Water for the World

Designing a Ground Level Storage Tank
Technical Note No. RWS. 5.D.2

Under suitable circumstances, ground level storage tanks may be used to deliver water to users by gravity flow. Storage tanks are a very important part of a water system because they ensure that adequate quantities of water are available to meet demand. Storage tanks also help in preserving water quality.

This technical note discusses the design of ground level storage tanks and offers suggestions for locating a suitable site, determining adequate capacity and selecting appropriate construction materials. Read the technical note carefully and attempt to adapt the suggestions to the local environment to ensure successful design of the storage tank.

The design process should result in the following three items which should be given to the construction supervisor.

1. A map of the area showing the location of the storage tank in relation to the water source and the community. Include important landmarks, elevations, if known, and distances on the map. Figure 1 gives an example of the type of map which should be provided.

2. A list of all labor, materials and tools needed similar to Table 1. The list will help make sure that adequate quantities of materials are available to prevent construction delays.

3. A plan of the storage tank with dimensions shown as in Figure 2. The plan shows a side, top and end view.

Useful Definitions

ALGAE - Tiny green plants usually found floating in surface water; may form part of pond scum.

HEAD - Difference in water level between the inflow and outflow ends of a water system.

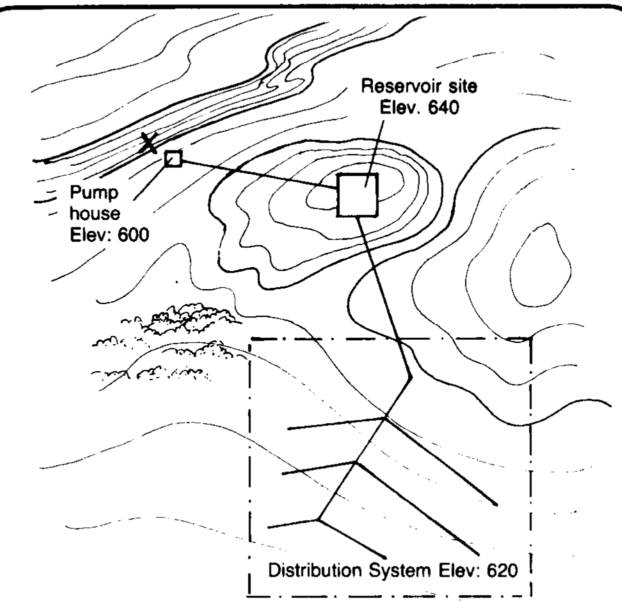

Figure 1. Location Map

Site Selection and Tank Location

The most important consideration in the choice of a site for a storage tank is the elevation. The height of water stored, measured from the bottom of the tank, must produce sufficient head or pressure to enable water to flow through a pipeline to the users. The height needed is determined by the height of the taps in the system and the amount of pressure desired for the distribution system.

Table 1. Sample Materials List

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers	____ ____	____ ____
Supplies	Portland cement Clean sand and gravel Clean water Reinforcing rod Pipe for inlets, overflow and drain (PVC or steel) Screening and wire mesh for pipes Boards and lumber for forms Lubricating oil Rocks, if masonry tank Float valve (if needed) Cut-off valves Lock for manhole cover Iron for steps in tank Lumber and rafters, if wooden tank Cover structure Shingles Plywood Rope or string Nails, tie wire		
Tools	Shovels, picks and other digging tools Measuring tape Plumb line Hammer Saw Buckets Carpenters square Level Mixing bin or machine Pipe wrench Adjustable wrench Trowel Hoe Wheelbarrow Sieve		

