

Module - Δ

Design of water Tank

Tanks are widely used for storing liquids like water, chemicals and petroleum etc... The tanks are generally circular or rectangular in shape. They are broadly categorized into following 3 types:

1. Tanks resting on ground.
2. Underground tanks.
3. Elevated or overhead tanks.

The tanks resting on ground are supported on the ground directly. The sedimentation tanks, aeration tanks, aeration tanks, filtration tanks and clear water storage reservoirs are generally of this type while the septic tank, inhoff tank and simple water tanks collecting water from the mains are generally constructed as underground tanks. Elevated or overhead water tanks, supported on staging are commonly used in water distribution system. For constructing any type of liquid containing structure, it is a must to ensure that the concrete is dense and impervious. It is essential not only from the leakage point of view, but also affects the durability, cracking and resistance against chemical attack to corrosion.

Design philosophy and Requirements

Design of liquid retaining structures is based upon the fact that the concrete should not crack and hence the tensile strength of concrete should be within permissible limits. In order to control cracking, various requirements regarding material, joints and reinforcement detailing are listed in IS 3370 (part 1): 2009.

Methods of Design

The design of water tanks can be done by any of 2 methods given below

- (i) Limit state method of design.
- (ii) working stress method of design.

limit state method of design

In this method, all relevant limit states should be considered and satisfied with an adequate degree of safety of serviceability.

(ii) working stress method of design

The working stress method for design of water tank is based on adequate resistance to cracking and strength.

The various assumptions in this methods are:-

- (a) plane section remains plane before and after bending.
 - (b) steel and concrete behave elastically and the modulus ratio, m is given by:
- $$m = \frac{280}{30\text{c.e.}}$$
- (c) The tensile stress in concrete is limited to the values given for calculation of resistance to cracking.
 - (d) The tensile strength of concrete is ignored for all strength calculations.

Note:- 1) Bond stress in compression should be increased by 25%
2) For deformed bars, the bond stress should be increased by 60%.

Permissible stress in steel

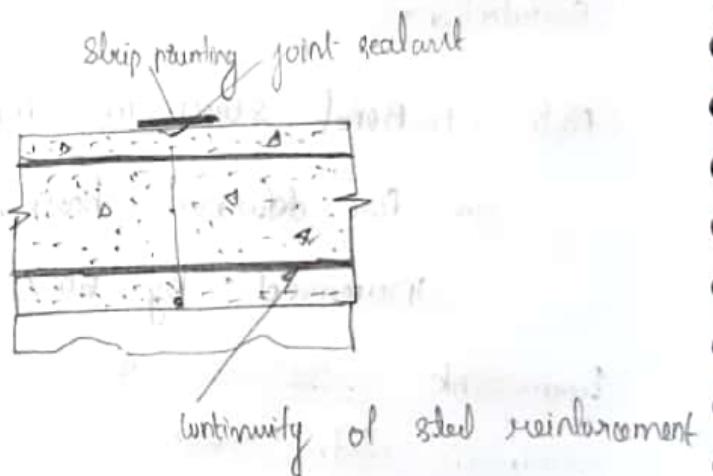
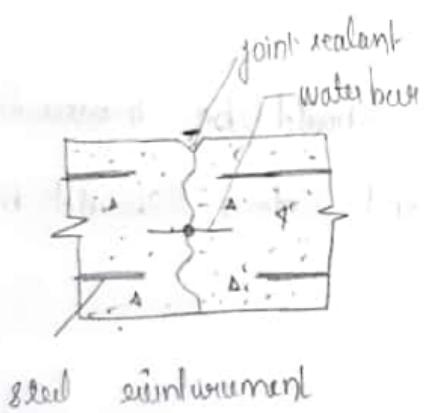
joints in water tanks

(e) Movement joints

In this type of joint, relative movement between the adjoining parts of a tank, such as wall and the floor slab, is permitted. These joints require the use of special materials, in order to maintain water tightness thus accomodating the relative movement b/w the sides of the joint. There are 3 types of movement joints:-

i) Contraction joint

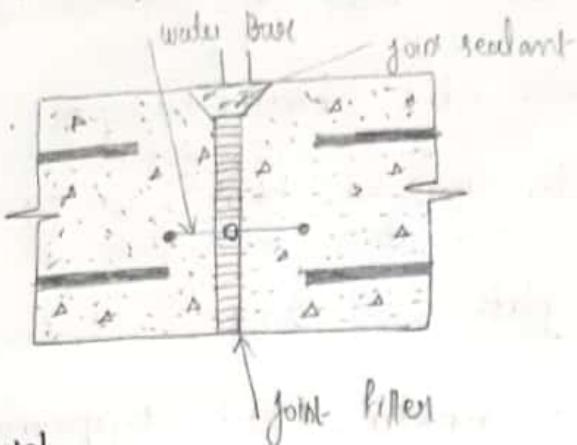
It is a movement joint, with deliberate discontinuity without initial gap b/w the concrete on either side of the joint. The joint is designed to accommodate contraction of the concrete. A contraction joint may be designed as complete or partial. In a complete contraction joint both concrete and steel are interrupted while in partial contraction joint only concrete is interrupted and the steel reinforcement is continuous.



ii) Expansion joint

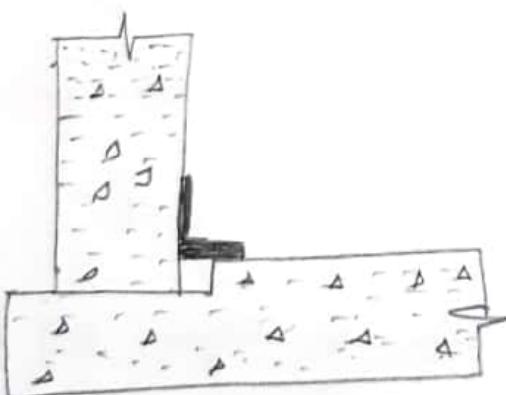
In this type of movement joint, complete discontinuity in both steel and concrete is provided to accommodate either expansion or contraction of the concrete. This joint has no restraint to movement. This type of joint requires an initial gap between the adjoining parts of a structure.

to accommodate expansion / contraction of the concrete.



