DESIGN OF WATER TANKS ①

Storage tanks are built for storing water, liquid Petroleum and other similar liquids.

Analysis and design of such tank are independent of chemical nature of product. They are designed as crack free structures to eliminate any leakage. Adequate cover to reinforcement is necessary to prevent corrosion. In order to avoid leakage and to provide higher strength, concrete of grade M20 and above is recommended for liquid retaining structures.

To achieve imperviousness of concrete, higher density of concrete should be achieved. The leakage is more with higher liquid head and it has been observed water head upto 15m does not cause leakage problem. use of high strength deformed bars of grade Fe415 are recommended for the construction of liquid retaing structure. However mild steel bars are also used. correct placing of reinforcement, use of small sized and use

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use of deformed bars lead to a diffused distribution of cracks. A crack width of 0.1mm has been accepted as permissible value in liquid retaining structures

While designing the liquid retaining structures the recommendations of "code of practice for the storage of liquids - IS 3370 (part I to IV)" should be considered. Fractured strength of concrete is computed using the formula $f_{cr} = 0.7\sqrt{f_{ck}}$ (IS 456-2000). This code does not specify the permissible stresses in concrete for ~~resisting~~ resistance to cracking. However Earlier version of this code published in 1964 recommends the permissible value (to resist cracking) as

$\sigma_{cat} = 0.27\sqrt{f_{ck}}$ for direct tension and

$\sigma_{cbt} = 0.37\sqrt{f_{ck}}$ for bending tensile strength.

Allowable stresses in reinforcing steel as per IS 3370 are

σ_{st} = 115 MPa for Mild Steel (Fe250) and

σ_{st} = 150 MPa for HYSD (Fe415).

In order to minimize cracking due to shrinkage and temperature, minimum reinforcement is recommended as :

i) For thickness $\leq$ 100mm (Wall) – Min % steel = 0.3%

ii) For thickness $\geq$ 450mm = 0.2%

iii) For thickness between 100mm to 450mm, varies linearly from 0.3% to 0.2%.

Note: (i) For concrete thickness $\geq$ 225mm, two layers of reinforcement be placed, one near water face and the other away from water face.

(ii) Cover to reinforcement is greater of (a) 25mm (b) diameter of main bar.

– Design constants (Working stress method)

(i) $m = 280/3\sigma_{cbc}$ (modular ratio)

(ii) $K = \dfrac{m\sigma_{cbc}}{m\sigma_{cbc} + \sigma_{st}}$ (NA const.)

(iii) $j = (1 - K/3)$ (Lever arm const)

(iv) compressive force $C = \frac{1}{2}\sigma_{cbc} \cdot b \cdot x$

Tensile force $T = \sigma_{st} \cdot A_{st}$.

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v) $Q = \frac{1}{2} \sigma_{cbc} \cdot K \cdot j$ (M.R factor for balanced Section)

v) $M = Q\, bd^2$ or $\sigma_{st} \cdot A_{st} \cdot j \cdot d$

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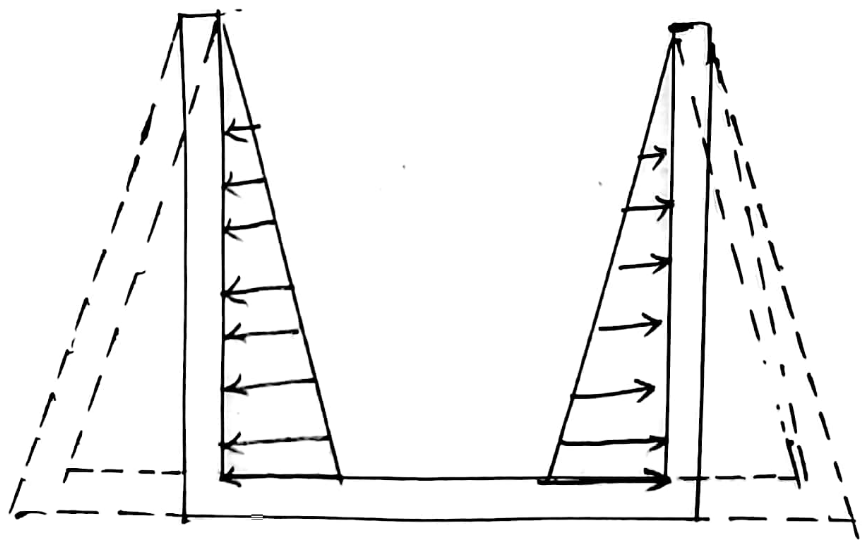
CIRCULAR TANKS

①. CIRCULAR TANKS RESTING ON GROUND:

Due to hydrostatic pressure, the tank has tendency to increase in diameter. This increase in diameter all along the height of tank depends on the nature of joint at the junction of slab (base) and wall as shown in fig.



