacteria colonies in these.

7. Do not use chemically polluted water for mixing of mortar and curing of ferrocement tank.

8. Do not use drinking water tank paint without specifying that it is conforming to Indian Standard Specification 158 (I.S. - 158).

एन.आई.डी.सी. NIDC	PROJECT DESIGN OF RAIN WATER HARVESTING SYSTEMS	SK. NO WHS-AI-$\frac{1}{10}$



PLAN
(TANKA FOR A SINGLE FAMILY)

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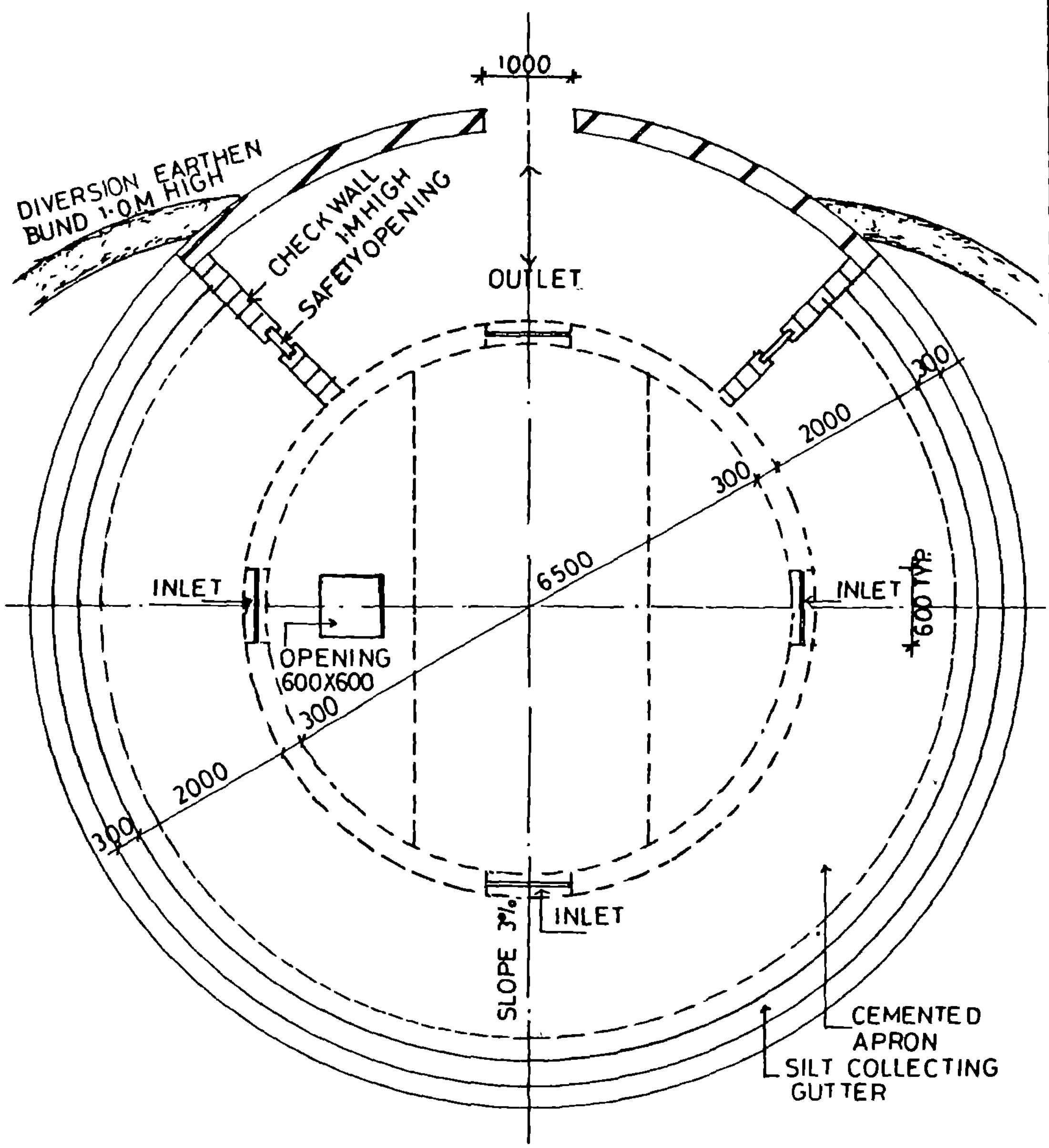
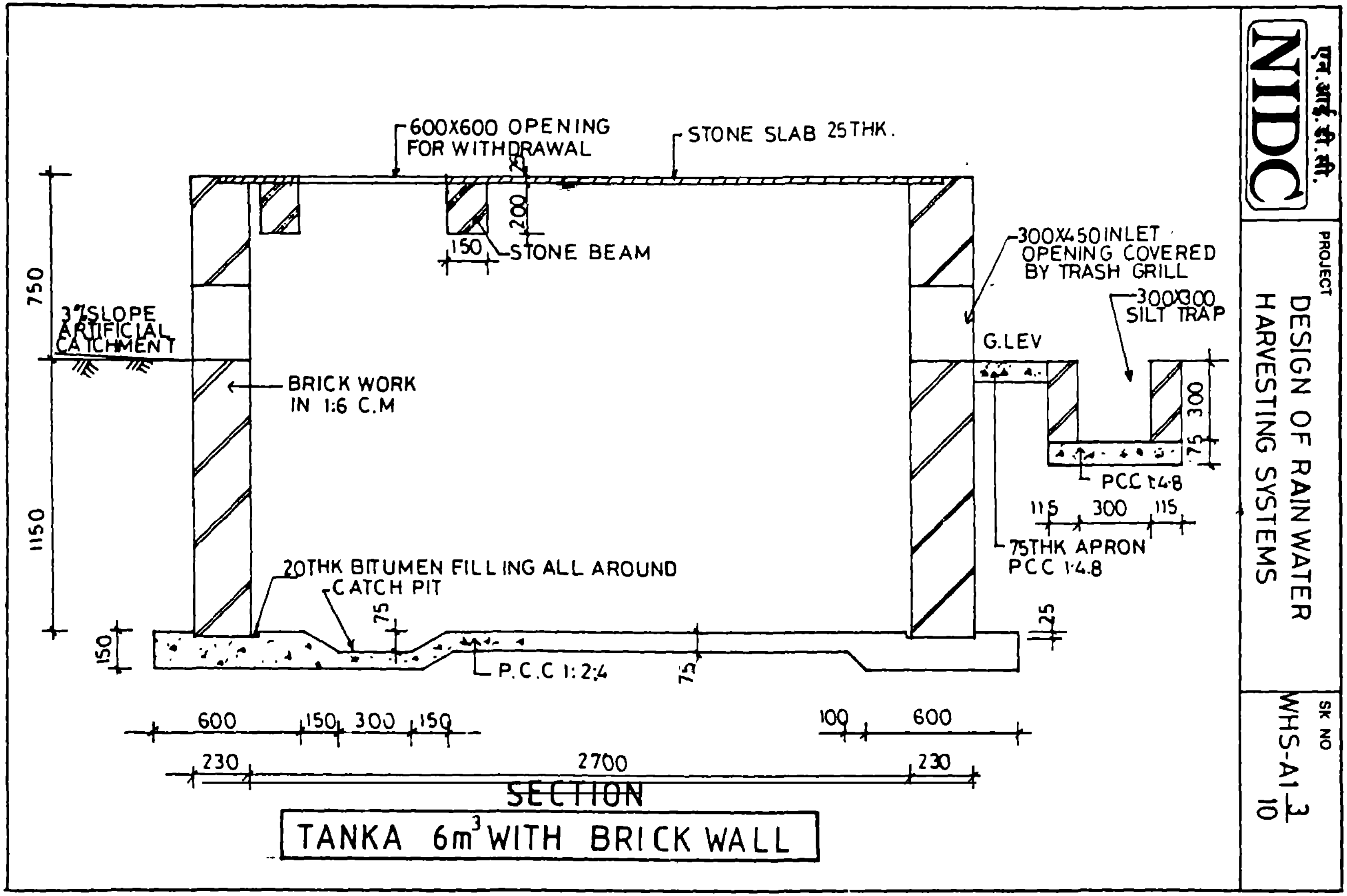
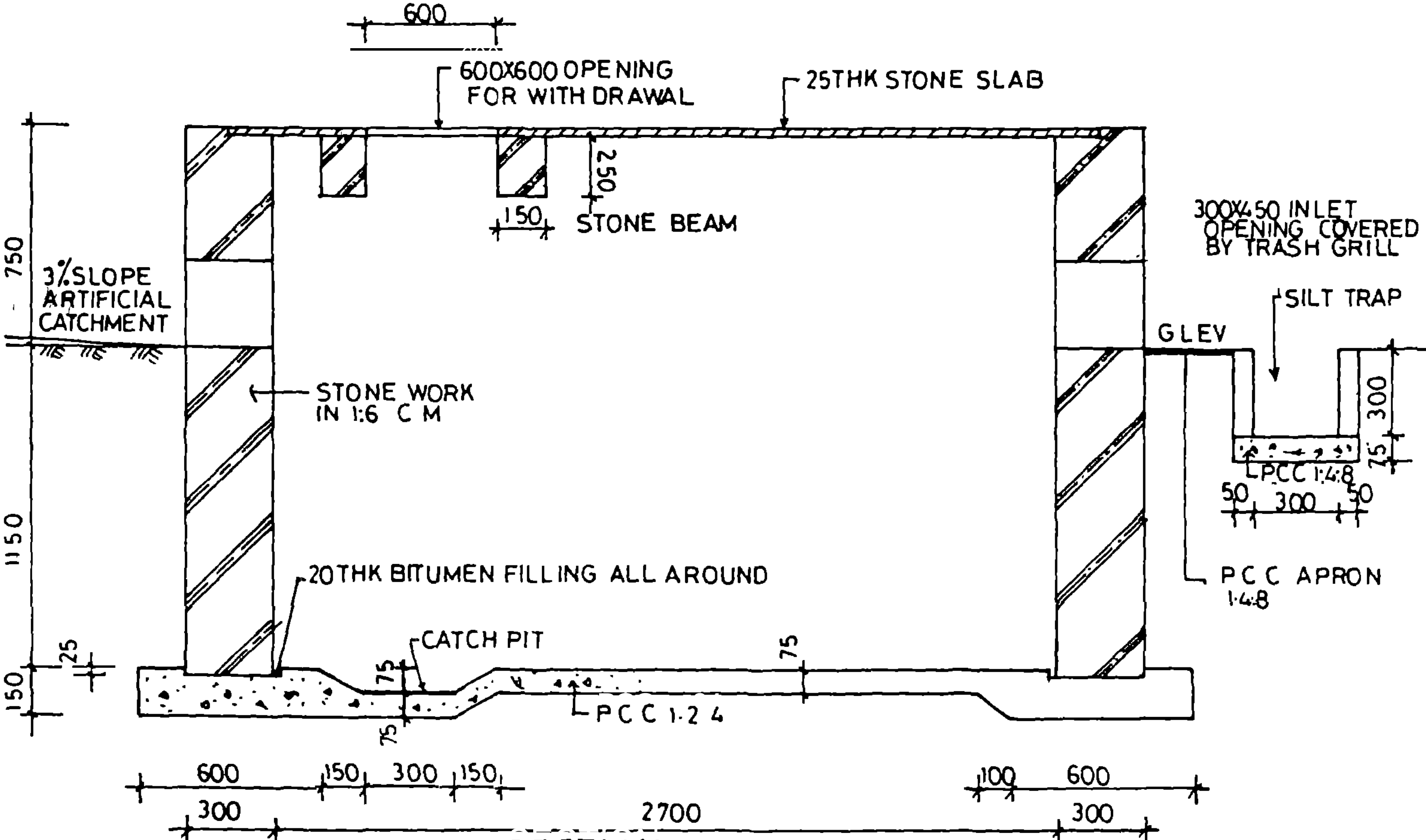


PLAN
(TANKA FOR A COMMUNITY)