3. sliding joint.

A movement joint which allows the adjoining panels of a structure to slide relative to each other with minimum restraint is known as sliding joint. In this joint, complete discontinuity is provided in both steel and concrete and at the discontinuity special provision is made to facilitate the relative sliding movement.



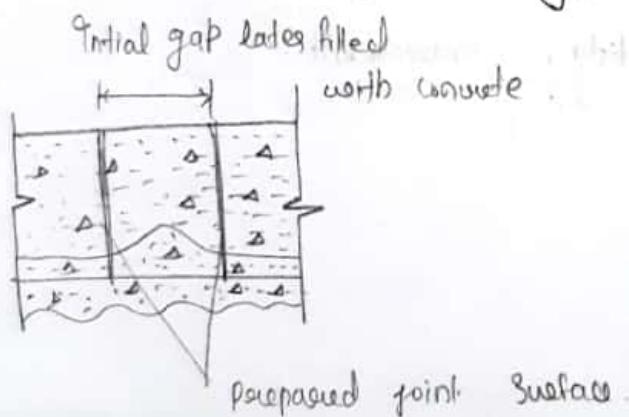
b) Construction joint

These joints are provided for convenience in construction. At these joints, special measures are incorporated to have subsequent continuity, without provision for further relative

movement. These joints may be grouted and concrete at the joints should be bonded properly. The no. of such joints should be kept as small as possible.

c) Temporarily open joints

A gap is sometimes left temporarily b/w the concrete of adjoining parts of a water tank which is filled with mortar or with suitable jointing material, after a suitable interval of the initial gap provided in the joint should be sufficient enough to allow the side to the prepared before filling jointing material.



Jointing materials

Joint filters, joint sealants and water bars should be as per the relevant standards. The jointing materials shall not have adverse effect on the quality of liquid/

water to be stored.

Analysis of water tanks

Circular Tanks Resting on the ground

The design of such tanks is based on the type of joint provided b/w the floor/base slab and the walls of the tank.

Tank with Flexible joint b/w the floor and the walls (Approximate method)

In this type of tank, the flexible joint provided b/w the floor and the walls of the tank is flexible, thus allowing the horizontal outward movement of the walls.

Hence, no moments are developed at the joints. In such tanks, walls are subjected to hoop tension only, which is developed because of the hydrostatic water pressure and is given by the eqn.

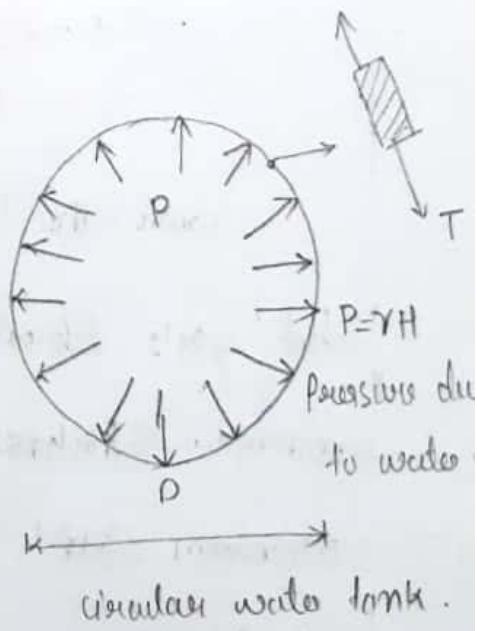
$$T = \gamma H D / 6$$

where, γ = unit weight of water

H = height of water

D = dia of the tank.

T = hoop tension.



The reinforcement for this hoop tension is to be provided all along the height of the wall, in the form of bars.

on wings suitably spaced apart. The area of steel required for carrying the hoop tension T .

$$T = \sigma_{st} \cdot A_{st} = \gamma H D / 2$$

$$A_{st} = \frac{\gamma H D}{2 \sigma_{st}}$$

The thickness (t) of the tank wall may be calculated from the requirement that tensile stresses in concrete should be within the permissible limit. If σ_{ct} is the permissible tensile stresses in concrete then,

$$\sigma_{ct} > \frac{T}{A_{eq}}$$

A_{eq} = area of transformed section.

$$\sigma_{ct} > \frac{T}{A + (m-1) A_{st}}$$

$$\sigma_{ct} > \frac{T}{1000 + (m-1) A_{st}}$$

Since the base slab of the tank rests on the ground load gets transferred to the soil directly and hence a minimum thickness of 150mm should be provided with minimum steel 0.35% each direction.

problems

- Design a circular water tank with a flexible base for a tank of 1,00,000 litre capacity. The depth of water in

tank is 5m. Use M25 concrete and Fe415 steel. Take unit weight of water as 9.8 kN/m^3 .

