CHAPTER TWO

REVIEW ON

WATER TANKS

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Review on Water

This chapter will discusses the reviewed literature and others issues regarding tank designing, definitions, types, and other related subdivisions. (Gould, J. and Nissen-Petersen, E., 1999)

2.1 Definition of Underground Tanks

An underground tank (or sub-surface tank), is a water storage structure constructed below the ground. The term also includes structures that are partially below ground. In most cases, underground tanks are collected and stored runoff from ground catchments such as open grasslands, hillsides, home compounds, roads, footpaths, paved and unpaved areas. However, in certain circumstances, roof catchments can also be channeled into underground tanks. (Gould, J. 1987).

An underground storage tank system (UST), is a tank and any underground piping connected to the tank that has at least 10 percent of its combined volume underground. The federal UST regulations apply only to UST systems storing either petroleum or certain hazardous substances.

2.2 Classification of tanks

In this section, the types of water tanks are discussed in detail. There are different type of water tank depending upon the shape, position with respect to ground level,… etc. From the position point of view, water tanks are classified into three categories. Those are:

a) Underground tanks

b) Tanks resting on ground

c) Overhead water tanks

In most cases the underground and on ground tank are circular or rectangular in shape but the shape of the overhead tanks are influenced by the aesthetical view of the surroundings and as well as the design. (Nissen-Petersen, E. 1992).

2.2. 1 Underground water tank

An Underground storage tank (UST) is a storage tank that is placed below the ground level. Underground storage tanks fall into three different types:

1. Steel/aluminum tank, made by manufacturers in most states and conforming to standards set by the Steel Tank Institute.
2. Composite overwrapped a metal tank (aluminum/steel) with filament windings like glass fiber/aramid or carbon fiber or a plastic compound around the metal cylinder for corrosion protection and to form an interstitial space.
3. Tanks made from composite material, fiberglass/aramid or carbon fiber with a metal liner (aluminum or steel).

Underground water storage tanks are used for underground storage of potable drinking water, wastewater & rainwater collection. So whether you call it a water tank or water cistern, as long as you are storing water underground these are the storage tanks for you. (Nissen-Petersen, E. 1992).

2.2.2 Tanks resting on ground

In this section, we are considering of the tank above only the tanks resting on ground like clear water reservoirs, settling tanks, aeration tanks,...etc. Which are supported on ground directly. The wall of these tanks are subjected to pressure and the base is subjected to weight of water. These tanks are rectangular or circular in their shape.

2.2.3 Overhead water tanks

Overhead water tanks of various shapes can be used as service reservoirs, as a balancing tank in water supply schemes and for replenishing the tanks for various purposes. Reinforced concrete water towers have distinct advantages as they are not affected by climatic changes, are leak proof, provide greater rigidity and are adoptable for all shapes.

From the shape point of view, water tanks may be of several types. (Neeta .K Meshram, Dr. P. S. Pajgade, .M, 2014).These are:

a) Circular tanks

b) Conical or funnel shaped tanks

c) Rectangular tanks

2.2.3.1 Circular tanks

Circular tanks are usually good for very larger storage capacities. This side walls are designed for circumferential hoop tension and bending moment, since the walls are fixed to the floor slab at the junction. The co-efficient recommended in IS 3370 part 4(1967) is used to determine the design forces. The bottom slab is usually flat because it's quite economical.

2.2.3.2 Conical or funnel shaped tanks

This tank is best in architectural feature and aesthetic. This tank has another important advantage that it is suitable for high staging as the tank's hollow shaft can be easily built. It can be economical and rapidly constructed using slip from processing of casting. They can also be built using pre-cast concrete elements. (Tarige M.Azabi, 2014)

2.2.3.3 Rectangular tanks

The walls of rectangular tank are subjected to bending moments both in horizontal as well as in vertical direction. The analysis of moment in the wall is difficult since water pressure results in a triangular load on them. The magnitude of the moment will depend upon the several factors such as length, breadth and height of tank, and conditions of the support of the wall at the top and bottom edge. If the length of the wall is more in compression to its height the moment will be mainly in vertical direction i.e. the panel will bend as a cantilever. If, however, height is larger in comparison to length, the moments will be in horizontal direction, and the panel will bend as a thin slab supported on the edges. The wall of the tank will thus be subjected to both bending moment as well as direct tension. (Nissen-Petersen, E., 1990*)*.