600X600 OPENING FOR WITHDRAWAL
STONE SLAB 25THK.
200
150
STONE BEAM
300X450 INLET OPENING COVERED BY TRASH GRILL
300X300 SILT TRAP
G.LEV
750
3% SLOPE ARTIFICIAL CATCHMENT
BRICK WORK IN 1:6 C.M
300
75
PCC 1:4:8
115
300
115
75THK APRON PCC 1:4:8
1150
20THK BITUMEN FILLING ALL AROUND
CATCH PIT
75
25
150
P.C.C 1:2:4
75
600
150
300
150
100
600
230
2700
230
SECTION
TANKA 6m³ WITH BRICK WALL
NIDC
PROJECT
DESIGN OF RAINWATER HARVESTING SYSTEMS
SK NO
WHS-A1 3/10



SECTION

TANKA 6m³ WITH STONE WALL

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PROJECT
DESIGN OF RAIN WATER HARVESTING SYSTEMS

SK NO
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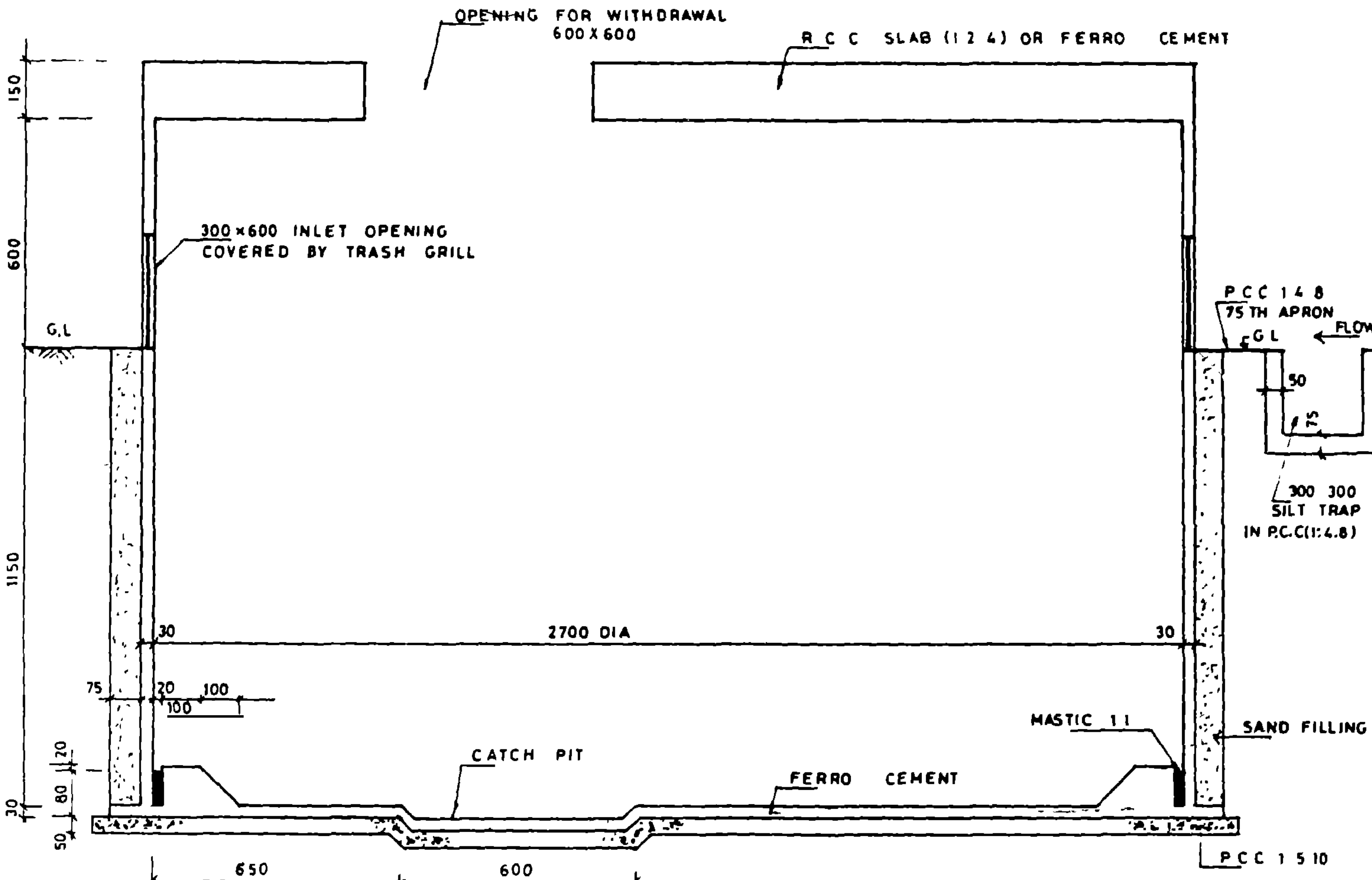
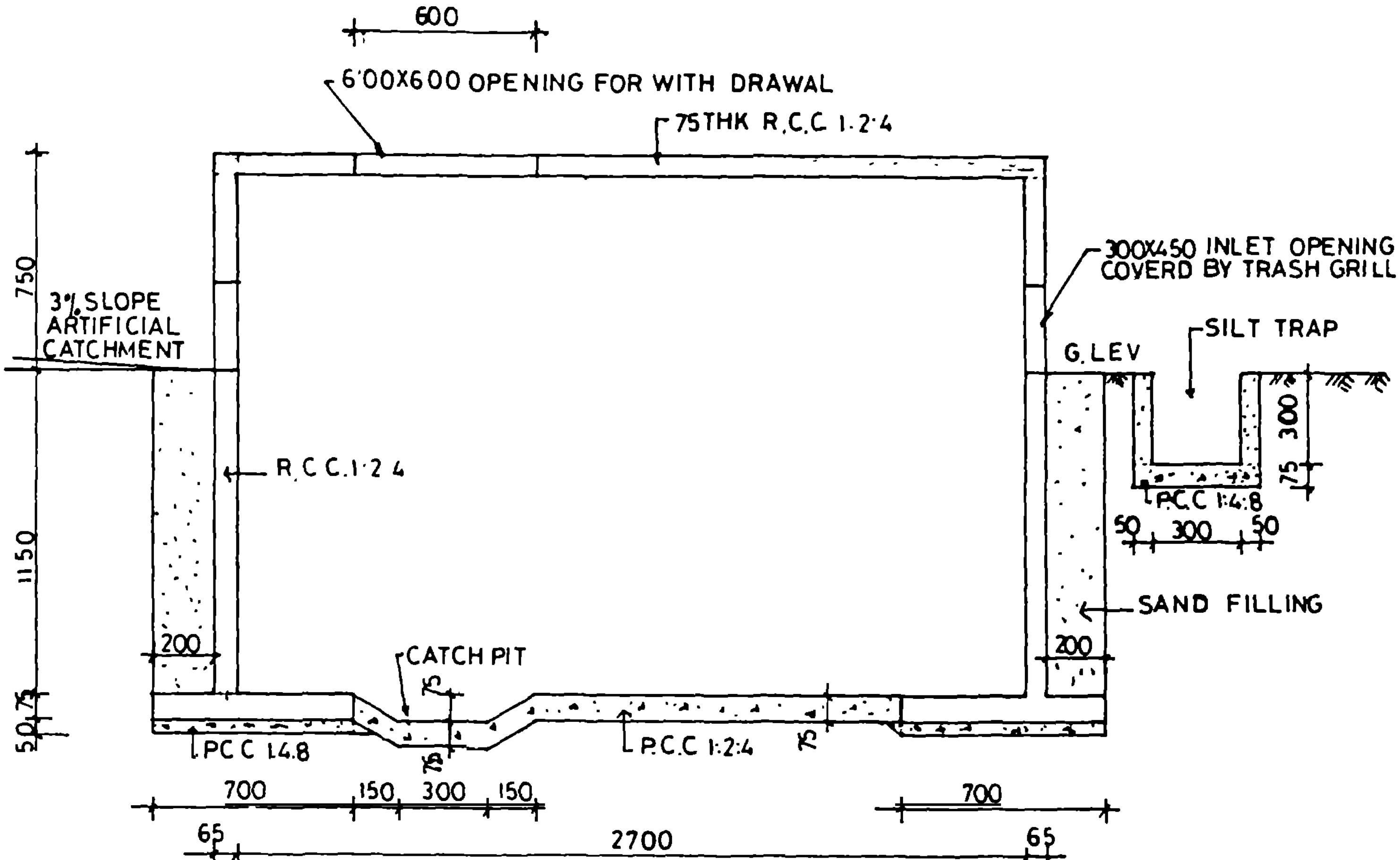


SECTION

(TANKA 6·0M³ WITH FERRO CEMENT)