Solution

Given data

Volume of water in tank = 1,00,000 l.

$$= \frac{100000}{1000} \text{ m}^3$$

height of water in tank (H) = 5.0 m

permissible tensile stresses in steel = 180 N/mm^2 for HYSD bars.

permissible direct tensile stresses in concrete

if D is the diameter of the tank then,

$$\text{volume of tank} = \frac{100000}{1000}$$

$$\pi/4 D^2 \times 5 = 100 \text{ m}^3$$

$$= 15.05 \text{ m} \approx 5.1 \text{ m}$$

Q:- Maximum hoop tension (T)

$$T = \frac{\gamma H D}{2} = 9.8 \times 5 \times \frac{5.1}{2}$$

$$= 124.95 \approx 125 \text{ kN}$$

3:- Area of steel

$$As = \frac{T}{\sigma_{st}} = \frac{124.95 \times 1000}{180} = 962 \text{ mm}^2$$

using 12mm dia bars,

$$\text{spacing required} = \frac{113 \times 1000}{113} = 117 \text{ mm}$$

Hence provide 16mm dia hoops @ 110 mm c/c.

$$Ast \text{ provided} = \frac{T}{1027 \text{ mm}^2}$$

At a distance 2.5 m from top $T = 62.15 \text{ MN per m}$, and $Ast_{\text{req}} = 1481 \text{ mm}^2$, hence spacing can be doubled.

Step 4:- Thickness of tank wall

The thickness of the wall should be such that the tensile stress in concrete should not exceed the permissible value (say)

$$\sigma_{ct} > \frac{T}{1000 \cdot t + (11 - 7) \times 1027}$$

$$t > 85 \text{ mm}$$

Hence providing a thickness of 100mm for tank wall

$$Ast_{\text{min}} = 0.35\% \text{ of } x_{\text{real}}$$

$$= \frac{0.35}{100} \times (1000 \times \frac{100}{2})$$

$$= 175 \text{ mm}^2 < 1027 \text{ mm}^2 \text{ Hence ok.}$$

The spacing of hoops $\geq 300 \text{ mm}$ w.r.t the thickness of section
i.e. providing 16 mm dia hoops @ 110mm c/c along the height
of the wall. The spacing is increased to 220mm c/c at a
distance 2.5 m from top.

5:- Distribution reinforcement-

Distribution of temperature steel is provided @ 0.35% =

Providing 8mm dia bars @ 250mm c/c vertical slab.

$$A_{st} = \frac{2 \times 50 \times 1000}{250} = 200 \text{ mm}^2 > 175 \text{ mm}^2, \text{ OK}$$

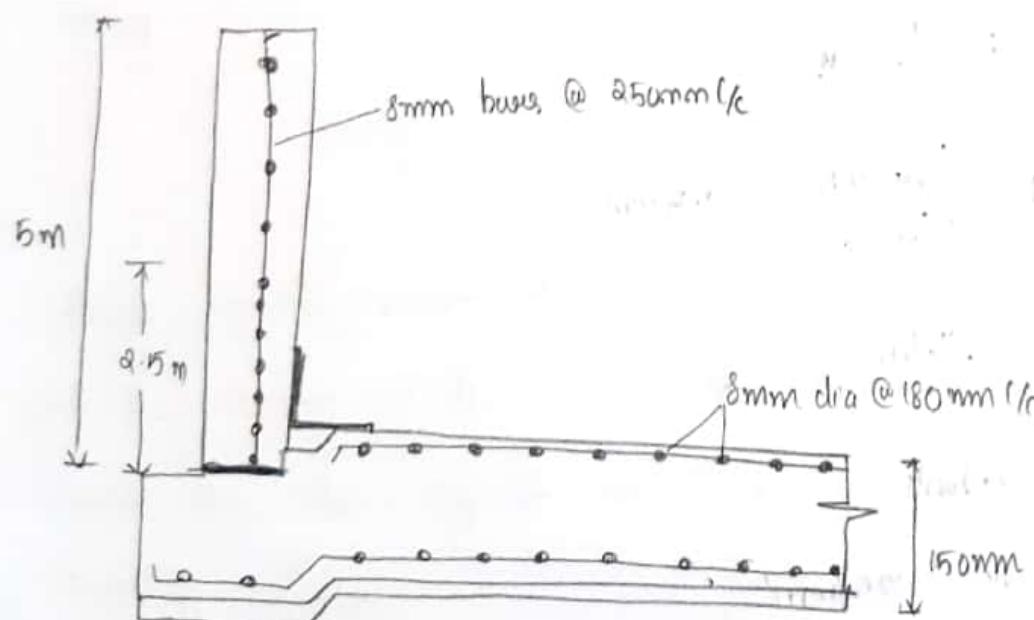
Q6:- Design of Base / Plaster Slab

Since the tank floor is resting on the ground, the load gets directly transferred to the soil.

$$= \frac{0.35}{100} \times 1000 \times \frac{150}{2}$$

$$= \underline{\underline{263 \text{ mm}^2}}$$

Hence provide 8mm dia bars @ 180mm c/c in both directions at top and bottom face of the floor slab.



a. Design a circular water tank with flexible base for a capacity of 450 kl. The depth of water is 4.5m. Allow suitable base bound.