Tanks with flexible base

When the joints at base are flexible, hydrostatic pressure induces maximum increase in diameter at base and no increase in diameter at top. This is due to the fact that hydrostatic pressure varies linearly from zero at top to maximum at base. Deflected shape of tank is shown in fig.

Design of Circular tanks resting on ground with flexible base:

Maximum Hoop tension is developed in the wall is at base. This tensile force 'T' is computed by considering the tank as thin cylinder.

$$T = \frac{wHD}{2}$$ where w = density or unit wt of water.

Reinforcement ~~is computed~~ required in form of Hoop steel is computed using

$$A_{st} = \frac{T}{\sigma_{st}} = \frac{wHD}{2\sigma_{st}}$$ or 0.3% (Min.)

Note: → When thickness of wall is less than 225mm, the steel is placed at centre.

→ When thickness exceeds 225mm at each face $A_{st}/2$ of steel as hoop reinforcement is provided.

Check: In order tensile ~~steels~~ stress in ~~in~~ concrete to be less than the permissible stress, the stress in concrete is computed

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using equation

$$\sigma c = \frac{T}{A_c + (m-1) A_{st}} = \frac{WHD/2}{1000t + (m-1) A_{st}}$$

If $\sigma c \leq \sigma cat$, where $\sigma cat = 0.27\sqrt{f_{ck}}$ then the section is safe from cracking, otherwise the thickness has to be increased so that

$\sigma c < \sigma cat$.

While designing the thickness of concrete wall can be estimated as $t = 30H + 50$ mm where H is in meters. Distribution steel in the form of vertical bars are provided such that minimum steel area requirement is satisfied.

As base slab is resting on ground and no bending stresses are induced hence minimum steel distributed at bottom and the top are provided

Problem:

Design a circular water tank with flexible connection at base for a capacity of 4,00,000 (4 lacs) litres. The tank rests on firm level ground. The height of tank including a free board of 200mm should not exceed 3.5m. The tank

is open at top. Use M20 concrete & Fe415 grade steel. Draw the reinforcement details.

Sol.

Step 1:- Dimensions of tank:

→ Depth of water $H = 3.5 - 0.2 = 3.3m$

→ Volume, $V = 4100,000$ litre
$= 400 m^3$

→ Area of tank, $A = V/H$

$$= \frac{400}{3.3}$$

$$A = 121.2 m^2$$

→ Diameter of tank $A = \frac{\pi D^2}{4}$

$$\Rightarrow D = \sqrt{\frac{4 \times A}{\pi}} = \sqrt{\frac{4 \times 121.2}{\pi}} = 12.42m$$

$D \simeq 13m$

→ Thickness of wall is assumed as

$t =$ ~~300H~~ $30H + 50$

$t = 30(3.3) + 50 = 149 mm$

$t \simeq 160mm$ (* any value > 149mm but not too much variation)

Step 2: Design of Vertical Wall:

→ Max. Hoop tension at bottom, $T = \frac{wHD}{2}$

$w = 10 kN/m^3$ (or $9.84 kN/m^3$)

$$\therefore T = \frac{10 \times 3.3 \times 13}{2} = 214.5 kN$$

$$\therefore \text{Area of Steel}, A_{st} = \frac{T}{\sigma_{st}} = \frac{214.5 \times 10^3}{150}$$

$$\Rightarrow A_{st} = 1430 mm^2$$

→ Minimum steel to be provided

$A_{st\,Min} = 0.24\%$ of area of Concrete

$$= \frac{0.24}{100} \times 1000 \times 160$$

$$= 384 mm^2$$

$\therefore A_{st} > A_{st\,Min}$ ∴ O.K

∴ Provide 16mm ϕ bars at a Spacing

$$= \frac{1430}{\pi (16)^2/4} \times 1000 = 140.6 mm c/c$$

∴ Provide 16mm ϕ ~~bars~~ @ 140mm c/c. in the form of hoops. (rings).