PROJECT
DESIGN OF RAIN WATER HARVESTING SYSTEMS

SK. NO
WHS-A1 5/10



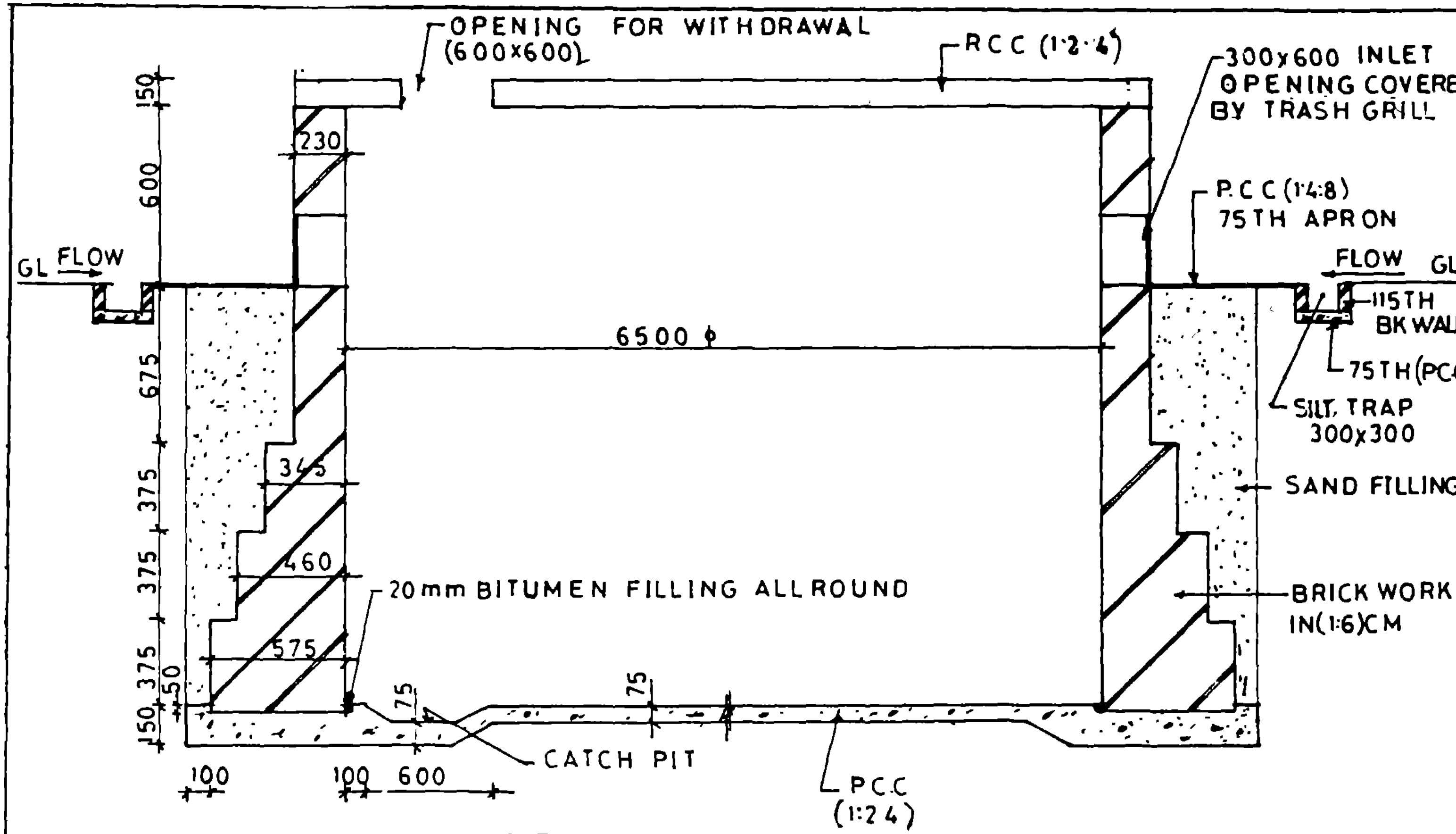
SECTION

TANKA 6m^3 WITH R.C.C WALL

NIDC

PROJECT: DESIGN OF RAIN WATER HARVESTING SYSTEMS

SK NO. WHS-A1 $\frac{6}{10}$



SECTION

TANKA 60·0 M^3 WITH BRICK WALL

NIDC

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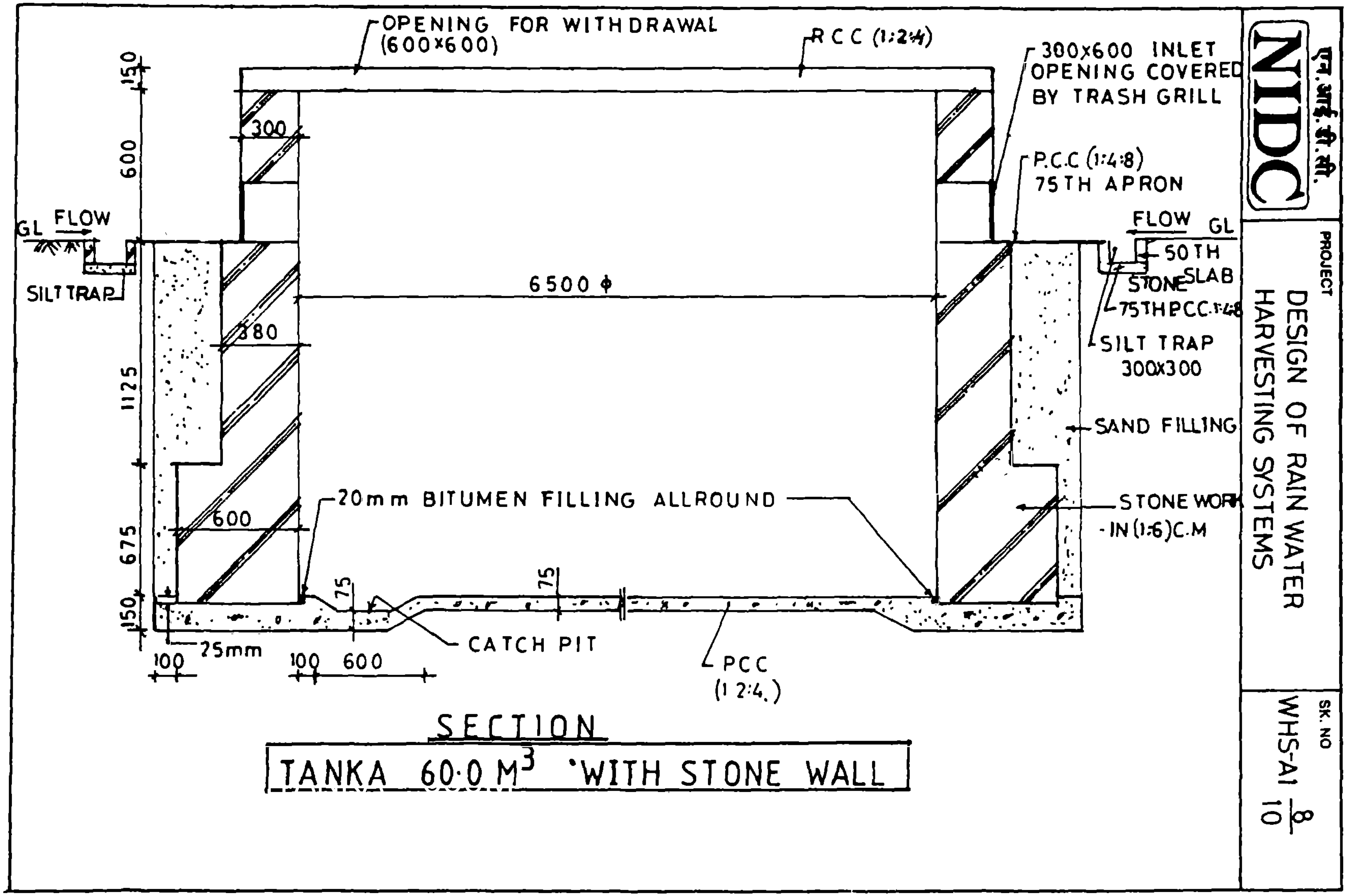
PROJECT

DESIGN OF RAINWATER HARVESTING SYSTEMS

SK. NO.

WHS-A1 $\frac{7}{10}$



SECTION

TANKA 60·0 M^3 WITH STONE WALL

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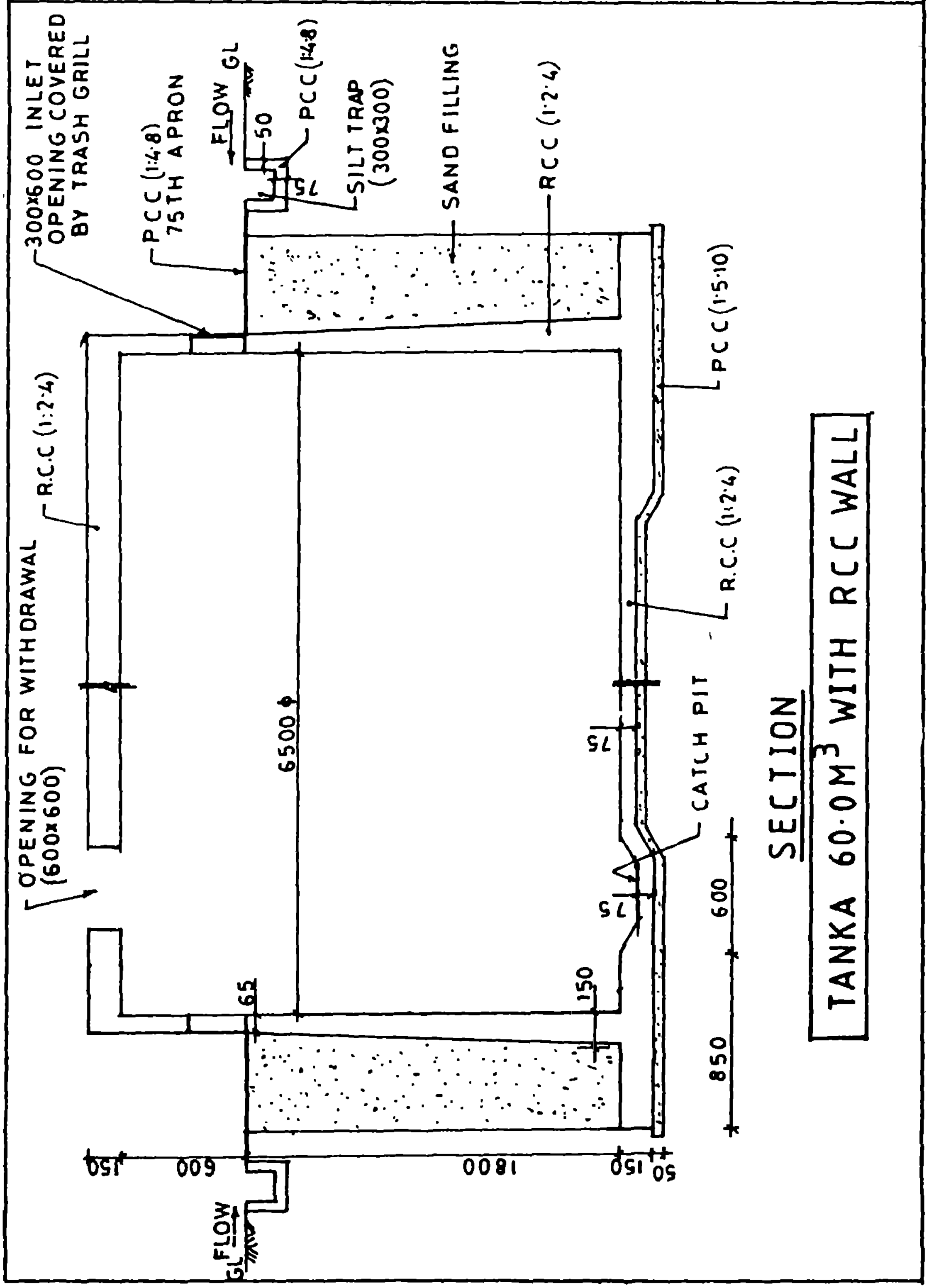