Total Estimated Cost = ____

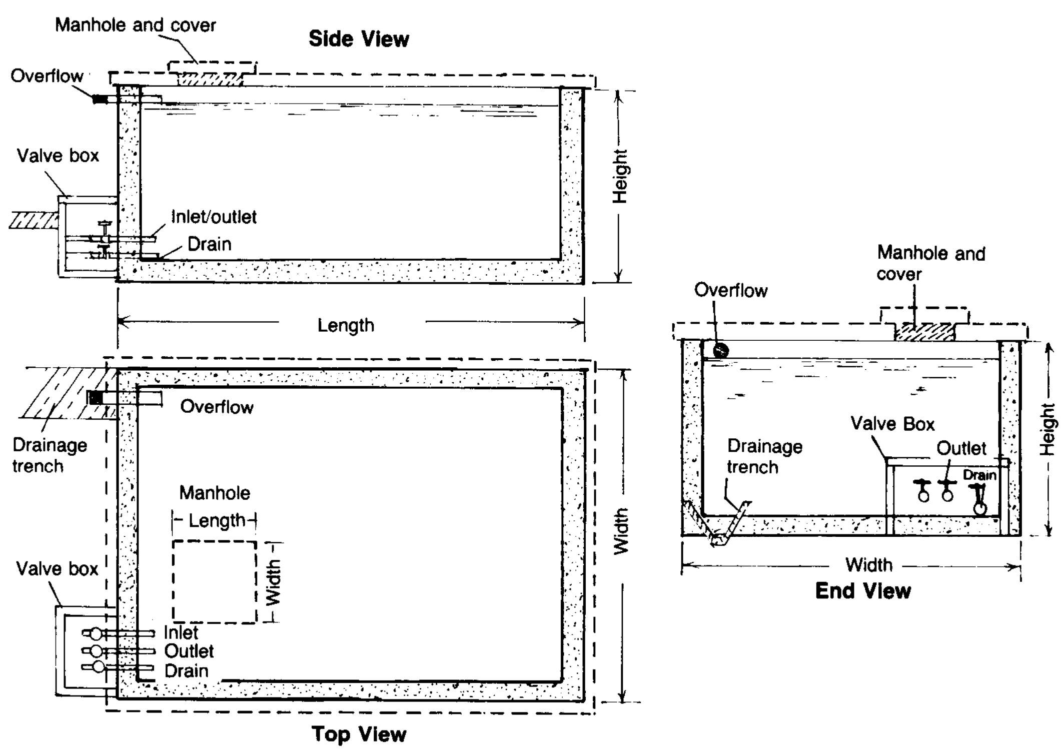

Figure 2. Storage Tank Design

A general rule to follow is that small water systems should have at least 14m of pressure. This means that the bottom of the storage tank must be at least 14m higher than the highest tap. A general rule is that the minimum water level in the storage tank should be 20-40m above the area served. Figure 3 shows a profile of a system. Note that the elevation of the highest tap is 210m and that the system is built for a minimum of 14m pressure. The ground storage is on a hill at an elevation of 230m which provides sufficient pressure to reach the highest tap in the community. If no location of suitable height is available, an elevated storage tank may be needed. For information of the design of elevated storage tanks see "Designing an Elevated Storage Tank," RWS.5.D.3.

In order to save money, try to locate the storage tank as close as possible to the water source and the population being served. If possible, put it between the source and the population to limit the need for long lines of pipe. The location of storage shown in Figure 3 is distant from the pump. This has the advantage of drawing water from the pump and tank drum peak demand periods. For complete information about the design of water transmission lines, the choice of pipe, and head losses due to friction, see "Designing a Transmission Main, RWS.4.D.3 and "Designing Community Distribution Systems," RWS.4.D.4.

Tank Capacity

The capacity of the storage tank is important for the efficient operation of a water supply system. The tank should be large enough to store sufficient water to meet both average and peak daily demands. When designing a storage tank keep in mind that demand for water varies during the year. In the hotter months, people use more water than in cooler months and on certain religious or cultural occasions water use may increase.

The first step in determining storage capacity is calculating the demand for water in the community. Follow the steps below in estimating demand.

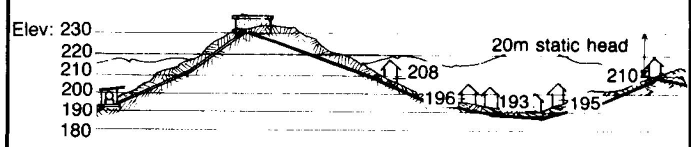

Figure 3. Distribution System with Ground Storage

Table 2. Population Growth Factors

Design Period Years	Yearly Growth Rate (%)					
7	1.5	2	2.5	3	3.5	4
10	1.1	1.15	1.19	1.23	1.27	1.32
15	1.16	1.22	1.28	1.34	1.41	1.48
20	1.25	1.35	1.45	1.56	1.68	1.80
25	1.35	1.49	.64	1.81	1.99	2.19

1. Determine the population of the community. Use census data or initiate a survey to obtain population figures. Check past records to determine the rate of population growth over the years. If funds permit, the storage tank should be designed to last for twenty-five years. Therefore, use the estimated population for 25 years in the future to determine demand for water. Use the growth factors in Table 2 when estimating future population. If money is short, the storage tank can be sized to serve only the current population and the size increased later on, if necessary.