2.3 Types of underground tanks

There are many types of underground tank, categorized according to shape, size, capacity, lining material, construction and utilization. The most common types of tanks include the following:

2.3.1 Cisterns

A cistern is a small underground reservoir of about 10 to 500 m^3 capacity. The term is sometimes synonymous with underground tank. Cisterns are indigenous water harvesting systems commonly found in the Middle East and other dry areas. They are normally used for human and livestock water consumption, and are mostly located at or near homesteads. In many areas, they are dug into the rock, or they could be constructed as underground tanks lined with concrete. In this system, runoff water is collected from catchments such as roofs, home compounds, rocky surfaces, roads or open areas. Stilling basins are sometimes needed to reduce sediment entry. Since the water is stored below ground. A lifting device, e.g. pump, bucket and rope is used to bring water to the surface for use. Other than domestic use, cisterns are also used for irrigation of small gardens.

Cisterns require little or no space above ground, and thus are unobtrusive, which is a safety feature.

The main problems associated with this system include the cost of construction, the cistern's limited capacity, and inflows of sediments and pollutants from the catchment.

2.3.2 Rectangular lined tanks

One of the easier ways of constructing underground tanks takes the shape of a rectangle or square.

However, most rectangular tanks have a trapezoidal profile in volume. This shape accords good storage with easy design and construction features, as builders use straight lines. The tank can be lined with geo-membrane plastics, concrete, bricks, and other water resistant material. Lined underground tanks have the advantage of applicability on almost any soil type. The design also makes it easier to roof or cover the tank with galvanized iron sheets, grass, polythene, wood or other material. The tank is particularly popular for runoff harvesting for agricultural purposes, especially supplemental irrigation of small plots. (Nibedita Sahoo, 2008).

2.3.3 Housed excavated tanks

In areas prone to high evaporation losses, housed excavated tanks, and used for rainwater harvesting from the same roof or compound. Such water tanks can hold enough water to serve as the main source of water supply to a household or irrigation of small gardens. Excavated earthen water tanks can be lined to reduce seepage. The lining materials include clay, fibrocement, or plastic sheeting. Sandy soils/earth can also be excavated and lined with 15 cm concrete and serve as water tight tanks. The method is good for hot areas, and provides security since the house can be locked. (De Verse, L. 1987).

2.3.4 Concrete (reinforced) underground tank

Underground tanks lined with concrete are used for storage of water for domestic use and agriculture including irrigation. They can store water from harvested rain or from river diversions and other sources. The tanks are usually rectangular shaped and can vary in size from a few cubic metres to about 5,000 m^3. The larger tanks are built with reinforced concrete. Some of these tanks are usually covered with a concrete slab which can also serve as a catchment area for rainwater harvesting. Sometimes the catchment area, ranging about 750 to 1.000 m^2 is paved with concrete to induce more runoff. In the absence of concrete, the catchment area can be graded and compacted to enhance runoff. These systems are used in areas with as low as 100 mm of annual rainfall. (Aditya Wad, Gore N. G , 2014).

2.4 Determination of storage capacity required water demand

Water demand is the volume of water requested by users to satisfy their needs. A simplistic interpretation considers that water demand equals water consumption. However, conceptually, the two terms cannot be equated because, in some cases, especially in rural parts of Africa, the theoretical water demand considerably exceeds actual consumptive water use. (Watt, S, 1978).

2.4.1 Calculating demand

Calculating the water needs by the user is relatively easy and involves a simple formula which includes the average daily consumption of water from the tank per person (or livestock), the number of days in the dry season, and the numbers of people using the tank.