Solution

Step 1:- Given data

Using M30 concrete w/ Fe415 steel.

$$\text{Capacity of tank} = 450 \text{ kl} \times 10^3$$

$$= 450,000 \text{ l.}$$

$$= \frac{450,000}{1000} \text{ m}^3$$

Taking 200 mm as freeboard effective depth of water in tank

$$\text{tank} = 4.5 - 0.2 = 4.3 \text{ m}$$

$$(\pi/4 D^2)^4 = 450$$

$$D = \sqrt{\frac{450 \times 4}{\pi \times 4^3}} = 11.54 \text{ m.}$$

$$\text{Taking } D = 11.6 \text{ m}$$

Step 2:- Design constants

$$\sigma_{chc} = 10 \text{ N/mm}^2$$

$$\sigma_{bt} = 2.0 \text{ N/mm}^2$$

$$\sigma_{ct} = 1.5 \text{ N/mm}^2$$

$$\sigma_{sl} = 130 \text{ N/mm}^2$$

is safe for M30 concrete.

$$m = \frac{280}{3\sigma_{cbc}} = \frac{280}{3 \times 10} = \underline{\underline{9.33}}$$

$$K = \frac{m \cdot \sigma_{cbc}}{\sigma_{cbc} + \sigma_{st}} = 0.416$$

$$j = 0.85$$

$$R = Y_2 \times \sigma_{cbc} k_j = \frac{1}{2} \times 10 \times 0.416 \times 0.86 = \underline{\underline{1.78}}$$

Step 3 - Design for hoop Tension

$$\text{Maximum hoop tension} = \gamma H D_b$$

$$= 10 \times 4.15 \times \frac{11.6}{2} = \underline{\underline{261 \text{ kN}}}$$

$$A_{st} = \frac{T}{\sigma_{st}} = \frac{261 \times 1000}{130} = \underline{\underline{2008 \text{ mm}^2}}$$

Using 20 mm dia hoops.

$$\text{Spanning} = \frac{94 \times 1000}{2008} = \underline{\underline{156 \text{ mm}}}$$

Hence provide 20mm dia hoops @ 150mm $\frac{1}{4}$ c/c at the bottom
at the centre of the wall. The spanning can be increased
near the top, say at 25mm top, 20mm hoops @ 300
mm $\frac{1}{4}$ c/c provided.

$$A_{st} \text{ provided} = 2043 \text{ mm}^2$$

$$\sigma_{ct} > \frac{T}{1000 \cdot t + (m-1) A_{st}}$$

$$\sigma_{st} > \frac{961 \times 1000}{1000 \times t + (4.33 - 1) \times 0.93}$$

$$\frac{961 \times 1000}{1000 \times t + 8.33 \times 0.93} < 1.5$$

$$t = 157 \text{ mm}$$

Hence providing, $t = 200 \text{ mm}$ with an effective cover = 30mm.

Step 4:- Vertical steel or distribution steel

Vertical steel is provided @ 0.35% of the surface %,

$$t < 200 \text{ mm}$$

$$A_{st\min} = \frac{0.35}{1000} \times (1000 \times \frac{200}{2})$$

$$= 350 \text{ mm}^2$$

Providing 10mm dia @ 200mm c/c.

