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UNDERGROUND RECTANGULAR RCC WATER TANK

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Abstract: Water tanks are containers for storing water. The need for water tank remains from olden civilization till date to supply stored water for many applications and processes such as drinking water, irrigation agricultural, fire suppression, agricultural farming, chemical manufacturing as well as many other uses. An Underground water storage tanks (or sub-surface tanks) is used for storing potable drinking water underground, wastewater & rainwater (from rain water harvesting) collected. It is a water storage structure constructed below the ground. This also includes structures which are partly below ground. This project gives in brief, the theory behind the design of liquid retaining structure i.e. rectangular underground water tank. This report includes design of a RCC underground rectangular water tank for required water demand.

1.INTRODUCTION

Underground water tanks are structures which act as a reservoir for small domestic or commercial buildings. Some of the basic components of underground water tanks are:

- Base slab
- Side walls
- Roof slab

These water tanks are too ductile, which enables them to withstand seismic forces and varying water backfill. Tanks utilize material efficiently – steel in tension, concrete in compression. Underground water tanks have very low maintenance cost as it is constructed with concrete, which is a durable material and it never corrodes. It also does not require coatings when in contact with water or the environment. One of the main advantage of Underground water tank over the surface water tank is that temperature inside underground water tank is lower than that of surface tanks which causes lesser loss of water due to evaporation.

Underground water tank faces different type of loads compared to other structures. These loads are mainly horizontal (lateral) loads due to earth and water pressure. The pressure loads at side walls are greater at the bottom and it linearly decreases as we move towards the top.

The inside water pressure is not the only load the tank bears, it also has to bear the surcharge above the ground level. So the roof slab of the underground tank should have enough strength to with stand the surcharge.

Earlier the loads acting on the structure are considered as static, but strictly speaking, with the exception of the self-weight (dead load) no structure load is static one. Now a day large number of application software's are available in the civil engineering field. All these software's are developed as the basis of advanced Finite element analysis which include the effect of dynamic load such as wind effect, earth quake effect bets etc. in the present work, an attempt has been made to study the efficiency of certain civil engineering application softwares. There are many classical methods to solve design problem, and with time new software's also coming into play. It is one of the effective software which is used for the purpose of analysis and design of structure by the structural engineers.

2. UNDERGROUND RECTANGULAR WATER TANK

Design Philosophy

A liquid retaining structure supported directly on the ground or below the ground may either be designed using limit state method or, working stress method in accordance with IS:3370- part 2- 2009. All relevant limit states must be considered in design to ensure an adequate degree of safety and serviceability in accordance with IS: 456. However, container of these structures is a critical component that actually stores the liquid. The container must surely be leak proof. The limit states of serviceability for crack and deflection are critical for such components. Clause 4.4.1.2 of IS:3370-part 2 states that the maximum calculated surface width of cracks for direct tension and flexure tension or restrained temperature and moisture effects must not exceed 0.2 mm with specified cover. Clause 4.4.3.1 states that the limit state of serviceability for cracking may be deemed to be satisfactory if the stress in steel under service conditions does not exceed 130 MPa in

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high strength deformed bars. Thus, there is no need to calculate crack width. Nevertheless, if crack width and spacing between cracks needs to be calculated in fresh concrete it may be calculated in accordance with the procedure given in Annexure A, and that in the hardened concrete is calculated, using the procedure given in Annexure B of IS:3370-part 2.In view of complicated geometrical shapes adopted for the container of such structures, it is quite tedious to design the container for the limit state of collapse as well as for the limit state of serviceability for deflection. The design of containers using the working stress method is much more convenient. The working stress method is equivalent to the limit state of serviceability for maximum compressive and tensile stresses.

Working stress design method

The design of members of the container is based on two conditions:

(1) adequate resistance to cracking, and

(2) adequate strength.

The whole section of concrete including the cover together with reinforcement can be taken into account in the calculation of stresses(both flexural and direct tension related to resistance to cracking), provided the tensile stress in concrete is restricted. That means the concrete has no tensile strength in strength calculation.

For the design of very large capacity circular water tanks, it may be desirable to choose prestressing of such tanks.

Impermeability of Concrete

The impermeability of concrete is a basic requirement for liquid retaining structures. It important not only for its direct effect on the leakage but also because it affects durability, resistance to leaching, chemical attack, erosion, abrasion frost damage and protection from corrosion of embedded steel. The permeability of any uniform and thoroughly compacted concrete of given mix proportions is largely dependent on the water cement ratio. Thus it becomes essential to select concrete mix adaptable to available particle shape and grading for attaining higher workability as well as the resultant concrete is sufficiently impervious.