Studies have shown that rural people with tanks next to their houses often use about 20 to 40 liters of water per person per day. This is high compared to people who must walk long distances for water who may use less than 10 liters per family per day. As an average, assume that each person will take 20 liters per day if it is a household tank, and 5 liters per day if it is a school or health centre tank. The formula is:

Demand (litres) = Total dry days x water required per person x total number of consumers.

It is good to note that if the consumption is higher than estimated, the tank will run dry before the next rainy season.

Volume of storage structure

This is calculated differently depending on the shape of the tank. The general formula adopted for all shapes is the prismoidal formula expressed as follows:

$$V = \frac{(\mathrm{A}+4\mathrm{M}+\mathrm{B})*\mathrm{d}}{6} \qquad (2.1)$$

For convenient calculating, the following derivations of the prismoidal formula can be used for each particular excavation shape:

Circular:

$$\mathrm{V} = \frac{\pi\left[R^2+(R*r)+r^2\right]*d}{3} \qquad (2.2)$$

Rectangular:

$$V = \frac{[(L*W)+(IF*WF)+[(L*IF)+(W*WF)]]*d}{6} \qquad (2.3)$$

Square shaped tank:

The design volume is calculated with the following equation:

$$V = \frac{L^2+(L*IF)+LF^2]*d}{3} \qquad (2.4)$$

2.5 Construction of underground tank

Several of the techniques used for building surface tanks can also be used for underground tanks. (Nissen-Petersen. K, 1992).

For these the tanks are constructed in excavations with the soil being back filled around the outside of the tank on completion. Where impervious soils exist, such as clay or loess, it is often possible to construct unlined sub-surface reservoirs. Invariably these suffer from problems of seepage evaporation and poor water quality.

2.5.1 Procedure

Excavation of underground tanks is carried out in two ways i.e. “hollowing out method” and “open excavation method”. Hollow-out way of excavation is adopted only in areas where the sub-soil is firm enough and involves digging by starting at the top of the ground and hollow out/making wider the body of the cellar when gets down . Whereas the open excavation method is adopted in areas where the sub-soil is relatively weak and more loose, to avoid pit collapse when digging in.

Casting (construction) of the top roof structure in the case of open excavation method will be undertaken after the construction of the tank is completed.

The tank, constructed in areas with firm sub-soil can be plastered by using clay mud or mud mortar or cement mortar for seepage control. But if the tank is constructed relatively in area with weak and looser soil lining by using clay mud or cement mortar (thin wall) is not effective. In places where the soils are clayey, and impervious, it is possible to build unlined sub-surface tanks, but they suffer from seepage, evaporation and poor water quality.

The following steps can be followed steps (i) Prepare site by pegging and referencing corners (square and rectangular shapes) or structure Centre (circular shape). Measure fall across site for calculation of any storage volume above excavation. Install a temporary bench mark in a protected location.

(ii) Remove topsoil and stockpile clear of embankment location.

(iii) Excavate core trench under embankments (walls) if pervious materials are present under topsoil. Core trench must extend 1 m into impervious material.

(iv) Build the embankments (walls) by excavating in 'floors' and pushing material to correct location. Compact embankment with bulldozer weight in 50 to 75 mm layers or compact 150 mm layers with a sheep's foot roller. Embankment side slope ratios can be confirmed by using an electronic builder's slope finder or battometer. Install inlet and outlet pipes early in construction of embankments.

2.5.2 Profile

(v) Construct the roof of the tank

(vi) Construct the overflow and 'final trim' structure.

(vii) Topsoil outside batters and embankment top using stockpiled topsoil. Topsoiling encourages vegetation and helps retain embankment moisture and resist cracking. (Watt, S. 1978)

2.5.3 Choice of construction materials

A good control over the quality of construction materials is a first important step in the construction of successful water tanks. Cost and availability are as well important initial considerations. Construction materials constitute a considerable proportion of the costs involved.

It would thus be sensible to make use of available local construction material, such as bricks to help in cost saving; these include various types of soils, gravel/pebble, rubble stones and boulders/rocks.