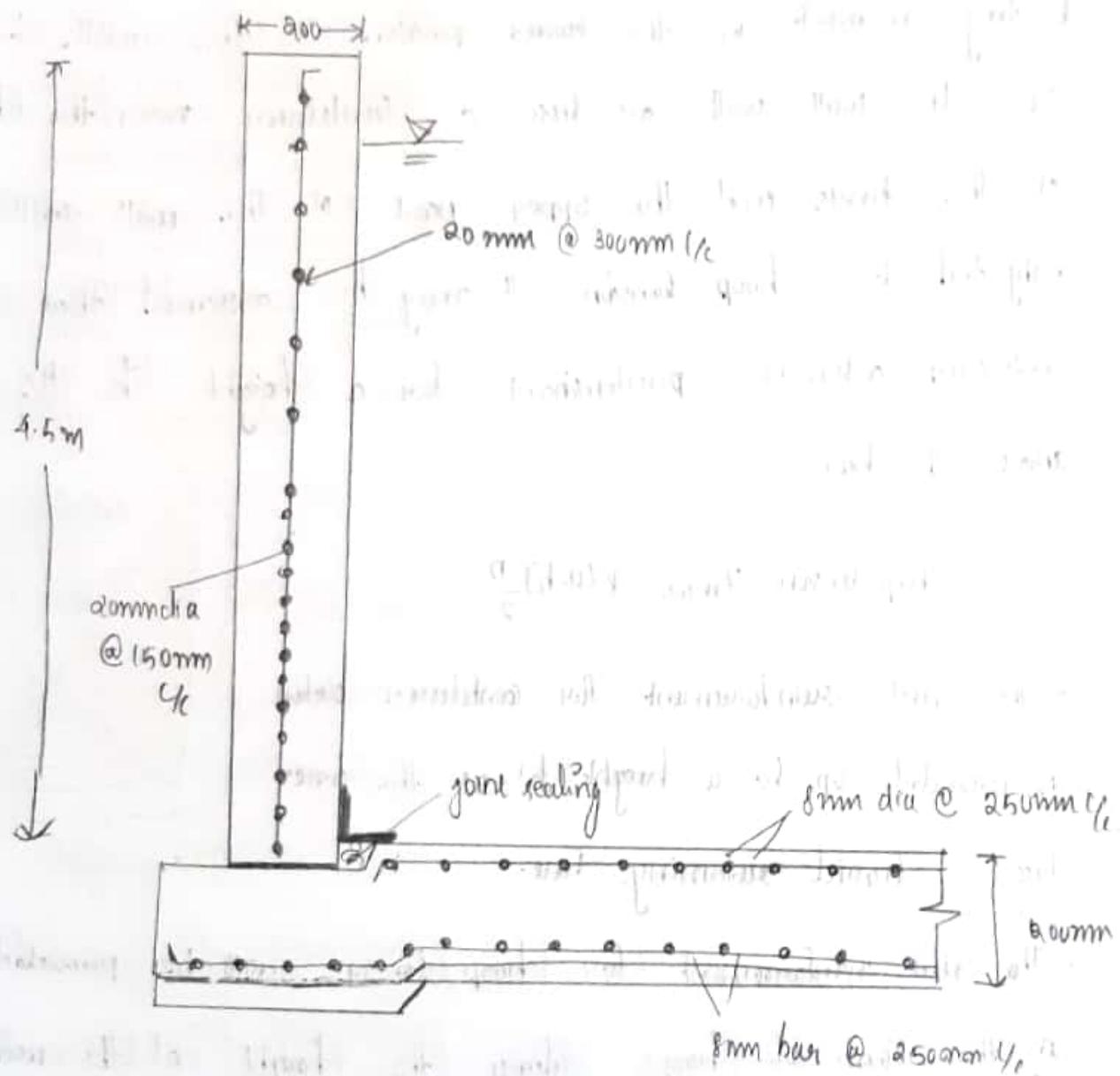
Step 5:- Design of base slab

As the tank is resting on ground, providing a thickness of 200mm and minimum steel @ 0.35%.

$$A_{st} = 350 \text{ mm}^2$$

Providing half on each face is 175 mm^2 .

Hence provide 8mm dia bars @ 250 mm c/c on each face. The details of reinforcement are:-



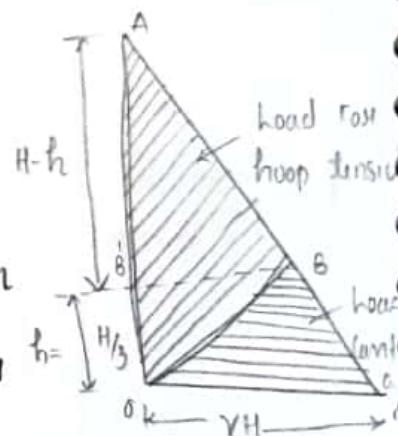
Cylindrical Tank with Rigid joint b/w floor and the wall

If the joint b/w the floor and the wall in water tank is rigid, the wall is constraint to move in the flexural direction and this will result in the development of the bending moment in the lower portion of the wall. In this case, the wall will act like a cantilever near the bottom of the tank and the upper part of the wall will be subjected to hoop tension. It may be assumed that the cantilever action is predominant for a height $h = H/3$ or above the base.

$$\text{hoop tension } T_{\text{max}} = \gamma(H-h) \frac{D}{2}$$

- The steel reinforcement for cantilever action is provided up to a height h at the inner face or liquid retaining face.
- The steel reinforcement for hoop tension will be provided in the form of hoops along the height of the wall.
- On liquid retaining face of the tank wall, the tensile stresses should satisfy the following condition:

$$\frac{\sigma_{ct}}{\sigma_{cl}} + \frac{\sigma_{bt}}{\sigma_{bt}} \leq 1$$



σ_{ct} = Computed stresses in concrete in direct tension.

σ_{ct}' = Permissible stresses in concrete in direct tension.

σ_{bt} = Computed stresses in concrete in bending tension.

σ_{bt}' = Permissible stresses in concrete in bending tension.

- Q3. Design the circular tank of 1,00,000 litre capacity. The depth of water in the tank is 5m. Use M25 concrete and Fe415 steel. Take unit weight of water as 10 kN/m^3 . Assuming it to have a ringed joint b/w the wall & floor of the tank. Use approximate method.

Solution

- 1:- The dia of the tank is calculated as before

$$D = 5.1 \text{ m}$$

$$H = 5 \text{ m}$$

Design constants

$$\sigma_{chc} = 8.5 \text{ N/mm}^2$$

$$\sigma_{ct} = 1.3 \text{ N/mm}^2$$

$$\sigma_{st} = 130 \text{ N/mm}^2$$

$$k = \frac{m \cdot \sigma_{chc}}{\sigma_{chc} + \sigma_{st}} = \frac{11 \times 8.5}{11 \times 8.5 + 130} = 0.418$$

$$j = 0.86 \quad R = 6.527$$

Step 2:- Bending moment or hoop tension

Hoop tension is maximum at height = $H-h$

where, $h = \frac{H}{3}$ or 1m whichever is greater.

$$= \frac{5}{3} = 1.66\text{m}$$

maximum hoop tension,

$$T = \gamma(H-h) \frac{D}{2} \text{ at B}$$

$$= 9.8 (5 - 1.66) \times \frac{5.1}{2}$$

$$T = 83.5\text{ kN}$$

Maxi BM will occur at the base of the wall.

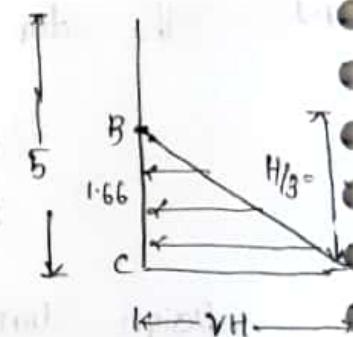
(Considering side loading B(0))

$$\begin{aligned} M &= \gamma_2 (\gamma H) \cdot h \cdot \frac{h}{3} \\ &= \gamma_2 (9.8 \times 5) \times 1.66 \times \frac{1.66}{3} \end{aligned}$$

$$M = 22.6\text{ kNm.}$$

Step 3:- Thickness of wall required (t)

$$t_{\text{req}} = \sqrt{\frac{M}{R_b}} = \sqrt{\frac{22.6 \times 10^6}{1.527 \times 1000}} = 182\text{ mm}$$



hence providing a local thickness of 180mm with an effective cover of 30mm

Step 4:- area of steel required for BM.