For example, the present population of a community is approximately 1300 and it has been growing at a rate of 3 percent per year. To determine the population in 25 years multiply 1300 by the population growth factor 1.81 found in the row marked 20 and the 3 percent column in Table 2.

Population = 1300 x 1.81

Population = 2350 or approximately 2400.

The reservoir should be designed for a population of 2400 people.

2. Once the population is known, the demand for water can be calculated. Demand can be estimated by considering the type of distribution system used. Table 3 shows estimated water consumption rates for different types of distribution arrangements. Another important factor affecting demand is the use of water for purposes other than household drinking and cleaning. If the community has hotels and restaurants or if animals will be watered from the public system consumption figures would reflect these uses. Table 4 shows estimated water use for various institutions and for animals. Use these figures when designing the capacity of the reservoir.

The total daily demand for water can be calculated using Worksheet A. The calculations are done for a population of 2400 people in a town that has a small hospital with twenty beds, one hotel for 75 people and two schools. A large chicken farm with 5000 chickens also uses water from the public system. It is estimated that 40 percent of the population will be served by multiple taps, 35 percent by single taps in the yard and 20 percent by standpipe. Five percent will have no service.

3. Once the total daily demand is determined, peak demand should be considered. Peak demand is the highest rate of demand during the day. Usually peak demand occurs during the morning when people get up to begin the day and in the early evening after work is completed. Peak demand is estimated by adding 20-40 percent to average daily demand. Multiply the average daily demand by 1.2 or 1.4. For example,

Average day = 120000 liters/day

Peak day = 1.2 x 120000 = 144000 liters/day

A general rule to follow is that the capacity of the storage tank should be 20-40 percent of the peak day water demand. With a peak daily demand of 144000 liters, the capacity of the tank should be at least $30m^3$: 144000 liters x .2 = 30000 liters. At the 40 percent value, the tank would be $58m^3$: 144000 liters x .4 = 58000 liters. In this case, a reservoir of between 40-50m3 would be needed to meet peak demand. A possible design size would be 5.5m x 4m x 2.3m. For this capacity tank, the water height in the tank should be at least 2m and some space should be available between the high water level and top of the tank.

Table 3. Estimated Water Consumption

Type of Water Supply	Average Water Consumption (Liters/Capita/Day)	Range (Liters/Capita/Day)
Community water point (i.e., well, spring, public standpipe)		
At distance 1000m	7	5-10
At distance 500-1000m	10	8-12
Village well (250m)	12	10-15
Standpipe (250m)	15	10-20
Yard connection or single tap	40	20-60
House connection (multiple taps)	70	50-120 (or more)

Table 4. Water Use Requirements

Category	Typical Water Use (Liters/Day)
Schools	15-30 per pupil
Hospital	
(with laundry)	200-300 per bed
(without laundry)	120-220 per bed
Clinics	15-30 per patient
Hotels	80-120 per guest
Restaurants	60-90 per seat
Office	25-40 per person
Bus Station	15-20 per user
Livestock*	
Cattle	25-35 per head
Horses and Mules	20-25 per head
Sheep	15-25 per head
Pigs	10-15 per head
Poultry*	
Chickens	0.15-0.25 per head

*If at all possible, use of water from a public supply for livestock and poultry should be avoided.

Tank Design

Ground level storage tanks are generally made from reinforced concrete, masonry or brick depending on the materials available in the area and the skills of the local people. Steel tanks may be purchased.

Reinforced concrete is used in many areas. Its advantages are that it provides a very sturdy watertight structure that will last many years, and it uses less concrete than mass concrete structures which reduces construction costs. A disadvantage of using a reinforced structure is that steel, lumber for forms and skilled labor and supervision are needed to build the tank. Neither the materials nor the expertise may be affordable or available; if not, an alternative structure design should be chosen.

If large building stone is available, the tank can be built of masonry. When building with masonry, no forms are necessary and construction is generally easier. Masonry tanks are not watertight, however. For best results, make thin masonry walls and fill in between them with concrete as shown in Figure 4.