2.5.4 Cement

Cement is packed in paper bags of about 50 kg and have a volume of 37 liters per bag. Cement contains principally lime (CaO) and silica (SiO2); it becomes plastic shortly after contact with water. After a couple of hours, a chemical reaction stiffens or sets cement to stone hard material, which bonds well with sand, aggregate and iron/steel, provided it is well cured for a minimum of three weeks., It is necessary to maintain the right proportion while mixing cement with other construction material. (A.M.Nivele, 1985).

2.5.5 Water proof cement

Water proof cement helps in sealing tanks; but it dries too quickly in hot and dry climates making fine cracks in the sealing coat. An alternative to water proof cement in such climates is a material called Nil. Nil is made by mixing cement with water to form a thin paste (cement slurry). It is applied to the final layer of plaster with a square steel trowel on the same day the plaster is applied.

2.5.6 Sand

Sand is an important ingredient used for making concrete, mortar, blocks,… etc. The main requirement on sand is that it should be free from organic or chemical impurities that would weaken the mortar/concrete. Sand should always be sieved before mixing, to remove organic materials which rot in tank walls and other parts of the structure. There should be a reasonable proportion of all grain sizes, without an excess of both fine and course sand particles. Course sand with particle sizes of 1-4mm is the most suitable for concreting foundations and flat roof slabs; finer sand is useful for mixing mortar for plaster. Most clean sands are suitable for use in RWH structures.

2.5.7 Aggregates

Another name for aggregate is crushed stone; it is used for making concrete. The size aggregate should be 8-32 mm; it should be very hard with rough surface for a good bonding with other material. Porous, soft or easily weathered stone should not be used for aggregate; and as with sand, aggregate should be free from soil and organic matter.

2.5.8 Water

Although water may not have to be necessarily very clean for mixing with and curing cement, saline water should never be used for construction.. More will be said in regarding the ratio of water that should be used while mixing it with other construction material and for making ferro-cement.

2.5.9 Reinforcement

There are different types of steel reinforcement mesh, which consist of thin wires either woven or welded in to a mesh. The main requirement on meshes is that they are handled easily, and that they are flexible enough to be bent around sharp corners. The wires should be tied and held firmly in place while the mortar is being applied/trowelled. Generally, various types of reinforcement wire can be used such as weld mesh. BRC (No. 65), galvanized wire 3mm, barbed wire (guage 12.5), twisted 12 mm iron bar, and chicken mesh (25 mm).

2.5.10 Cement Based Mixtures

The preparation of a high-quality mixture of mortar/concrete from cement, sand aggregate/crushed stone and water is one of the most important stages in building water tanks.

The following the very basic and crucial rules for mixing and applying mortar and concrete. If neglected, the strength and water proof properties of tanks are greatly reduced, leading to cracks and leaks.

Cement, sand, aggregate and water should be mixed thoroughly well, without adding too much water.

Mortar/concrete should be applied while fresh, within half an hour after mixing; and the cement work should be cured properly by keeping it moist and under shed for at least three weeks.

Mortar and concrete should be mixed with the right proportions, which varies depending upon the tank component.

It is necessary to mix cement and sand alone first (for mortar and aggregate as well for concrete), before adding water. Water should be added to the dry mix when everything else is ready for mortar/concrete application. This helps in making use of the cement mixture while it is fresh, and also avoids the extra heavy work of unnecessarily mixing water right at the start with the other ingredients. Water should be kept to a minimum, just enough to make the mortar/concrete workable.

The lower the water content the higher the strength of the mortar/concrete. If too dry and stiff however, it will be difficult to work on to the formwork to achieve full compaction, and is likely to contain air voids and be imperfectly bonded to the reinforcement. A good mortar should be moist and never wet. Water should never be visible and should not look shiny in the mixture. Ideally this should be for a 1:3 cement: Most sand mix ratio of mortar, a water to cement weight (not volume) ratio of 0.5:1 will be satisfactory. Under most conditions, and owing to varying reasons however, workability needs to be controlled by eye during mixing. (A.M.Nivele, 1985)

2.5.11 Pumps

Pumps are usually needed to lift water from underground tanks. They can be small motorized or manual pumps operated by hand or treadle. Pumps however need better management for operation and maintenance/repair which is generally not easily available, especially in rural areas.