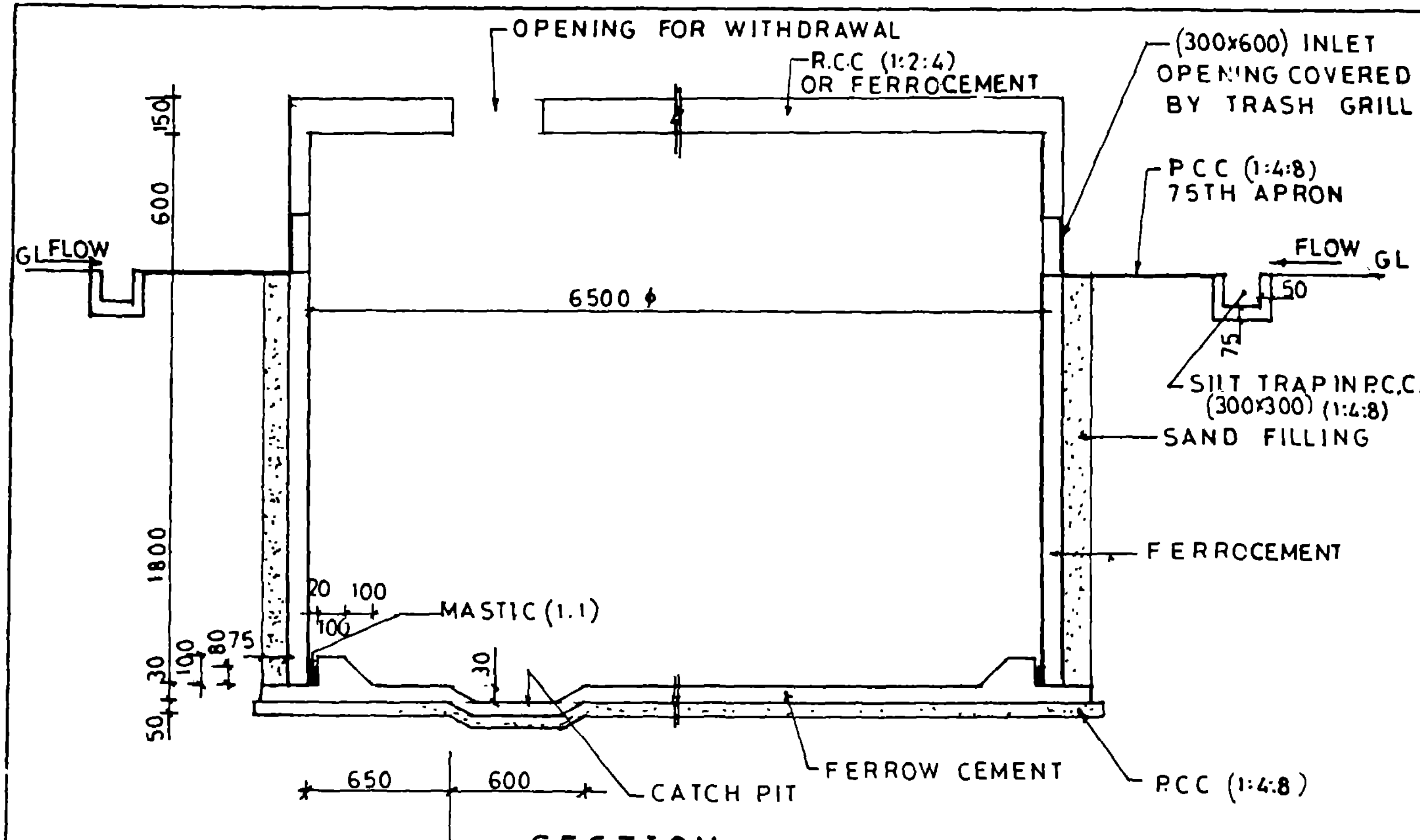

SECTION

TANKA 60·0 M^3 WITH FERROCEMENT

NIDC

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PROJECT

DESIGN OF RAIN WATER HARVESTING SYSTEMS

SK NO

WHS-A1 $\frac{10}{10}$

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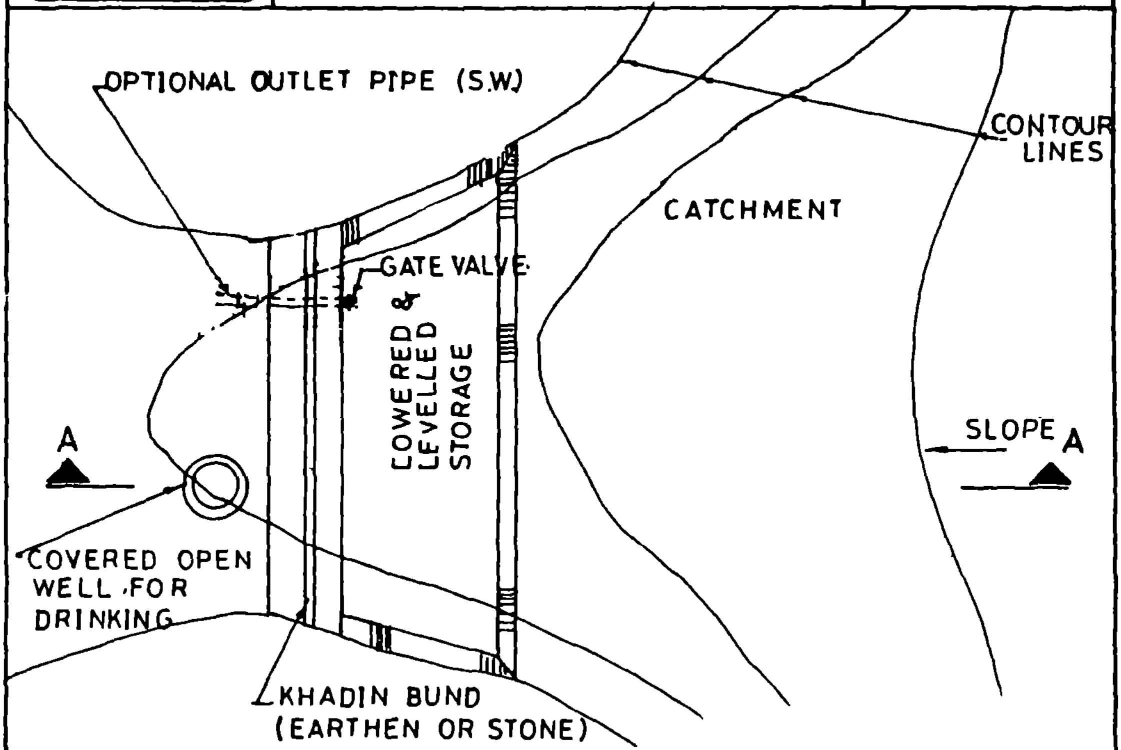
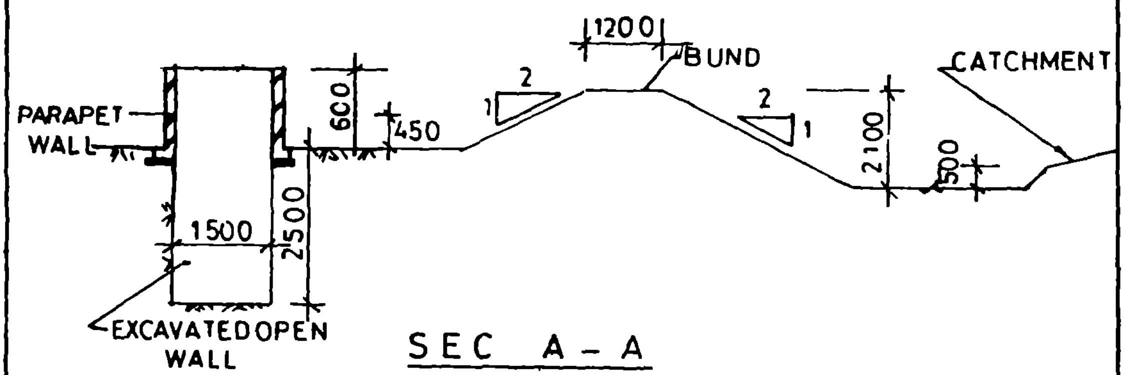


PLAN



SEC A - A

(KHADIN SYSTEM)

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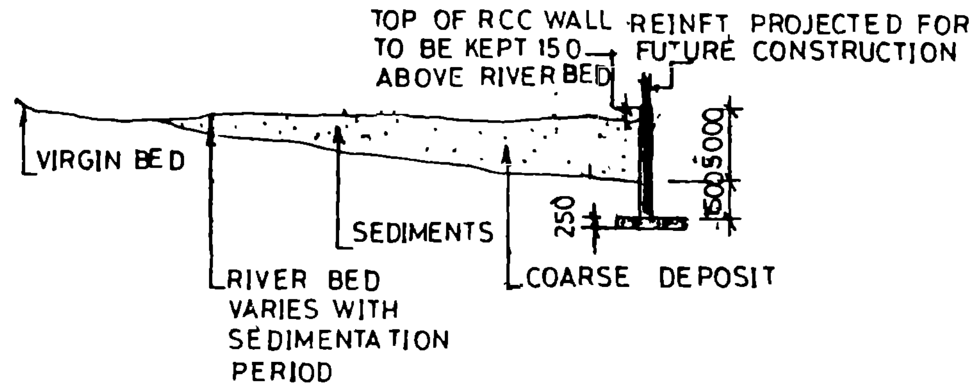
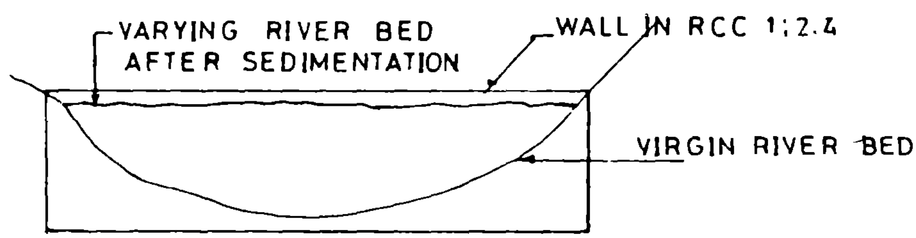
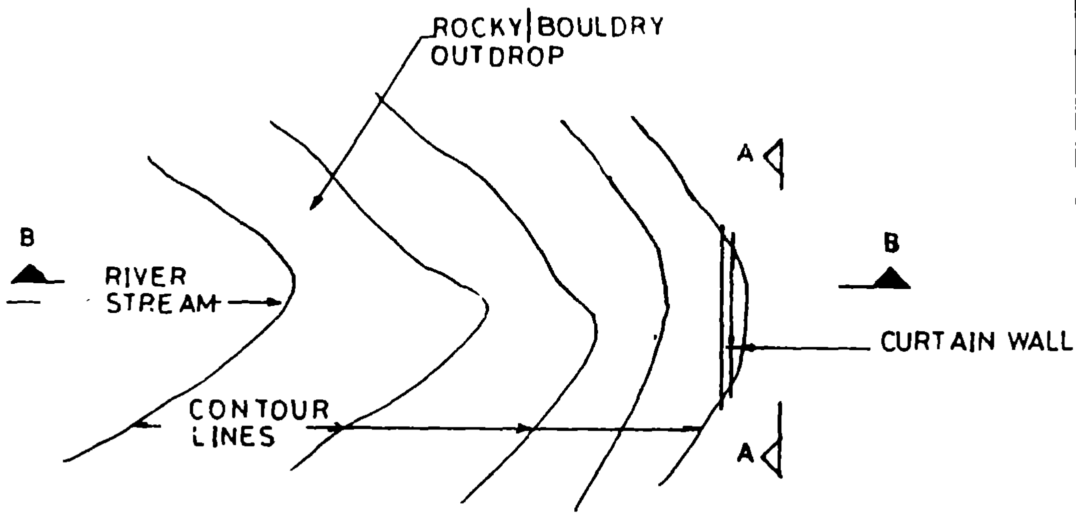


SEC. B - B



VIEW A - A



PLAN

(SANDFILL DAM)

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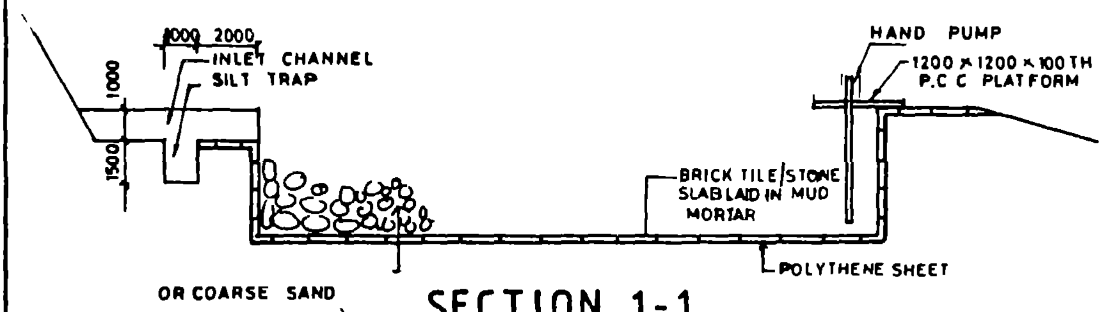
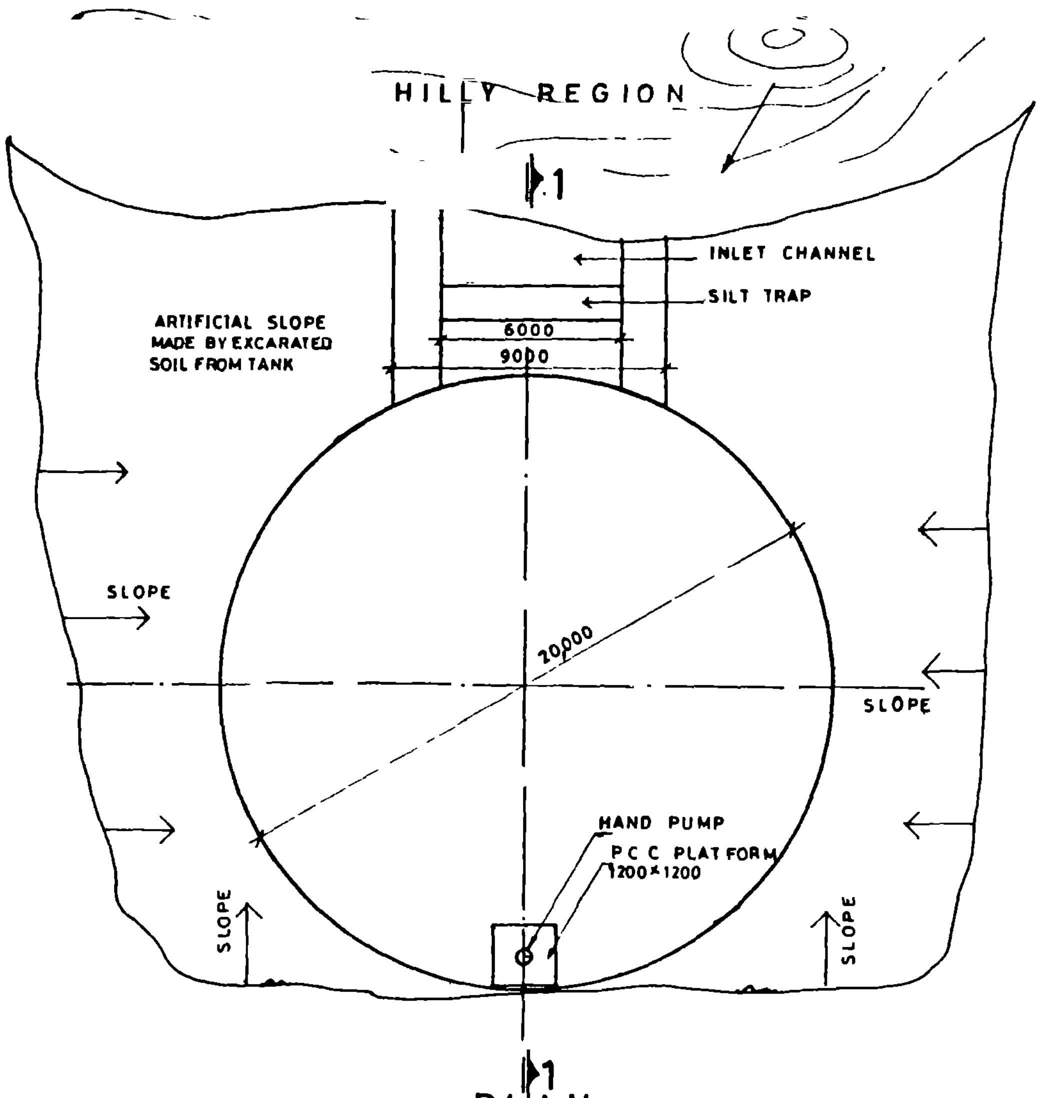