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Step 3: Check for tensile Stress

→ Area of steel provided = $\frac{\frac{\pi (16)^2}{4} \times 1000}{140}$

$A_{st\,pro} = 1436.16\,mm^2$

$m = \frac{280}{3\sigma_{cbc}} = \frac{280}{3 \times 7} = 13.33$

→ Stress in concrete $\sigma_c = \frac{T}{1000t + (m-1) A_{stp}}$

$\sigma_c = \frac{214.5 \times 10^3}{1000 \times 160 + (13.33 - 1)\,1436.16} = 1.2\,N/mm^2$

→ Permissible stress $\sigma_{cat} = 0.27\sqrt{f_{ck}}$ ← (as per IS 456-2000 LSD)

$= 0.27\sqrt{20}$

$= 1.2\,N/mm^2$

Actual stress is equal to permissible stress. Hence Safe :)

Step 4 Curtailment of Hoop Steel:

Quantity of Steel required at 1m, 2m and at top are tabulated.

Height from top	Hoop tension $T = wHD/2$ (kN)	$A_{st} = T/\sigma_{st}$ mm^2	spacing of #16 mm c/c
2.3m	149.5	996	200
1.3m	84.5	563.33	350
Top	0	Min steel (0.24%) = 384mm²	400 (max 3t = 480mm)

Step5 Vertical Reinforcement:

For temperature and shrinkage distribution steel in the form of vertical reinforcement is provided @ 0.24% i.e $A_{st} = 384mm^2$

spacing of 10mm dia. bar = $\frac{\pi(10)^2/4 \times 1000}{384}$

= 204mm c/c

≃ 200mm c/c

Step6: Tank floor:

As the slab rests on firm ground, min. steel @ 0.3% is provided.

Thickness of slab is assumed as 150mm

Provide 8mm dia bars @ 200mm c/c in both directions at bottom and top of slab.