Communally owned tanks are more prone and complicated in this regard, than those individually owned. The advantage of pumps is however that when they fail/break water is not drained, and the tank emptied as is generally the case with gravity fed taps. A, rope and bucket can be used to abstract the water which requires to be cleaned out.

2.5.12 Fencing

Tanks should be fenced with suitable material, e.g. barbed wire or life-fence. A lockable door should be provided to exceptionally avoid the reach of domestic and wild animals and small children. Holes underneath made by burrowing animals, e.g. moles, should also be checked. Water Take off from underground tanks should use low cost water lifting devices e.g. rope and washer pump or other manual and small motorized pumps.

2.5.13 Seepage control methods in underground tanks

Lining with cement mortar, mud mortar or clay mud is applied when the sub-soil is firm and dense enough to keep the tank stable. It is usually thin lining. It can be kept stable in an excavated vertical section with a height up to 10 m without any support. The underground tank can work with thin wall. The stability of the structure mainly depends on the soil and role of the thin lining is to prevent from seepage. Depending on the firmness of the sub soil, the side slope is utilized varying from zero slope to 1:10 (horizontal to vertical) to stabilize the wall of the tank To make the seepage control activity more effective leave earth of the last 3-4 cm at the outer diameter of the tank unexcavated and to be compacted by wooden hammer to increase the density of the soil by which the cement mortar will be pasted. This is good for improving anti-seepage effect and strengthens the combination of soil/cement mortar, mud mortar and clay mud. (Nissen-Petersen, E. 1992).

2.5.14 Lining with clay mud

When cement is not affordable, clay may still be an option, for seepage control. Application of clay for lining involves (i) Dry up the clay; (ii) Crush the clay into fine particles by screening; (iii) Add water in proper quantity and mix hard; and (iv) Press the clay mud by hands or feet andsqueeze it into dough-like mix. Cement mortar is common material for lining underground tank.

It is more expensive than the clay mud, however it is less permeable.

2.5.15 Clay grouting

Clay grouting involves applying a clay blanket to cover the entire surface of the tank or pond over which water is to be impounded. The material for grouting should contain at least 20% clay particles by weight. The clay material should be at optimum moisture content and spread uniformly in layers of 15 cm to 20 cm thick, with each layer being thoroughly compacted before the next layer is added. There should be suitable clay borrow site that is close enough to get clay soil at reasonable cost. The minimum thickness of the clay blanket should be 30 cm for all depths of water up to 3 m. If the water depth is greater than 3 m, the thickness of the blanket should also be increased proportionally. Generally it is recommended to increase this thickness by 5 cm for every

30 cm of water exceeding 3 m depth. Clay blankets may require protection from cracking that may results from drying and from rupture caused by freezing and thawing. After completion of the clay-sealing, it is recommended to spread a cover of gravel 30 cm to 45 cm thick over the blanket.

The method is suitable for underground tanks and ponds which have high percentage of course- grained soils but lacking sufficient clay to prevent excessive seepage.

2.5.16 Sealing with bentonite

Bentonite is clay with a high shrink swell ratio. It is fine-textured colloidal clay, when wet; absorbs water several times greater than its own weight and, at complete saturation, swells to as much as to 15 times its original volume. This action tends to seal soil that lack clay-size particles. Therefore, adding bentonite is another method of reducing seepage in soils containing high percentage of coarse-grained particles and not enough clay. Bentonite, like clay blankets, must also be protected against drying. Since it returns to its original volume when dry, bentonite is not recommended for sealing ponds with wide fluctuations in water levels. If considerable time elapses between applying the bentonite and filling the pond, protecting the treated area against drying and cracking may be necessary. A mulch of straw or hay pinned to the surface gives this protection.