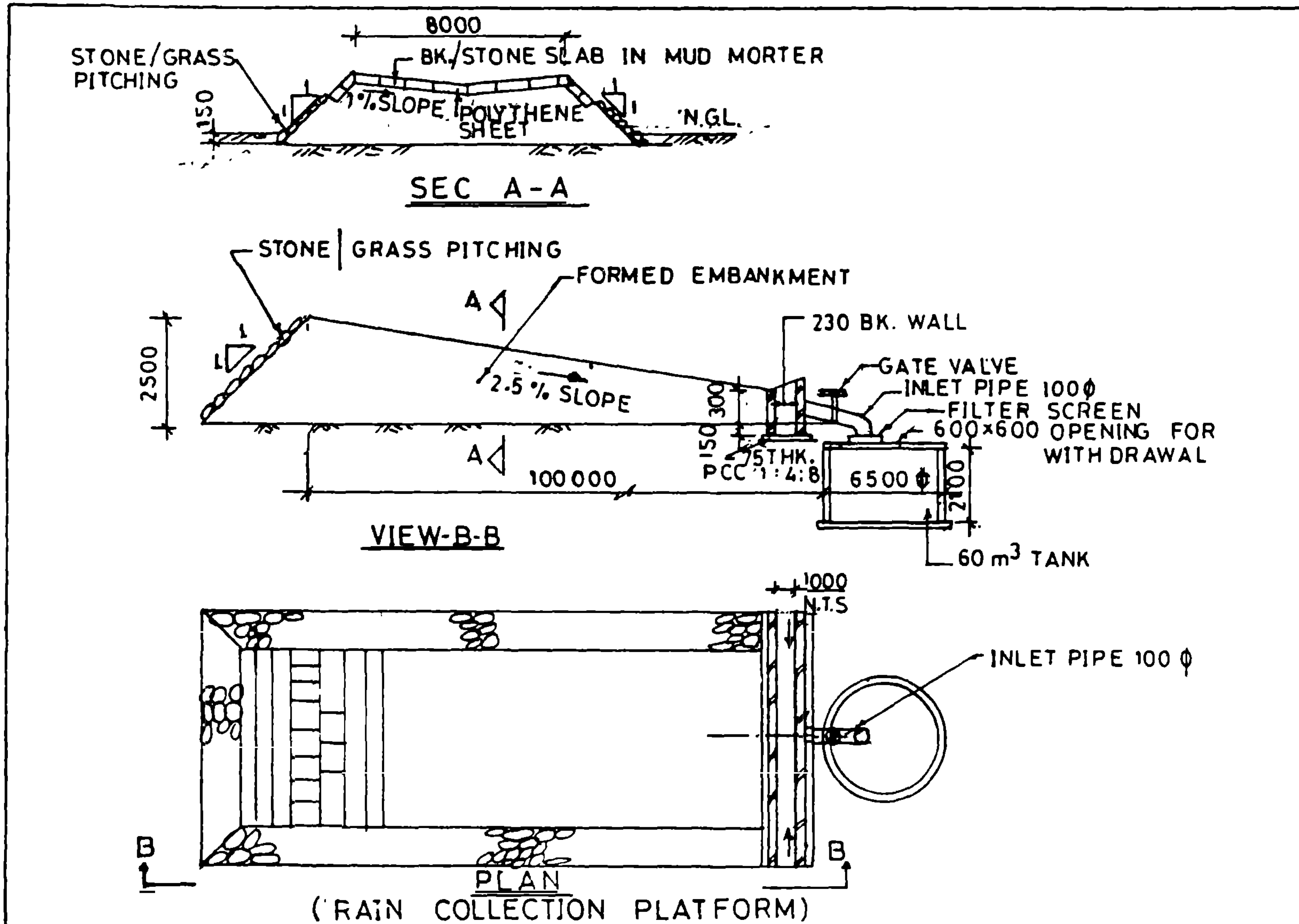
SECTION 1-1



PLAN

(TANK 20 0M DIA 3 0M DEEP)

HILL TOP COLLECTON SYSTEM



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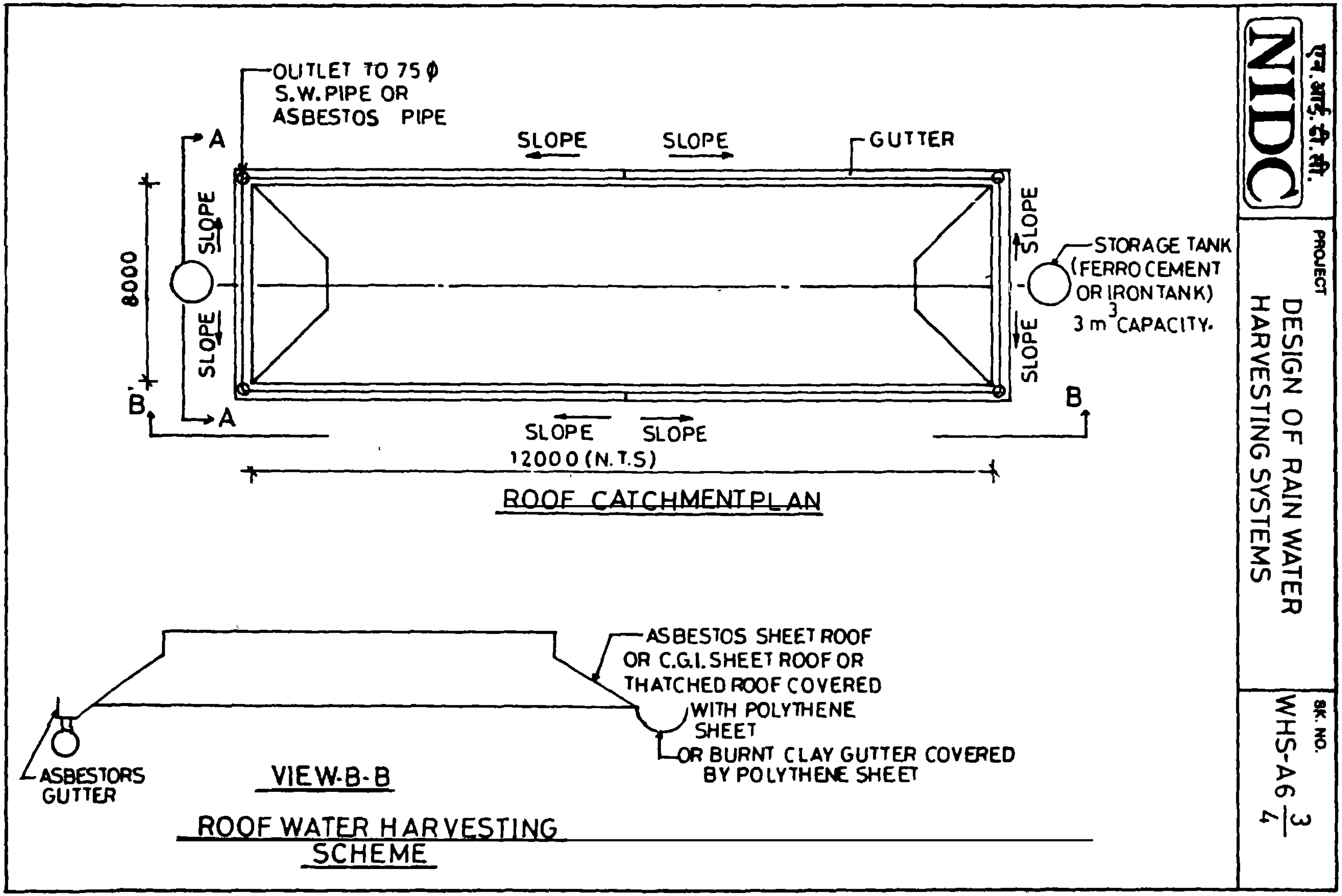
PROJECT:- DESIGN OF RAIN WATER HARVESTING SYSTEMS

SK.NO. WHS-A6 2/4


OUTLET TO 75 ϕ S.W. PIPE OR ASBESTOS PIPE
A
SLOPE
SLOPE
GUTTER
SLOPE
SLOPE
8000
STORAGE TANK (FERRO CEMENT OR IRON TANK) 3 m3 CAPACITY.
SLOPE
SLOPE
B
B
A
SLOPE
SLOPE
12000 (N.T.S)
ROOF CATCHMENT PLAN
ASBESTOS SHEET ROOF OR C.G.I. SHEET ROOF OR THATCHED ROOF COVERED WITH POLYTHENE SHEET
OR BURNT CLAY GUTTER COVERED BY POLYTHENE SHEET
ASBESTORS GUTTER
VIEW-B-B
ROOF WATER HARVESTING SCHEME
NIDC
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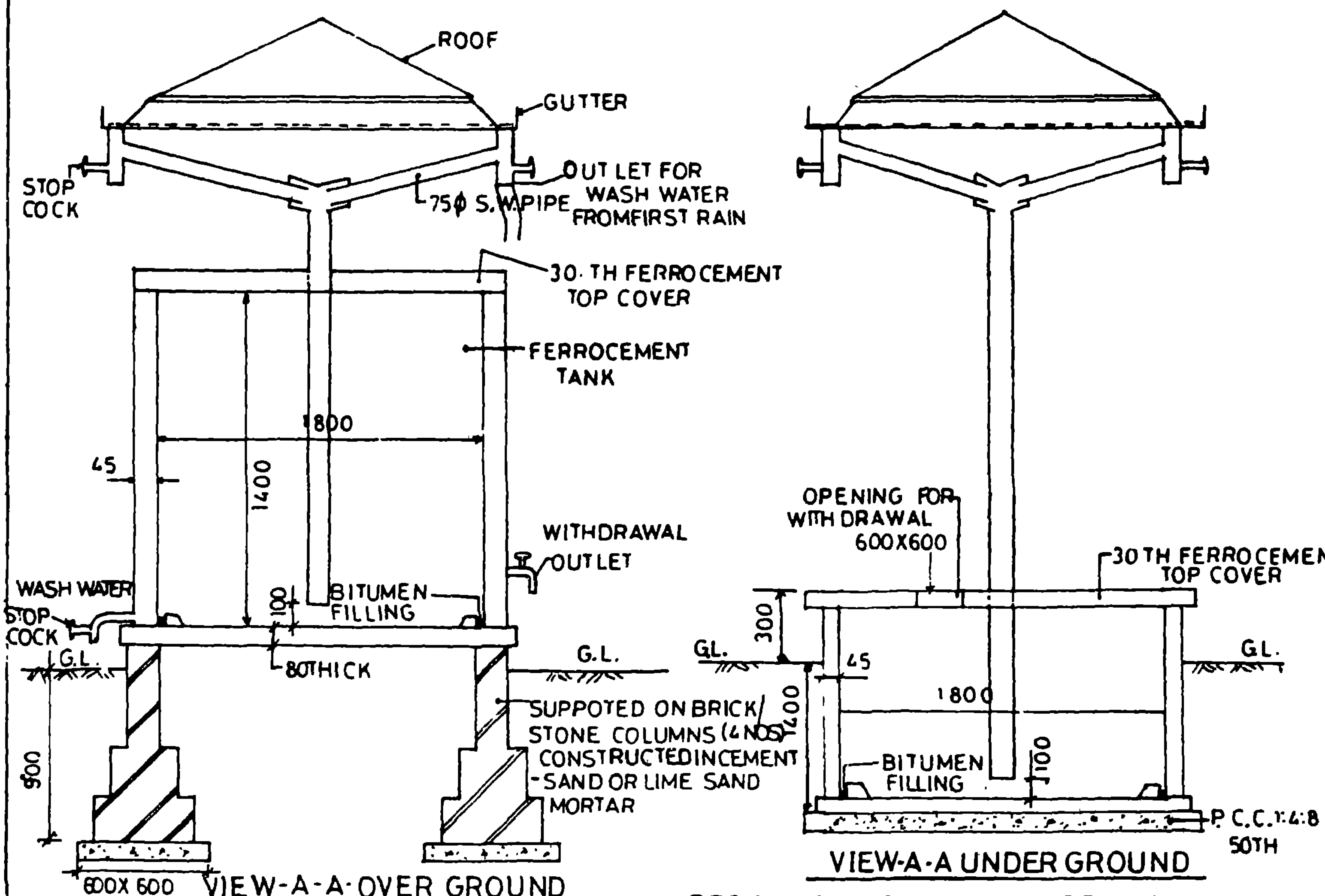
PROJECT
DESIGN OF RAIN WATER HARVESTING SYSTEMS
SK. NO.
WHS-A6 3/4