Clause 4 of IS:3370-part I states that the minimum grade of concrete used in such structures is based on exposure condition of the structure, that is, severe as per IS:456. Thus, the minimum grade of concrete has to be **M30**. Higher the grade, lesser is the porosity of concrete. However, for small capacity tanks less than 50 kL capacity, in non-coastal areas, the minimum grade of concrete may be taken as M25 as per Table 1 of IS:3370-part 1. It is therefore important to develop an understanding of the behaviour of members subjected to axial tension only, bending moment only, and combined axial tension and bending moment.

2.1. GENERAL DESIGN REQUIREMENTS OF CONCRETE

Plain concrete member of reinforced concrete liquid retaining structure may be designed against structural failure by allowing tension in plain concrete as the permissible limits for tension in bending. This will automatically take care of failure due to cracking. However, nominal reinforcement shall be provided, for plain concrete structural members.

Permissible Stresses in Concrete

(a) For resistance to cracking:

For calculations relating to the resistance of members to cracking, the permissible stresses in tension (direct and due to bending) and shear shall confirm to the values specified in Table. The permissible tensile stresses due to bending is applied to the face of the member in contact with the liquid. If the members are less than 225mm, thick and in contact with liquid at one side these permissible stresses in bending apply also to the face remote from the liquid.

Table 1: Permissible tensile stresses in concrete (MPa) IS:3370-part 2

Stress	Grade of concrete				
	M25	M30	M35	M40	M50
Direct tension	1.3	1.5	1.6	1.8	2.1
Bending tension	1.8	2.0	2.2	2.4	2.8

(b) For strength calculations: In strength calculations the permissible concrete stresses shall according to the Table. In place where the calculated shear stress in concrete alone exceeds the permissible value, reinforcement acting in conjunction with diagonal compression in the concrete shall be provided to take the whole of the shear.

Table 2: Permissible compression stress in concrete (MPa) IS:3370-part 2

Stress	Grade of concrete				
	M25	M30	M35	M40	M50
Direct compression	6.0	8.0	9.0	10	12
Bending tension	8.5	10.0	11.5	13	16

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Permissible Stresses in Steel

(a) Resistance to cracking

The tensile stress in the steel is limited by the requirement that the permissible tensile Stress in the concrete does not exceed; so the tensile stress in steel shall be equal to the product of modular ratio of steel and concrete, and the corresponding permissible tensile stress in concrete. If permissible stress in bending tension in concrete is 2 MPa for M30 concrete, the corresponding stress in tension steel will be m x 2, i.e., 9.30 x 2 = 18.6 MPa only.

(b) For strength calculation

The permissible stress in steel is taken as 1360 MPa for high strength deformed bars. It means a slight cracking is acceptable in concrete such that the crack width is not more than 0.2 mm. It should be remembered that it is steel (not concrete) which resists entire force of tension.

Table 3: Permissible stresses in reinforcement (MPa)

Stress	High strength deformed bars
Tensile stress in direct tension, bending and shear	130
Compressive stress in columns subjected to direct load	140

2.2 DESIGN REQUIREMENTS

The tanks like purification tanks, Imhoff tanks, septic tanks, and gas holders are generally built underground. The design principle of underground tank is same as for are subjected to internal water pressure and outside earth pressure. The base is subjected to weight of water and soil pressure. These tanks may be covered at the top. Whenever there is a possibility of rise of water table, soil becomes saturated and earth pressure exerted by saturated soil is taken into consideration. As the ratio of the length of tank to its breadth is greater than 2, the long walls will be designed as cantilevers and the top portion of the short walls will be designed as slab supported by long walls. Bottom one meter of the short walls will be designed as cantilever slab. As the ratio of the length of the tank to its breadth is less than 2, the bottom one-fourth portion of the wall will be designed as cantilever and the remaining portion of wall will be designed as continuous frame. (Design shown below is for length of the tank to its breadth is less than 2).