2.5.17 Lining with stone masonry/bricks

Tanks are usually lined with stone masonry, bricks, or concrete. This involves using a concrete foundation and then building the concrete wall within the excavation. To ensure a water tight structure, it is very important to lay the masonry in a proper way. A layer of stone/bricks is laid and mortar is poured on top of the first layer of stones. The mortar should be pressed into all the voids between the stones to ensure a dense masonry. Then the next layer of stones is laid as before. It is important to make sure that the joints between stones should be arranged in an alternate manner and 'straight' joints in both vertical and horizontal directions should be strictly avoided. Once completed, soil is squeezed firmly in the space between in the outer space created during construction to ensure good fit with the ground. The tank can be roofed or covered with grass or canvas. (Gould, J. 1999).

2.5.18 Plastic geo-membrane linings

Another option is to use plastic geo-membranes. These are specially made plastic linings used in dam construction. Normally, a geo-membrane is made to measure in a factory and the tank is constructed to fit its dimensions. Its cost varies, being cost effective in some countries.

The advantage of plastic geo-membranes is that they can be installed by the user easily. Also, if well protected, they control seepage quite effectively, and can be used on almost any soil. A major limitation is the shorter lifespan, which rangers 5-10 years. They can also be easily damaged by agricultural equipment.

Care is needed while installing geo-membrane linings to ensure that there is proper handling and storage i.e. transporting of the sheet in rolling pattern than sharp folding. Also, the surface of the pond should be smoothened to remove any piercing materials. Proper anchoring of the geo-membrane in the trench at the top edges. Fencing of the pond in order to protect it from animals and children.

2.5.19 Advantages of flexible geomembrane

Compared to other sealing methods flexible geomembranes have the following advantages. (I)They can be applied to various soil types (i.e. fine, medium and coarse course textured soils). (ii)The cost is getting lower as their popularity grows with more manufacturers and suppliers.(iii) Geo-membrane covers can be transported easily to place of use.

If punctured, the membrane can be easily repaired by farmers themselves or local practitioners (by using used plastic products, heat, gluing using adhesives of bicycle inner tube maintenance techniques). Also, seepage losses can be completely reduced. (Vazirani & Ratwani, 2004)

2.6 Water quality

Although ground catchment systems are sometimes used to collect rainwater for drinking purposes, it is strongly recommended, where possible, that this water should be treated by e.g. boiling, chlorinated or passed through a slow sand filter before being consumed. Natural treated

Soil or compacted surfaces may form suitable catchment surfaces, although excess sediment may need to be removed from the harvested water. Due to the low runoff coefficients of many natural soil surfaces, especially where the slopes are small, various techniques have been developed to increase the amount of rainwater runoff. These basically involve three approaches – covering treating or compacting of the surface.

The treatment of catchment surfaces should be done so as to reduce infiltration and hence increase the runoff from natural surfaces. Among the materials added to soil surfaces to try to seal and reduce infiltration are cement, butyl rubber, lime, paraffin wax oil, bitumen and asphalt. Sodium salts may also be used to encourage crusting in soils containing clay is of another approached that can be used. The compaction and shaping of natural soil surfaces using machinery to form catchments made of a series of cambered roadways known as roared catchments. These catchments feed parallel drains, normally leading into a single surface reservoir. Although not generally used to provide community supplies, due to the poor quality of the water for domestic purposes. The potential for developing roaded catchments exists wherever road construction and earth-moving machinery are available. (Hasse, R. 1989).

2.7 Operation and maintenance

As with other water harvesting systems, underground tanks require proper operation and regular maintenance. There should be regular checks on the tank for seepage, cracking and piping and movement cracks within embankment. Also, the side slopes, inlets and outlets should be inspected for any damages. If present and attended to early, most of these problems can be treated.

Regular cleaning of inlets, silt pits and the tank itself of any of debris and eroded soil material should be done. Vermin can burrow into inlets, outlets, embankments causing damage. Burrows should be dug out and repacked with clay. Vermin around the structure should be eradicated. The whole area around the tank should be fenced to improve safety.