ROOF WATER COLLECTION STRUCTURES

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DESIGN OF RAIN WATER HARVESTING SYSTEMS

SK. NO.

WHS-A6 4/4

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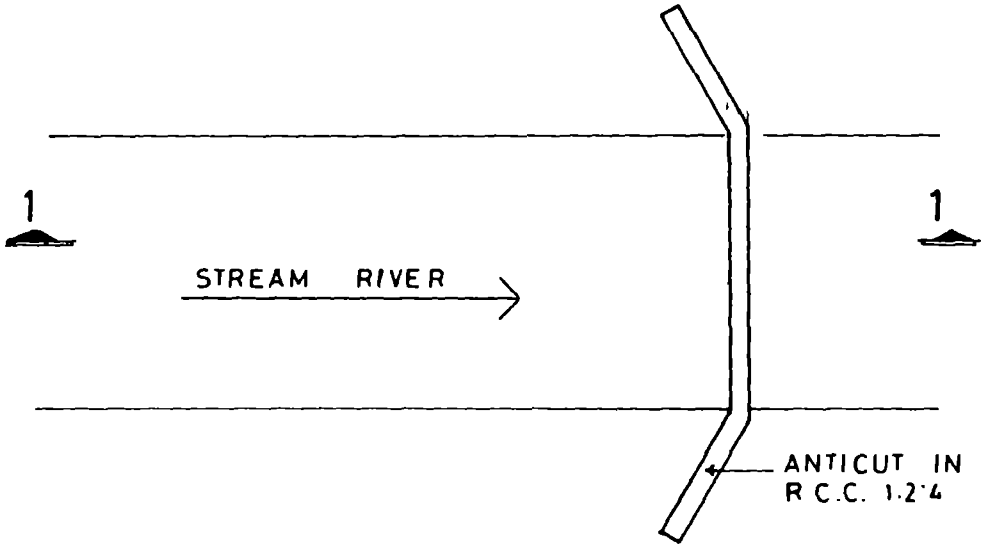
PROJECT

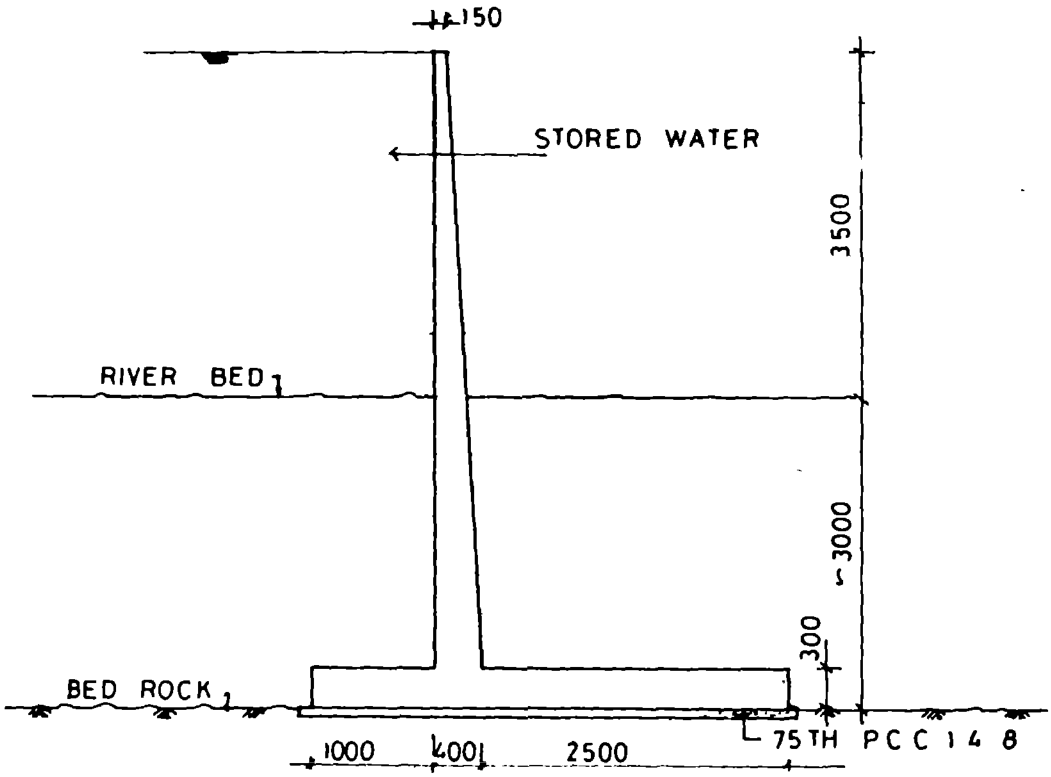
DESIGN OF RAIN WATER HARVESTING SYSTEMS

SK. NO

WHS-A7 $\frac{1}{1}$



PLAN



SECTION 1-1

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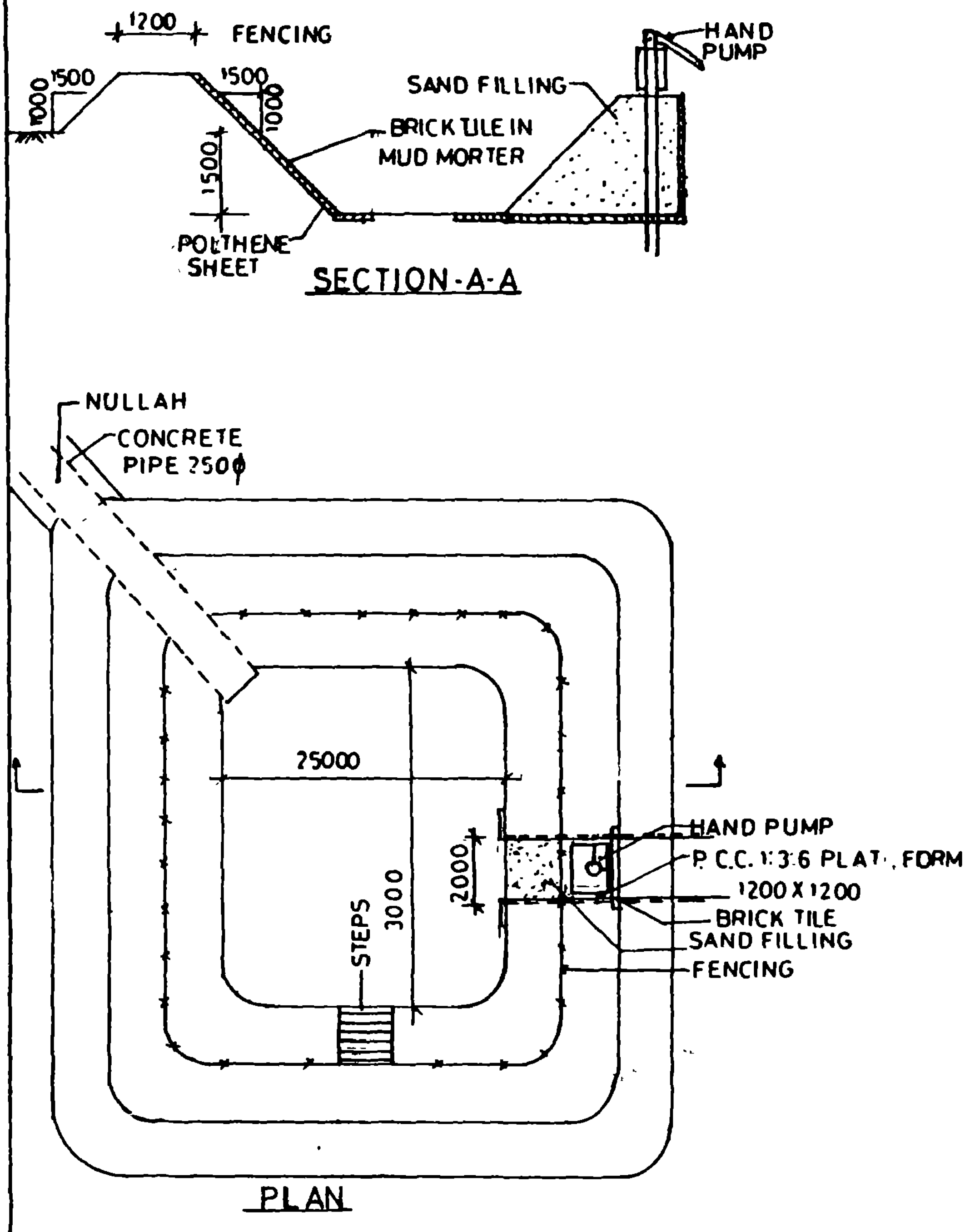
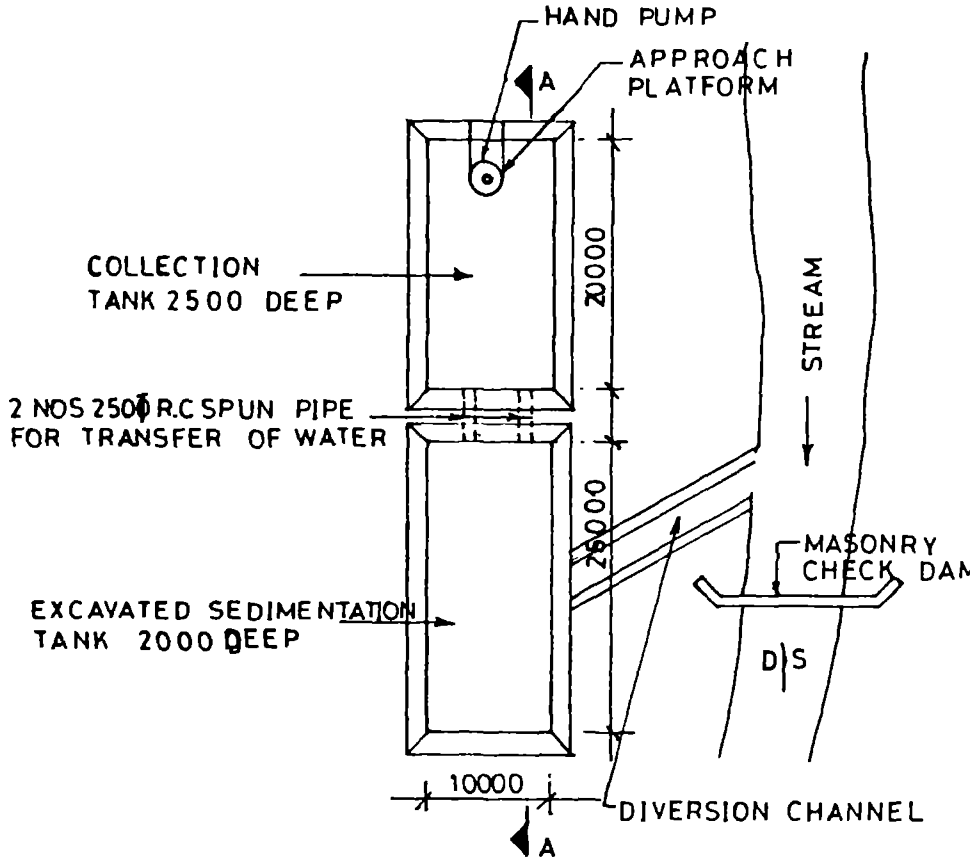
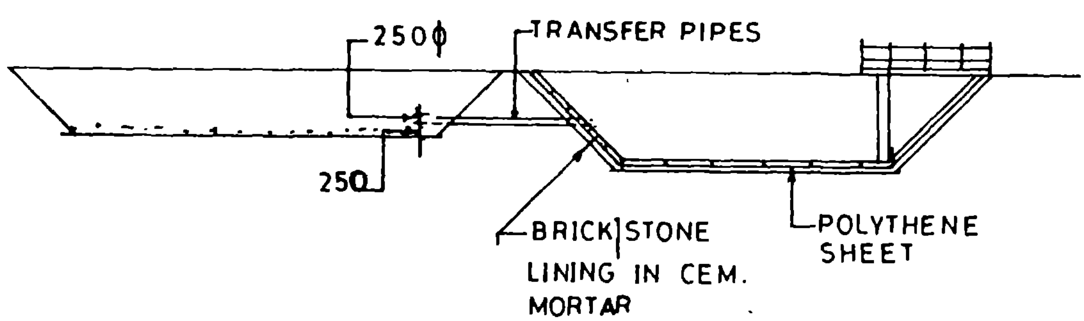