Comparative Study on the Design of Rectangular and Circular Concrete Water Tanks

Structural Layouts:

The rectangular and circular walls were considered to be propped cantilevers. Each of the propped cantilevers were made rigidly fixed to its base slab and were expected to be drawn inward at the top by the wall/top slab connecting reinforcements; in response to the outward hydrostatic loading on the wall. This was put in view based on the fact that continuity reinforcement must be provided at corners and at member-junctions to prevent cracking. The base slabs were typically a double overhanging single-spanned continuous slab, with wall point load and its applied fixed end moment at each overhang end. And the top slabs were laid out to be either two-way spanning or simply supported as stated by Anchor. The tank dimensions were deduced by the application of the related formula for solid shapes‟ volume calculations. Therefore, (L x B x H) for cuboid (or cube) was used for the rectangular tank and (π x R^2 x H) for cylinder was applied for the circular tank; where L, B, H and R are Length, Breadth, Height and Radius respectively. For each tank, the preliminary member sizing was done for the walls, base slab and top slab. Water free-board was also provided for the possible volume increase above the require capacity in order to limit or check the overflow of the tanks in accordance with recommendations by BS 8007 (1987), and Reynolds and Steedman (1988). This was practically allowed to ease the reinforcing and construction of joints.

Wall Loading:

The average water force or load, P in kN per meter width of the rectangular tank walls under flexural tension was derived as a concentrated or point load by calculating the areas of the triangular pressure diagrams of the water content on the walls, to be (ρH) x H/2, where ρ is the water density. By the centroidal consideration of loading of the pressure diagram, one-third distance from the base, up each wall, was chosen as the point of application of the concentrated load. The circular tank wall would be clearly in a state of simple hoop tension and its amount in kN per meter height of wall would be (ρH) x D/2. And it would still act at one-third distance from the base up each wall. The wall total working loads for both options were assumed purely hydrostatic. And the inclusion of wind load in the working load was purely made to be dependent on tank elevation above the ground level, but would always be applicable in the design of its support. The wind load’s application point, if considered, would be at one-half the tank’s height and acting against the lateral water force. Hence, the resultant lateral force, from the combination of the water force and wind force; if applicable, would be one-half way between the two forces, that is, five-twelfth of the tank’s height. For the purpose of this study, tanks elevated at 12 m and above were considered to be influenced by wind load.

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Base Slab Loading:
For each of the water tank options, the characteristic of the base slab serviceability uniformly distributed load in kN/m per m run, was the sum of its dead load; the concrete self weight and its finishes, and its live load; that is, the weight of water to be contained. And the serviceability point load in kN per meter run, acting on each of the base slabs, at the extremes of the overhangs was derived by adding up the dead load of the wall; i.e. the base projection's weight and a calculated fraction of the top slab load. But some noticeable difference might be experienced in the calculations of the fractions of the loads from the rectangular and the circular top slabs.

Top Slab Loading:
The uniformly distributed load of top slab, in kN/m per meter run was calculated by adding up its combined dead load; that is, self-weight of concrete, waterproof finish and its live load (for tank access), to derive the characteristic serviceability load. Factors of safety of 1.4 and 1.6 were applied to the combined dead and live loads respectively before their sum was made to achieve the required ultimate design load for the top slab. The ultimate requirement, that is, stability would dictate its design and serviceability requirements; basically, deflection would be checked (BS 8007, 1987)

Structural Analysis:
General: This entails the analyses of the loaded structural elements; walls, base and top slabs in order to determine their bending moments for the required design conditions. Serviceability loadings were considered for the general analysis to concentrate on crack width and reinforcement tensile stress limit except for top slab where this requirement would only be a check on the structural performance through measure of deflection. The maximum bending moment from the support and span for each condition was generally used and confirmed less than the moment of resistance, Mu= 0.156 f bd^2, where f is the 28-day concrete characteristic strength, b is one-meter width of slab and d is the effective slab depth (BS 8110, 2007).

2.3 MINIMUM REINFORCEMENT

The minimum reinforcement in walls. floors and roofs in each of two directions at right angles. within each surface zone shall not be less than 0.35 percent of the surface zone, cross section as shown in Fig for high strength deformed bars and not less than 0.64 percent for mild steel reinforcement bars. The minimum reinforcement can be further reduced to 0.24 percent for deformed bars and 0.40 percent for plain round bars for tank having any dimension not more than 15 m. In wall slabs less than 200 mm in thickness. the calculated amount of reinforcement may all be placed in one face. For ground slabs less than 100 mm thick (see Fig) the calculated reinforcement should be placed in one face as near as possible t0 the upper surface consistent with the nominal cover. Bar spacing should generally not exceed 300 mm or the thickness of the section. whichever is less.