$$A_{\text{st req}} = \frac{M}{\gamma \cdot E}$$

$$= \frac{0.2 \times 6 \times 10^6}{130 \times 0.86 \times 150} = 134.8 \text{ mm}^2$$

Using 16mm dia bars,

$$\text{Spanning} = \frac{801 \times 1000}{134.8} = 144 \text{ mm}$$

Hence providing 16mm dia bars @ 144mm C/c on inner face.

$$\text{Development length, } L_d = \frac{\phi \cdot 0.8t}{47hd} = \frac{16 \times 180}{4 \times 144}$$

$$L_d = 361 = 0.86 < 1.6 \text{ m} \quad \text{Hence ok}$$

Step 5:- Area of steel required for hoop tension

$$T = 83.5 \text{ kN}$$

$$\text{Area of steel required} = \frac{T}{0.8t} = \frac{83.5 \times 1000}{130}$$

$$A_{st} = 643 \text{ mm}^2$$

$$A_{st \min} = 0.35 \% \times \text{net area}$$

$$= \frac{0.35}{100} \times (1000 \times \frac{180}{2}) = 915 \text{ mm}^2 < 643 \text{ mm}^2$$

Providing 16mm dia hoops @ 100mm C/c up to a height of 3m from the base.

$$\begin{aligned} \text{Hoop tension at 3m from the base} &= \pi(5.3) \times D/2 \\ &= 9.8 \times 2 \times \frac{5.1}{2} \\ &= 49.98 \text{ kN} \end{aligned}$$

$$A_{st} = \frac{49.98 \times 1000}{130} = \underline{\underline{385 \text{ mm}^2}} > 315 \text{ mm}^2$$

Step 7:- check for tensile stresses in concrete

$$\sigma_{ct} = \frac{T}{1000 \cdot 9 + (m-1) A_{st}}$$

$$= \frac{83.5 \times 1000}{1000 \times 180 + (11-1) \cdot 385} = \underline{\underline{0.14 \text{ N/mm}^2}} < 1.3 \text{ N/mm}^2$$

Hence O.K.

Step 7:- Distribution steel

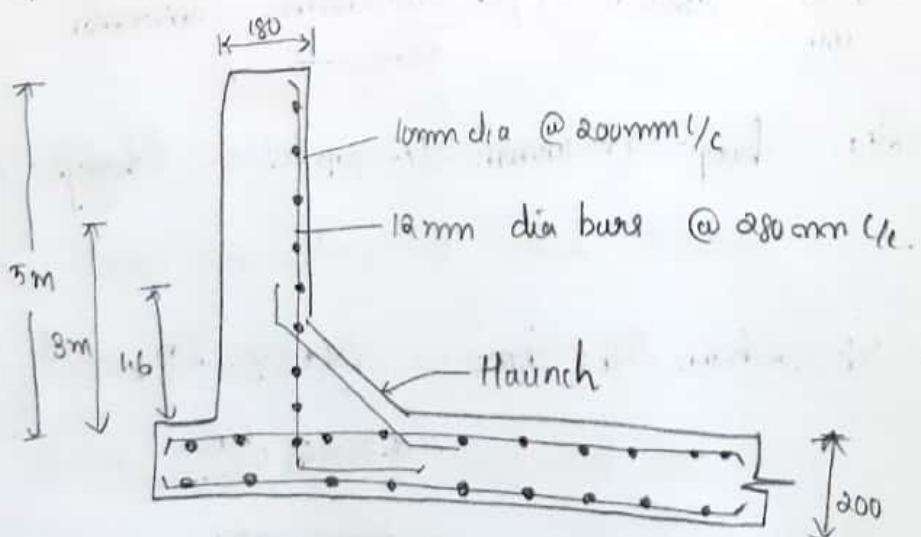
$$A_{st,min} = 315 \text{ mm}^2$$

No additional steel is required because vertical steel provides
For cantilever action will act as distribution reinforcement.

Step 8:- Design of Base slab

As the tank is resting on the ground, a thickness of 200mm base slab is provided along with minimum steel, i.e. 8mm dia @ 250mm c/c in both directions at top

& bottom face.



Design the wall of a circular tank 7m dia and 4m high
 The tank is fixed at the base and resting on the ground
 Sketch the details.

Solution

Given data

using M30 concrete and Fe 415 steel

$$\sigma_{cbc} = 10 \text{ N/mm}^2$$

$$\sigma_{bt} = 8 \text{ N/mm}^2$$

$$\sigma_{ct} = 1.15 \text{ N/mm}^2$$

$$\sigma_{st} = 130 \text{ N/mm}^2$$

Design constants

$$m = \frac{280}{3 \sigma_{cbc}} = \frac{280}{3 \times 10}$$

$$m = 9.33$$

$$n = \frac{m \cdot \sigma_{cbc}}{\sigma_{cbc} + \sigma_{st}} = \frac{9.33 \times 10}{9.33 \times 10 + 130}$$

$$K = 0.416$$

$$j = 1 - \frac{0.416}{3} = 0.86$$

$$R = Y_2 \cdot \sigma_{cbc} \cdot j = Y_2 \times 10 \times 0.416 \times 0.86$$

$$R = \underline{\underline{1.78}}$$

Assuming the wall to be 200 mm thick.