VILLAGE POND

एन.आई.डी.सी. NIDC	PROJECT DESIGN OF RAIN WATER HARVESTING SYSTEMS	SK NO WHS-A13 $\frac{1}{2}$



PLAN



SEC A - A
(COMPREHENSIVE SYSTEM)

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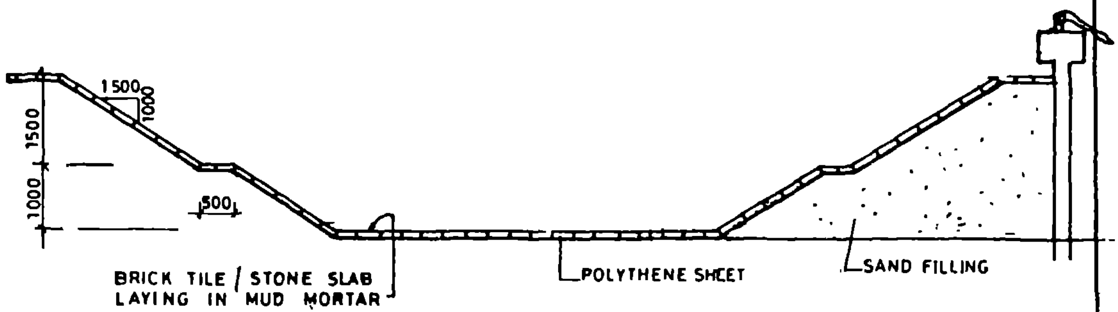
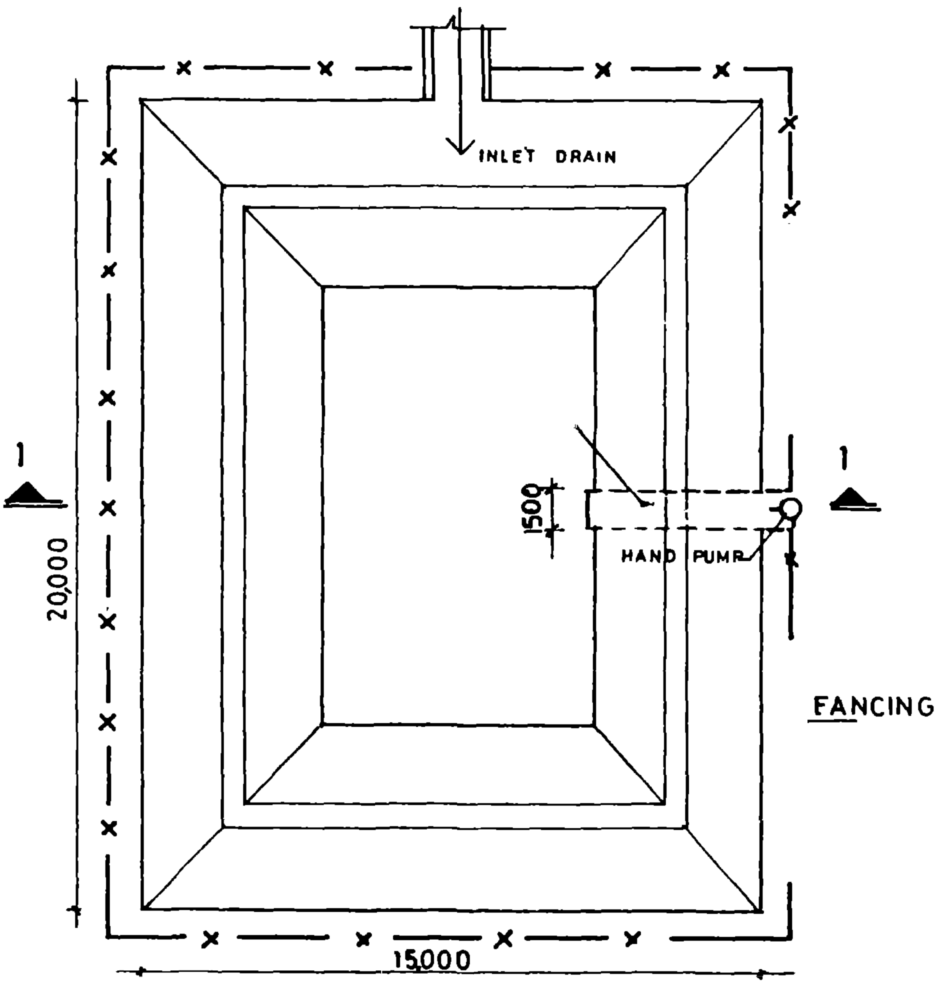


SECTION 1-1
SCALE 1 100



PLAN
SCALE 1 150

(COLLECTION TANK IN ROCKY STRATA)

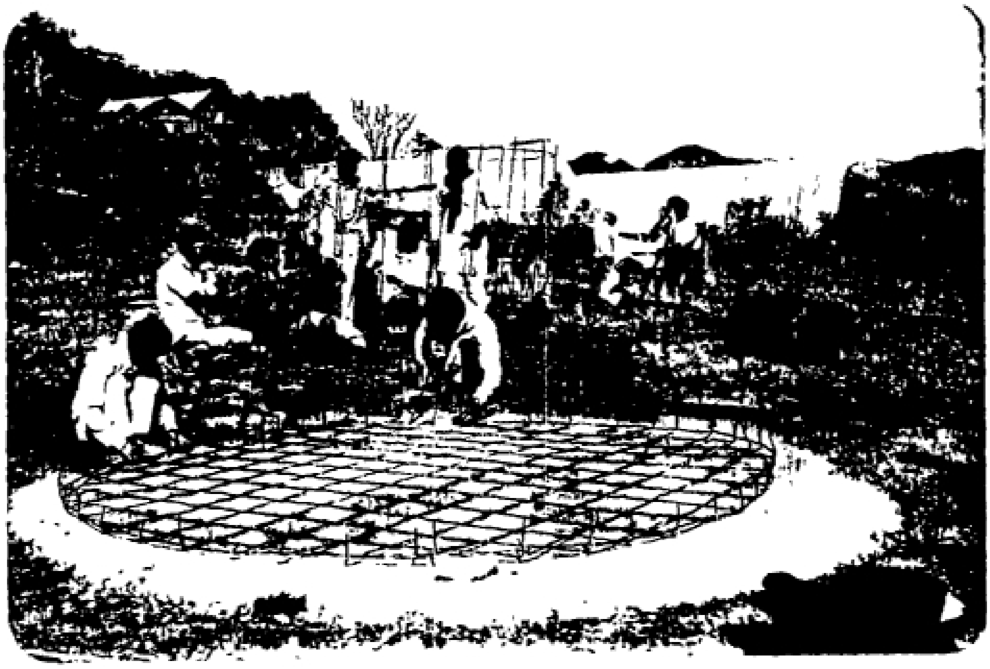


Fig. 1.7 : PREPARATION OF BASE CAGE

Fig. 1.8 : TYING OF WALL REINFORCEMENT CAGE

Fig. 1.9 : PLACING OF A COMPLETED CAGE IN POSITION —
CAPACITY OF TANK 5000 LIT. LOCATION MARAM (MANIPUR)