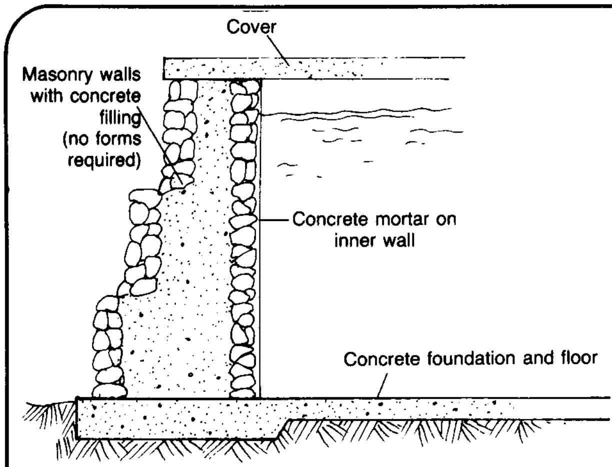

Figure 4. Example of Mass Concrete Wall Construction

The storage tanks can be built either above or partially or completely below ground. Underground structures provide added support for the walls. If soil conditions permit and elevation is sufficient, a storage tank partially or totally underground is recommended. Where such a tank cannot be installed, at least build the form work in the ground for support. If a steel tank is purchased, the tank will be placed directly on a concrete slab on the surface of the ground. Steel tanks provide good storage but may not be feasible in many places due to their cost.

All tanks must have covers. In some cases, reinforced concrete is used but forms are expensive and construction difficult. Cast-in-place roofing may not be possible. A concrete cover can be built by casting several sections and fitting them together on the top of the tank. See Figure 5. The advantage of casting in sections is that the smaller sections can be cast at ground level and lifted into place.

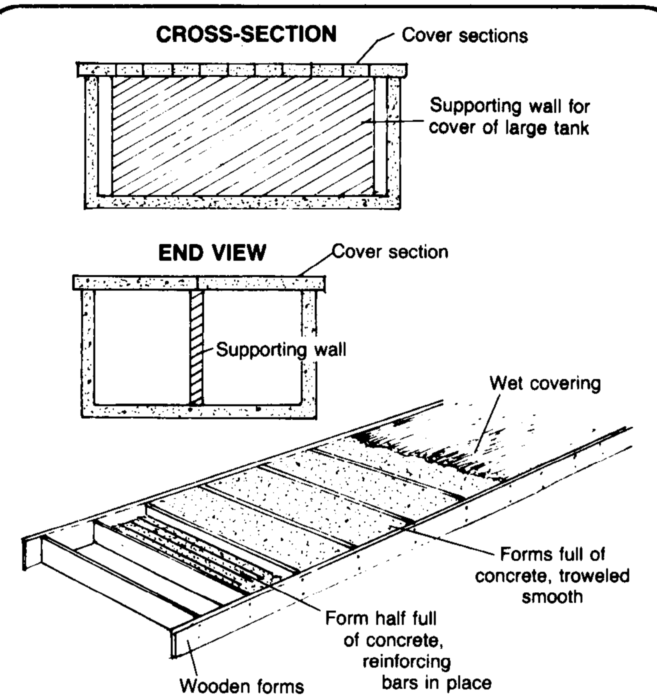

Figure 5. Casting Cover Sections

A wooden roof structure can be made with shingles, slate, or roofing tar placed on it to make it watertight. Roofing structures follow the general design pattern for house roofs and should extend well beyond the ends of the tank so that rain runs away from the structure.

All ground level storage tanks should be designed with the following features. See Figure 6.

Manholes and Tightly Fitting Manhole Covers. Manholes with raised covers should be installed in each tank. They prevent the entrance of dust, debris and sunlight which is a major factor in the growth of algae. The manholes should have a diameter of 0.8-1m, sufficient to allow a person access to the tank for cleaning.

Ventilation. A screened ventilation pipe should be installed to allow air to escape from the tank when water enters. The pipe should be screened so that no insects, bats or debris can enter the storage tank.

Inlet, Outlet, Overflow and Drain. The inlet pipe should be located near the bottom of the tank. In many cases, the same pipe acts as both intake and outlet. The end of the pipe should be screened and should be at least 150mm above the floor of the tank. Below the intake-outlet pipe, water is not able to leave the reservoir. Instead, this area acts as a settling zone for particles. Plastic, PVC, or steel pipe can be used for the outlet. The choice depends on availability and cost.

The overflow pipe should be located above the expected high water level in the tank. The overflow pipe should be screened. Water that overflows from the tank should be moved away from it to prevent contamination and the accumulation of standing water in which mosquitoes can breed. Lay rock around the tank or line a small diversion ditch to move all water away from the area. The overflow pipe can also serve as an air vent.