$$b = 200\text{mm}$$

$$H = 4.0\text{m}$$

$$D = 7\text{m}$$

$$\frac{H^2}{Dt} = \frac{4^2}{7 \times 0.2} = 11.4$$

Maximum moment coefficient at the bottom of wall.

$$= \left[0.0104 + \frac{(0.0122 - 0.0104)}{2.0} \times 1.4 \right] = \underline{\underline{-0.0117}}$$

Maximum -ve moment at the bottom of the wall

$$= -0.0117 \times VH^3$$

$$= -0.0117 \times 10 \times 4.0^3$$

$$M = \underline{\underline{7.5 \text{ kNm}}}$$

Step 2:- Thickness required (q)

$$t = \sqrt{\frac{M}{R \cdot b}} = \sqrt{\frac{7.5 \times 10^6}{1.78 \times 1000}}$$

$$q = \underline{\underline{65\text{mm}}}$$

Assuming an effective cover of 50mm,

$$q_{\text{req}} = 65 + 50 = \underline{\underline{115\text{mm}}} > 200\text{mm}$$

Step 3:- Maximum hoop Tension (T)

Maximum hoop tension occurs at $0.6H = 2.4\text{m}$

$$\frac{H^2}{Dt} = 11.4$$

$$\text{Hoop tension coefficient} = 0.608 + \left(\frac{0.628 - 0.608}{2} \right) \times 1.4 \\ = \underline{\underline{0.622}}$$

$$\text{Muai hoop tension} = (\text{Hoop tension coefficient}) \times V H D_h \\ = 0.622 \times 10 \times 4 \times \frac{1}{2} \\ T = 87.08 \text{ KN}$$

$$\text{Area of steel required} = \frac{T}{\sigma_{st}} = \frac{87.08 \times 1000}{130} = 67 \text{ mm}^2$$

$A_{st-min} = 0.35\% \text{ of area of surface zone}$

$b < 300 \text{ mm}$

$$A_{st-min} = \frac{0.35}{100} (1000 \times \frac{200}{2}) \\ = 350 \text{ mm}^2 < \underline{\underline{67 \text{ mm}^2}}$$

using 10mm dia hoops and providing reinforcement on both faces.

$$\text{spacing required} = \frac{78.5 \times 1000}{\frac{670}{2}} = \underline{\underline{230 \text{ mm}}}$$

1.6 Therefore providing 10mm diameter hoops @ 200 mm / c up to a height of $0.3 H$ from top as above this half of the basis can be contained as the hoop tension becomes almost half of maximum value.

$$A_{st} \text{ provided} = 2 \times 39.2 = 78.5$$

$$\sigma_{ct} = \frac{T}{1000 t + (m-1) s_{st}}$$

$$= \frac{87.08 \times 10^3}{1000 \times 200 + (4.83-1)785} = 0.42 \text{ N/mm}^2 < \sigma_{ct} \text{ Hence OK}$$

Ans:- Design for moment

Max -ve moment is 7.5 kNm occurs at the base of the wall

$$s_{st} = \frac{M}{\sigma_{st} J_d} = \frac{7.5 \times 10^6}{130 \times 0.86 \times 150} \quad [d = 200 - 50 = 150 \text{ mm}]$$

$$s_{st \text{ reqd}} = \underline{418 \text{ mm}^2} > 350 \text{ mm}^2$$

Using 8mm dia bars @ 100mm Cc on the inner face as vertical steel at the bottom of the wall. These are required for a height of 1m above the bottom only.

$$l_d = \frac{\phi_{st}}{A T_{bd}} = \frac{8 \times 180}{4 \times 1.6} = \underline{163 \text{ mm}}$$

Hence curving half of the bars and continuing other half till top. The moment is, causing tension on the outer face is maximum at 0.7H i.e. 2.8m from the wall.

$$M = 0.0042 \times 10 \times 4.0^3$$

$$M = \underline{2.7 \text{ kNm}}$$

Hence providing minimum steel @ 0.35%

$$s_{st} = 350 \text{ mm}^2$$

8mm dia bars @ 140 mm c/c on the outer face as vertical steel.

Q5:- Base slab :-

Base slab is provided as column thick with minimum steel as 850mm^2 in each direction. Hence, providing 8mm dia bars @ 140mm c/c in both directions at top and bottom face.

- Q. Design a circular water tank with fixed base, resting on the ground, for a capacity of 500kl. The depth of water in tank is 5m and a free board of 200mm is to be provided. Use M₂₀ concrete and Fe415 steel.

Solution:-

Given data

$$\text{Capacity of tank} = 500000\text{L} = 500\text{m}^3$$

$$\text{Depth of water} = 5\text{m}$$

$$\text{Free board} = 200\text{mm}$$

For M₂₀ concrete

$$\sigma_{cbc} = 10 \text{ N/mm}^2$$

$$\sigma_{ct} = 1.5 \text{ N/mm}^2$$

$$\sigma_{bt} = 2 \text{ N/mm}^2$$

$$\sigma_{st} = 130 \text{ N/mm}^2$$

$$H = 5 + 0.2 = \underline{5.2 \text{ m}}$$

Step 2:- Design Constants

$$m = \frac{0.80}{3\sigma_{chc}} \quad \alpha = \frac{0.80}{3 \times 10} = 0.033$$

$$K = 0.416$$

$$\beta = 0.86$$

$$R = 1.78$$

Step 3:- Diameter of tank (D)

$$\left(\frac{\pi}{4} \cdot D^2\right) \times 5 = 500$$

$$D = 11.28 \text{ m}$$

$$D = 11.3 \text{ m}$$

Hence taking \nearrow

Assuming thickness of wall as 150mm

$$\frac{H^2}{Dt} = \frac{5.2^2}{11.3 \times 0.15} = 15.45 \approx 16 \text{ m}$$

Step 4:- Design values

1) Max BM coefficient from Table 10 - for $\frac{H^2}{Dt} = 16 = 0.0079$
at bottom of wall.