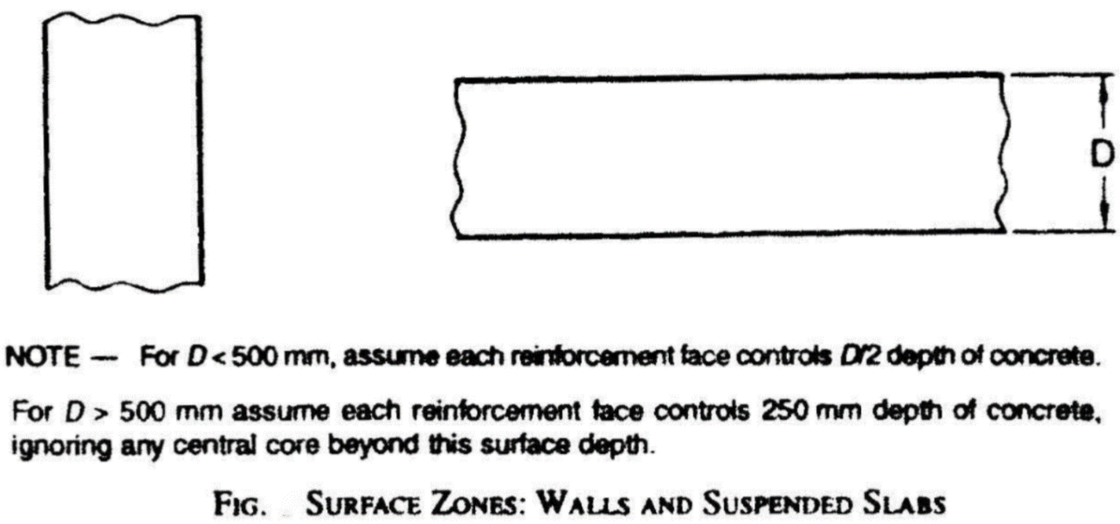

Figure 1: Surface zones walls and suspended slabs

2.4 MINIMUM COVER TO REINFORCEMENT

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For liquid faces of parts of members either in contact with the liquid (such as inner faces or roof slab) the minimum cover to all reinforcement should be 25mm or the diameter of the main bar whichever is greater. In the presence of the sea water and soils and water of corrosive characters the cover should be increased by 12mm but this additional cover shall not be taken into account for design calculations.
For faces away from liquid and for parts of the structure neither in contact with the liquid on any face, nor enclosing the space above the liquid, the cover shall be as for ordinary concrete member.