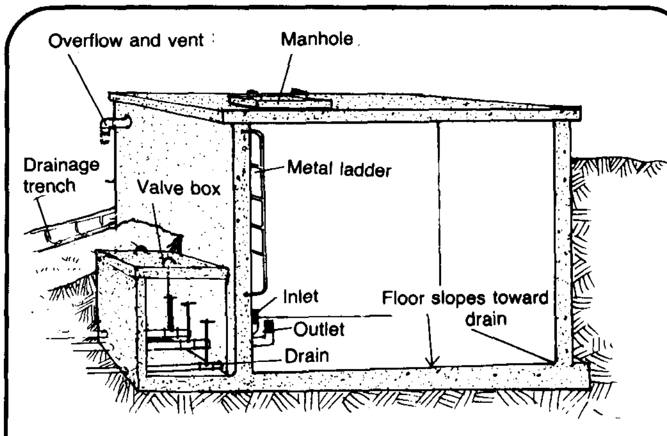

Figure 6. Ground Level Storage Tank

A drain pipe should be installed at the bottom of the tank. To ensure adequate drainage, slope the floor toward the drain. Install a drain pipe with a diameter large enough, perhaps 200mm, so that sediment can be flushed without clogging the pipe.

Other Design Features. To control the level of water in the tank, the installation of a float valve is recommended. If a float valve is not used, the operator must be well trained to ensure that water is pumped to storage when needed and not wasted through the overflow.

Small tanks can either be built as a single unit as shown in Figure 6 or divided into two sections as shown in Figure 7. A wall divides the two storage compartments and pipes and valves are arranged so that each can be used separately. This arrangement allows for continuous service when one side is being cleaned. One alternative is to build a single storage tank as in Figure 6 and make a wall strong enough to act as a partition if expansion is desired in the future. Another compartment can be added when and if it is needed, and the cost can be postponed to a later date.

Where suitable conditions exist, ground level storage tanks are a good choice. They require a great deal of material for construction. Worksheet B shows the general calculations for a one compartment storage tank made of reinforced concrete. Using these calculations, determine the specific amounts needed and cost of all materials.

The concrete mixture should be 1 part cement to 2 parts sand to 3 parts gravel (1:2:3) and 10mm reinforcing bars laid in a grid pattern should be used for the walls and cover. All bars should be separated by 150mm.

For all storage facilities, experienced builders are needed to do the work properly whether masonry tanks or reinforced tanks are built, construction expertise is essential. Never attempt construction without the expert advice of an engineer or builder.

Worksheet A. Calculating Water Demand

Population 2400	
1. Multiple taps in homes of 40% of population 40% x 2400 x 70 lpcd	67200
2. Single tap in yards of 35% of population 35% x 2400 x 40 lpcd	33600
3. Standpipe for 20% of population 20% x 2400 x 15 lpcd	7200
4. Two schools with 500 students 1000 x 20 lpcd	2000
5. Chickens (5000) 5000 x 0.2 lpcd	1000
6. Hospital with 20 beds without laundry 20 x 160 lpcd	3200
7. Hotel 75 guests 75 x 75 lpcd	5625
Total	119825