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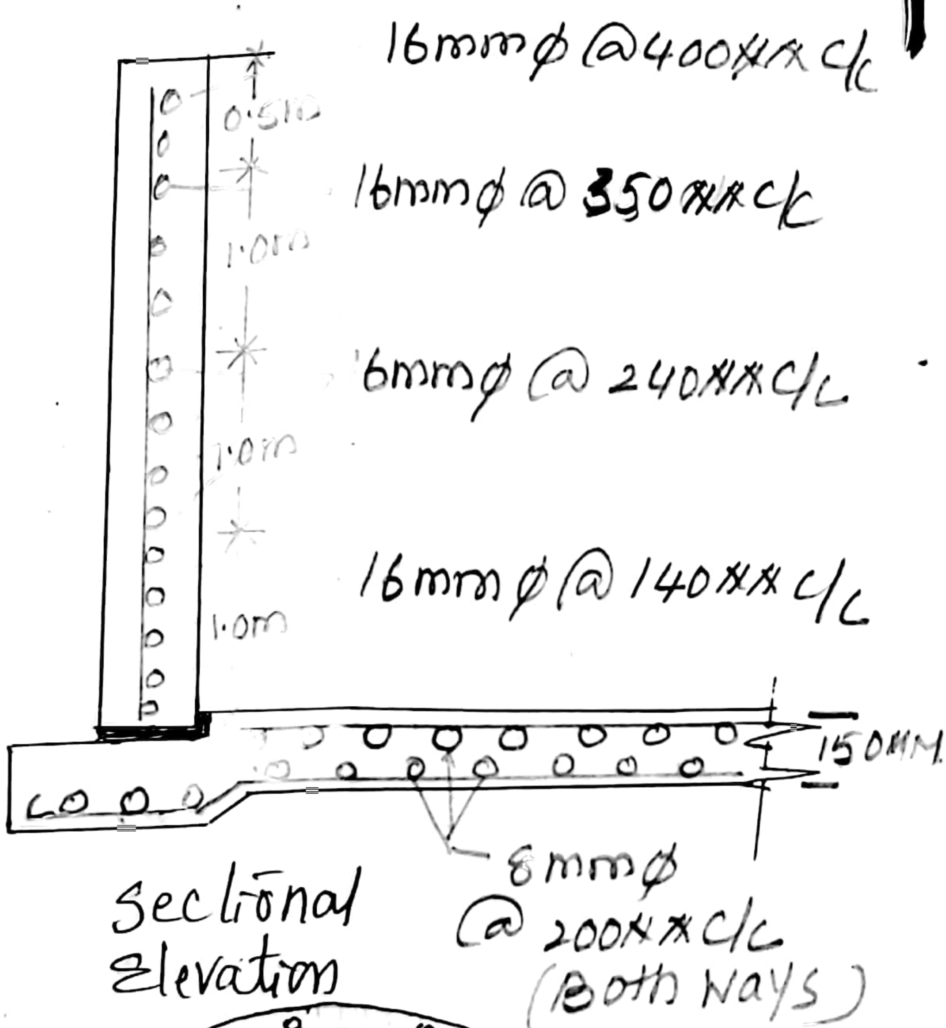
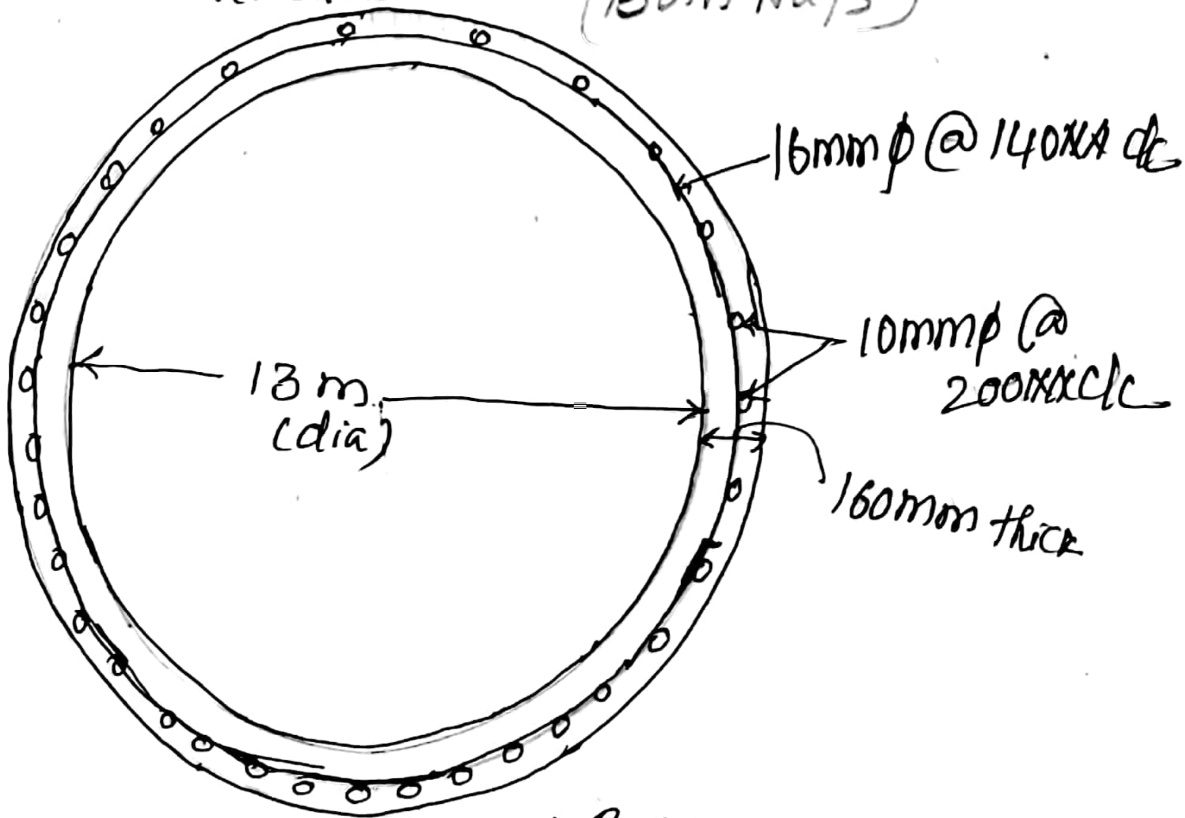
Step 7: Reinforcement Details:



Sectional Elevation



Plan at Base