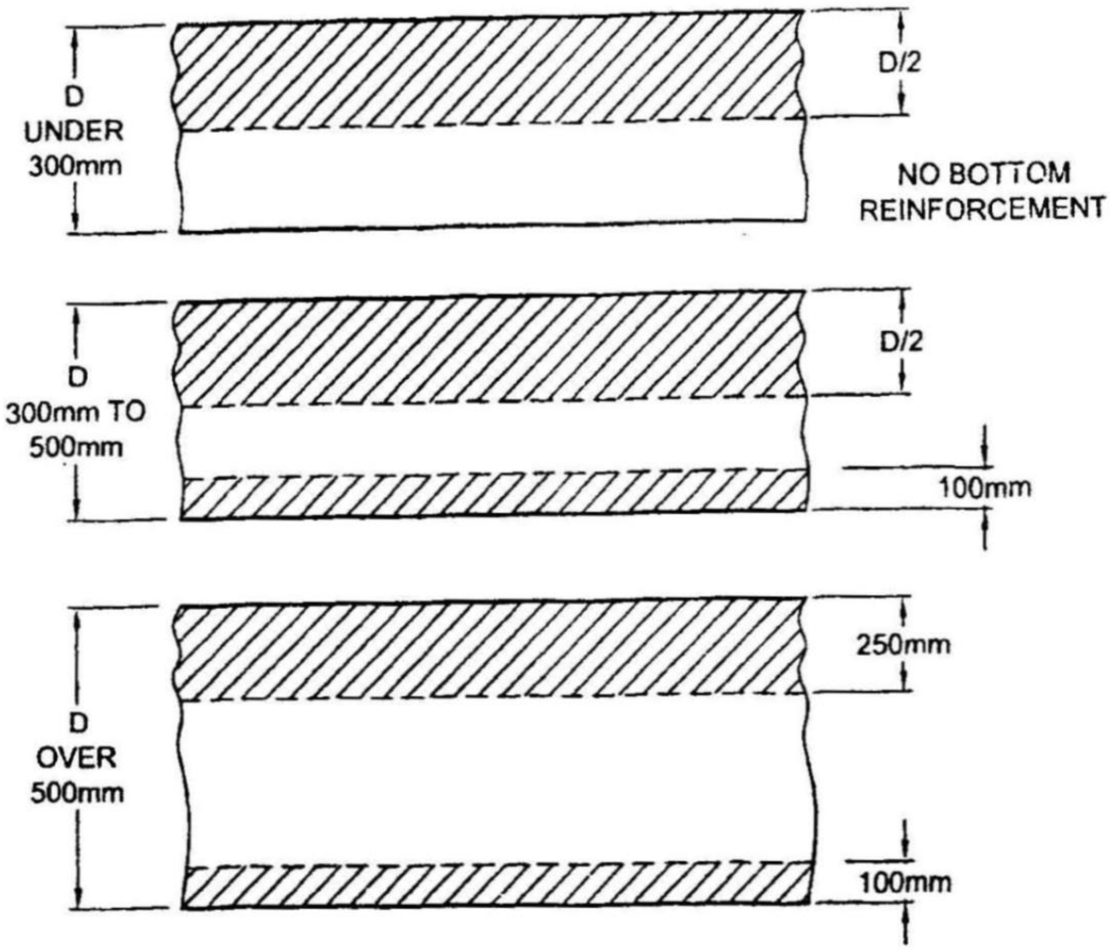

FIG.__ SURFACE ZONES: GROUNDED SLABS

Figure 2: Surface zones: grounded slabs

2.5 DESIGN OF TANK
Roofs
The roof slab of a tank may be either a flat slab or a dome. The latter is more economical as it resists the load through membrane action along the radial and circumferential directions. The roof is designed for the self-weight, surcharge if any, live load and mechanical equipment, if any. A manhole with a steel ladder is generally provided for maintenance and a ventilator is provided for air circulation.
Floors
If a tank is resting directly over ground, the floor may be constructed in concrete with a nominal reinforcement provided that the soil can carry the loads without appreciable subsidence in any part. In case the water table is close to the floor or above it, the bearing capacity should be modified accordingly. If the tank is supported on walls or ring beam, the floor should be designed as floors in buildings for bending moment and shear force due to load of water and self-weight. Generally, the floor is rigidly connected to the walls. Thus, the direct forces transferred to the floor from the walls and

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vice versa should be duly accounted. It is economical to provide circular tanks with a floor in the shape of a dome. In such cases, the dome should be designed for the vertical load of the liquid. The rise of the dome and its diameter should be so adjusted that the stresses in the dome are compressive as far as possible. The dome is supported at its bottom on the ring beam which is designed for resultant circumferential tension in addition to vertical loads.

Walls of rectangular tank

In plane walls, the liquid pressure is resisted by bending moment in vertical and horizontal planes. The horizontal tension caused by direct pull due to water pressure on the adjoining end walls should be added to that resulting from horizontal bending moment. Extra care is required in detailing the reinforcement at the vertical edges where the walls are rigidly joined together.In rectangular or square tanks, the wall may act as one-way slab or two way slab It may be fixed or hinged at the bottom, and hinged or free at the top. In the horizontal direction, it may be either continuous or restrained. The walls thus act as thin plates subjected to triangular hydrostatic pressure with boundary conditions varying between full restraint and free edge. The analysis of such walls may be carried out using the theory of elasticity. Reynolds Handbook (1988) and **IS:3370-Part 4 1965** given moment and shear force coefficients for some common cases.

Walls of the underground water tanks should be designed for the following load cases:

(i) Tank full-hydrostatic pressure due to water and earth pressure due to earth around it.

(ii) Tank empty-earth pressure due to earth around it. In case the tank is likely to be submerged due to water table, the soil properties should be modified.

(iii) In case of an earthquake, there will be additional earth pressure having its own point of application which needs to be considered.

3. CONCLUSION

Rectangular underground water tank of desired capacity is planned, designed, and analysed. In this project we analysed all materials behaviour that are used for water storage and found that concrete tanks can be effectively used for water storage. The other details of reinforcement used, Concrete mixture, Symbols used, Tables, Diagrams and plan are shown in the project. This project helped us to gain sufficient knowledge about the planning, Design and analysis of rectangular underground concrete water tanks. Design of water tank is a very tedious method. Particularly design of underground water tank involves lots of mathematical formulae and calculation. It is also time consuming. Hence program gives a solution to the above problems. There is a little difference between the design values of program to that of manual calculation. The program gives the least value for the design. Hence designer should not provide less than the values we get from the program. In case of theoretical calculation designer initially add some extra values to the obtained values to be in safer side In Underground tank, Uplift pressure plays predominant role in design which is caused by surrounding soil on outside walls of tank. The shape of the tanks plays predominant role in the design of overhead and underground water tanks.

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