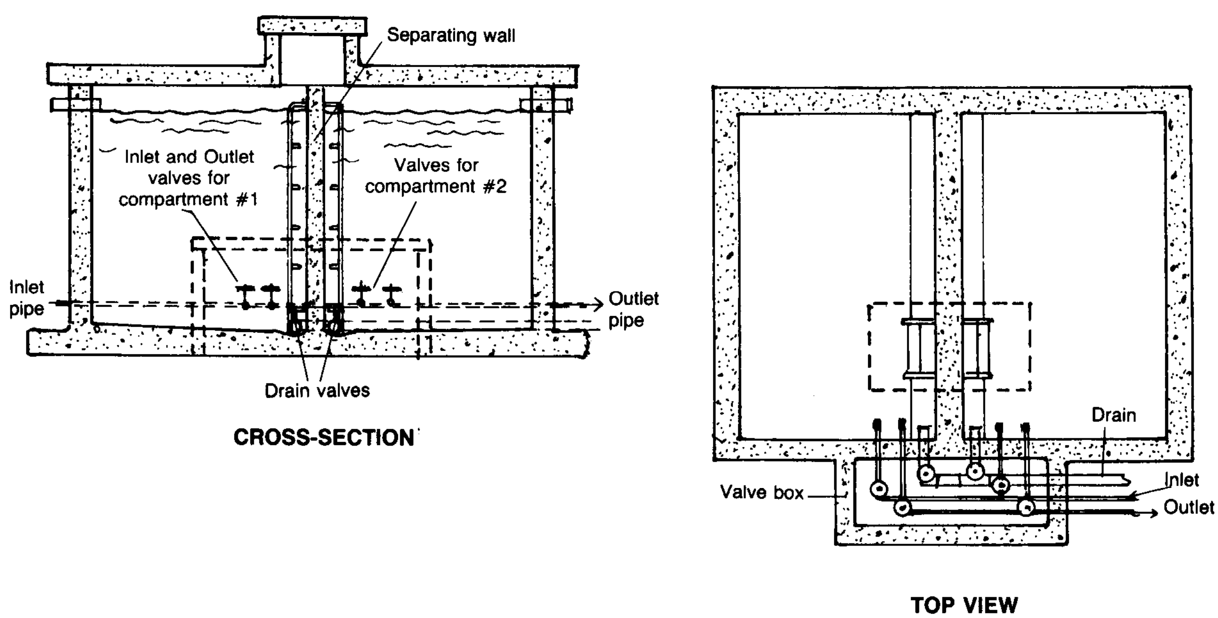

Figure 7. Storage Tank with Two Compartments

Worksheet B. Calculation of Quantity of Materials Needed for a Reinforced Concrete Reservoir (5.5m × 4m × 2.3 with Cover of Concrete Sections)

Total Volume of Reservoir = length x width x height

Thickness of walls = 0.2m

1. Volume of top cover[1] = 5.7 x 4.2 x 0.2 m = 4.8 m^3
2. Volume of two front walls = 5.5 x 2.3 x 0.2 x 2 = 5.0 m^3
3. Volume of two side walls = 4.0 x 2.3 x 0.2 x 2 = 3.7 m^3
4. Volume of bottom including foundation = 5.7 x 4.2 x 0.2 = 4.8 m^3
5. Total volume = sum of 1, 2, 3, 4, = 13.3 m^3
6. Unmixed volume of materials = total volume x 1.5 = 18.3 m^3 x 1.5 = 27.5 m^3
7. Volume of each material (cement, sand, gravel 1:2:3 or 1/6, 1/3, 1/2)[2]

   Cement: .167 x total volume 27.5 m^3 = 4.6 m^3 cement

   Sand: .33 x total volume 27.5 m^3 = 27.5 m^3 = 9 m^3 sand

   Gravel: .5 x total volume 27.5 m^3 = 13.75 m^3 gravel
8. Number of 50k bags of cement = $\frac{\text{volume of cement}}{\text{volume per bag } (.033m^3/\text{bag})}$
9. Volume of cement = 4.6 m^3 ÷ 0.033m^3 = 140 bags
10. Volume of water = 28 liters/bag x 140 bags = 3920 liters
11. Number of reinforcing bars placed at 150mm apart

    Length ÷ 150mm + height ÷ 150mm = number of bars needed[3]

    Sides = 5.5 ÷ .15 + 2.3 ÷ .15 x 2 = 36.67 + 15.33 x 2 = 52 x 2 = 104

    2 ends = 4 ÷ .15 + 2.3 ÷ .15 x 2 = 26.67 + 15.33 x 2 = 42 x 2 = 84

    Top and Bottom 5.7 ÷ .15 + 4.2 ÷ .15 x 2 = 38 + 28 x 2 = 66 x 2 = 132

Total = 320 bars

Notes: [1]Cover overhangs 0.1m on each side
[2]To save cement, use a mixture of 1:2:4
[3]Rods are placed so that last rod parrallel to the edge is .75mm from the edge; tips of rods are 25mm from the end of walls; place reinforcing rods in forms so that they are one-third the distance from the outside edge

Technical Notes are part of a set of "Water for the World" materials produced under contract to the U.S. Agency for International Development by National Demonstration Water Project, Institute for Rural Water, and National Environmental Health Association. Artwork was done by Redwing Art Service. Technical Notes are intended to provide assistance to a broad range of people with field responsibility for village water supply and sanitation projects in the developing nations. For more detail on the purpose, organization and suggestions for use of Technical Notes, see the introductory Note in the series, titled "Using 'Water for the World' Technical Notes." Other parts of the "Water for the World" series include a comprehensive Program Manual and several Policy Perspectives. Further information on these materials may be obtained from the Development Information Center, Agency for International Development, Washington, D.C., 20523, U.S.A.

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