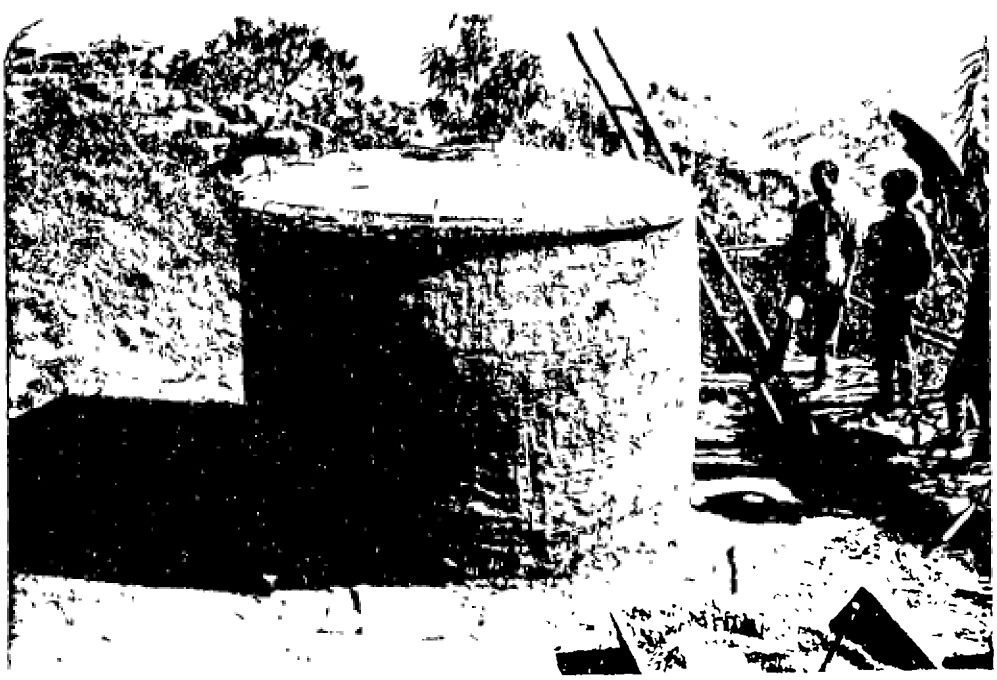


Fig. 1.10 : MORTAR APPLICATION FOR WALL & BASE COMPLETED
THE CASE FOR ROOF PLACED IN POSITION

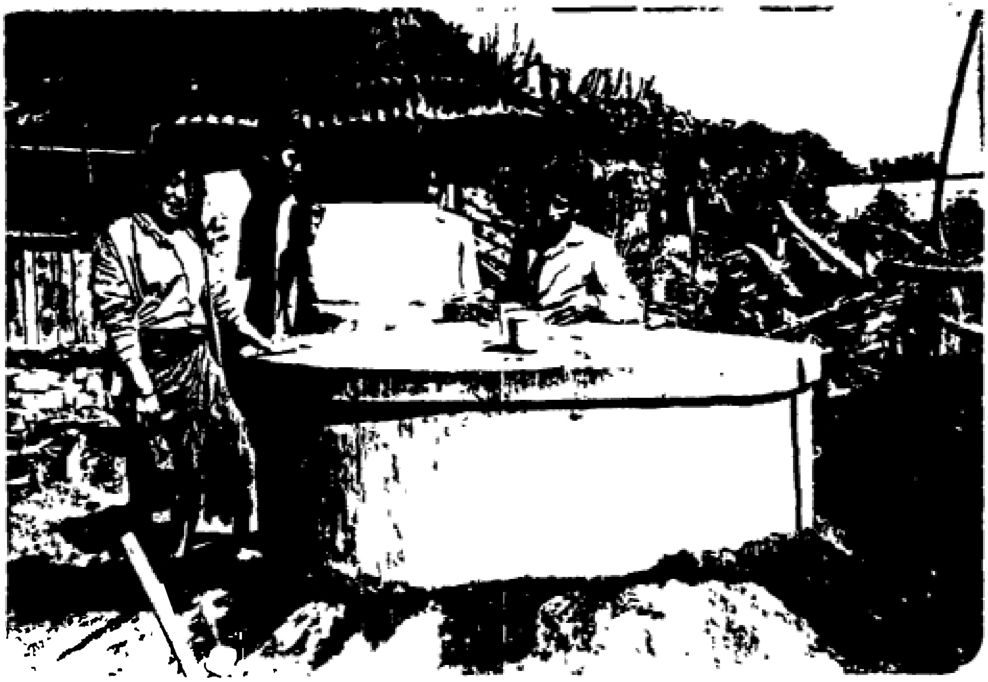


Fig. 1.11 : COMPLETED RAINWATER HARVESTING TANK
5000 LITRE - PARTLY ABOVE GROUND

Fig. 1.12 : COMPLETED F.C. TANK, 5000 LITRE IN MARAN HILLS
IN MANIPUR - FILTER BEING INSTALLED

Fig. 3.3 : CAGE MAKING FOR A SEGMENT

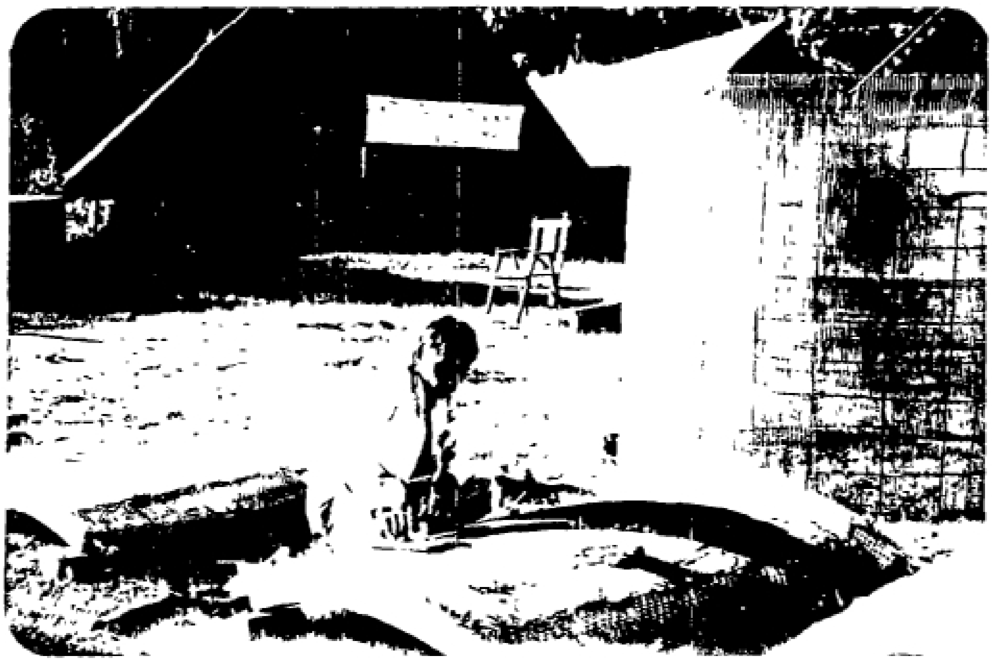


Fig. 3.4 : CASTING OF A SEGMENT FOR 10000 LIT. TANK IN MANIPUR

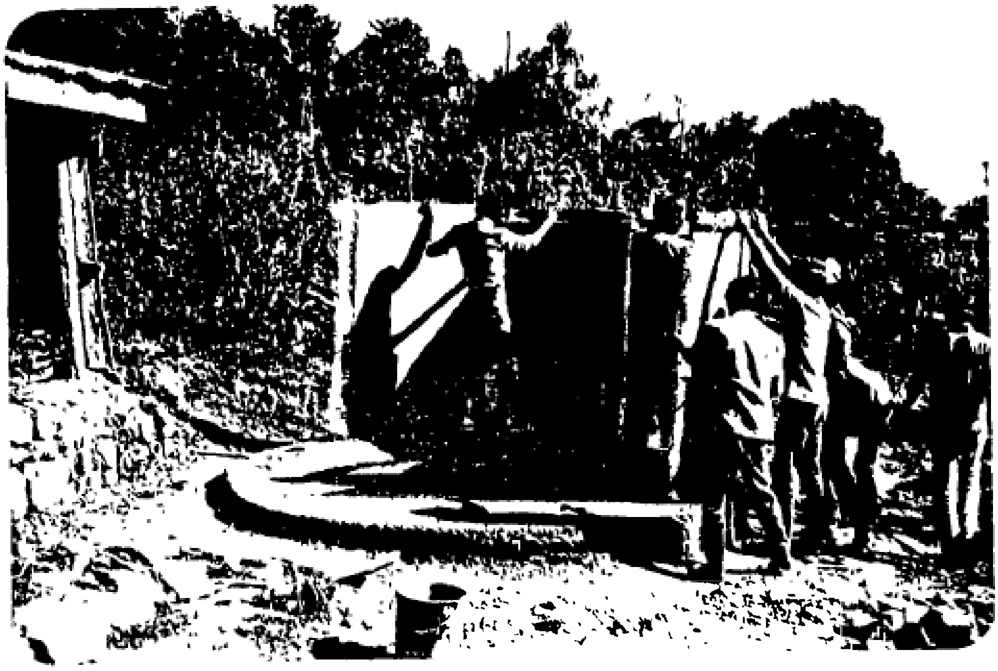


Fig. 3.5 : ASSEMBLING OF SEGMENTS FOR A 10000 LIT. TANK

Fig. 3.6 : TYING OF MESH LAPS AT JOINTS

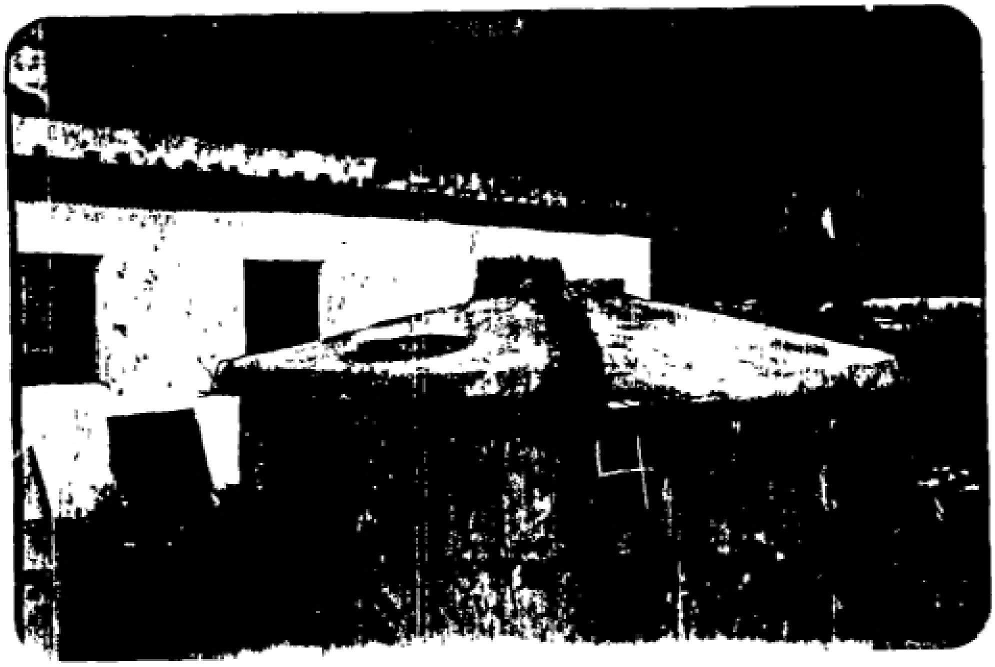
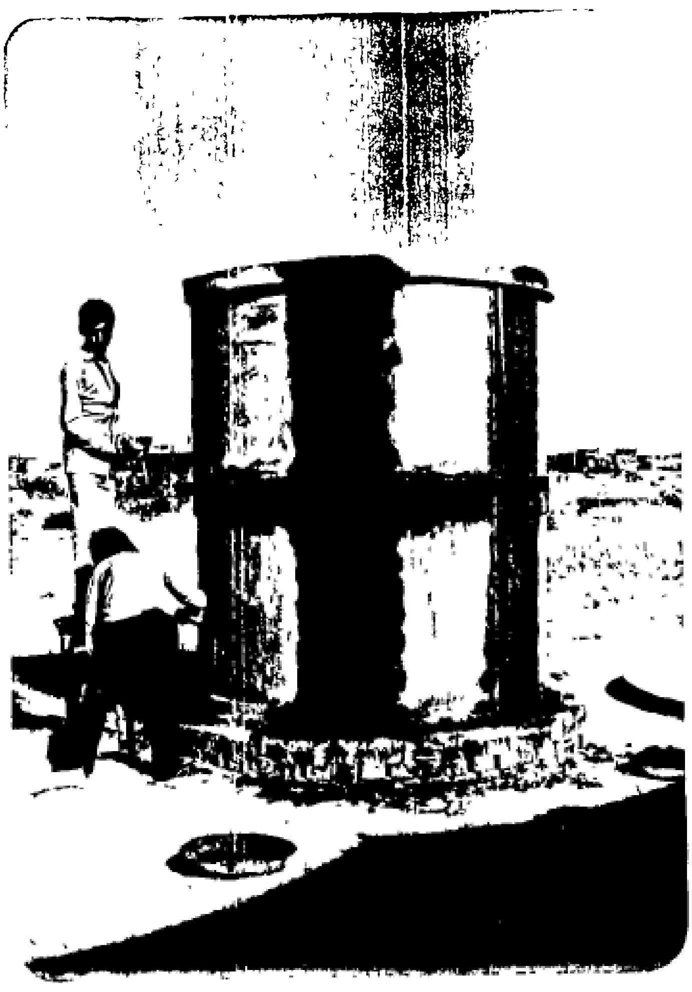


Fig. 3.7 : SEGMENTAL F.C. ROOF FOR A 12000 LITRE F.C. TANK



[illegible]

Fig. 6.4.1 : CUTTING OF TWO HESIAN CLOTH PIECES

Fig. 6.5 : BOTH THE PIECES ARE STITCHED TOGETHER FOR

Fig. 6.6 : SACK MOULD IS FILLED WITH RICE HUSK - TOP CLOSED REINF. FIXED OVER THE MOULD

Fig. 6.7 : CASTING OF TANK BEING CARRIED OUT BY NAGA BOYS

Fig. 7.3 : MAKING OF A MASONARY MOULD FOR ROOF OF A TANK

Fig. 7.4 : MAKING OF A REINF. CASE FOR TANK ROOF

Fig. 7.5 : MORTAR APPLICATION FOR THE F.C. TANK ROOF

Fig. 7.6 : ASSEMBLING OF THE F.C. TANK ROOF OVER WALL