2) Max SF coefficient from Table 11 = 0.127

3) Max hoop tension coefficient = 0.687 at 0.74 or 3.64 m from
top

$$\text{Design BM } M = -0.00797H^3$$

$$= -0.0079 \times 10 \times 10^3$$

$$M = 9.875 \text{ kNm}$$

$$\text{Design SF} = +0.187\sqrt{H^2} = 0.187 \times 10 \times 5^2$$

= 31.75 kN per m height of wall

$$\text{Design hoop tension} = 0.687\sqrt{H} D/2 = 0.687 \times 10 \times 5 \times \frac{11.3}{2}$$

$$\underline{\underline{= 194.08 \text{ kN}}}$$

At $0.8H$ or $0.3 \times 5 = 1.5 \text{ m}$ hoop tension is $0.804 \times 10 \times 5 \times \frac{11.3}{2}$
which is \approx half of the max hoop tension value.

Step 5:- Depth / thickness required

$$d_{req} = \sqrt{\frac{M}{R.b}} = \sqrt{\frac{9.875 \times 10^6}{1.78 \times 1000}}$$

$$d_{req} = 15 \text{ mm}$$

Total thickness provided = 150 mm

$$d_{provided} = 150 - 30 = 120 \text{ mm}$$

Step 6:- area of steel for BM

$$A_{st} = \frac{M}{0.87j'd} = \frac{9.875 \times 10^6}{150 \times 0.86 \times 120}$$

$$\underline{\underline{A_{st} = 737 \text{ mm}^2}}$$

Using 18mm dia bars

$$\text{Spacing required} = \frac{113 \times 1000}{737} \\ = 153 \text{ mm}$$

Hence providing 18mm dia bars @ 150mm c/c at inner face in vertical direction curving half of the bars at 1m from ground and continuing the rest to 18mm dia @ 300mm c/c till top.

Step 2:- Area of steel per hoop tension

$$T = 194.08 \text{ kN}$$

$$A_{st} = \frac{T}{\sigma_{st}} = \frac{194.08 \times 10^3}{130} = \underline{\underline{1493 \text{ mm}^2}}$$

Using 20mm dia bars.

$$\text{Spacing} = \frac{314 \times 1000}{1499} = \underline{\underline{216 \text{ mm}}}$$

Hence using 20mm dia bars @ 200mm c/c from base up to a height of 9.5m from base or providing 20mm dia hoops @ 400 mm c/c in top 15m position.

check Bar permissible direct tensile stress in concrete.

$$\sigma'_{ct} = \frac{T}{1000t + (m-1) A_{st}}$$

$$\sigma'_{ct} = \frac{194.08 \times 10^3}{1000 \times 150 + (9.33 - 1) 1570}$$

$$\sigma'_{ct} = 1.14 \text{ N/mm}^2 < 1.5 \text{ N/mm}^2$$

Vertical Reinforcement

Min. vertical reinforcement is provided @ 0.35% of Surface Area.

$$\text{Ast min} = \frac{0.35}{100} \times \left(1000 \times \frac{150}{\alpha} \right)$$

$$= \underline{863 \text{ mm}^2}$$

Steel provided for cantilever action is 10mm bars @ 30mm. γ_c is $376 \text{ mm}^3 > 863 \text{ mm}^2$ will also act as distribution steel.

Check For Shear

Maximum SF = 31.75 kN

$$\tau_v = \frac{V}{bd} = \frac{31.75 \times 10^3}{1000 \times 120}$$

$$\tau_v = \underline{0.26 \text{ N/mm}^2}$$

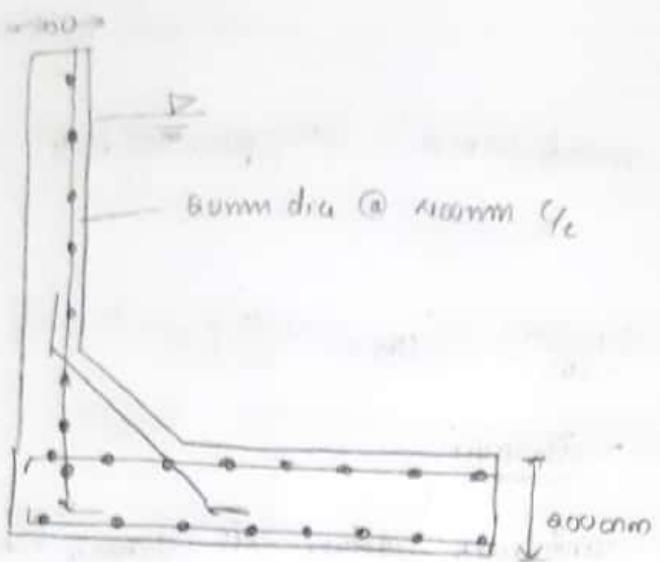
$$\text{Ast provided} = \frac{11900}{150} = \underline{793 \text{ mm}^2}$$

$$p_f = \frac{793 \times 100}{1000 \times 120} = 0.6\%$$

$$\tau_c = 0.3a \text{ N/mm}^2$$

$$\underline{\tau_c > \tau_v}$$

Detailing



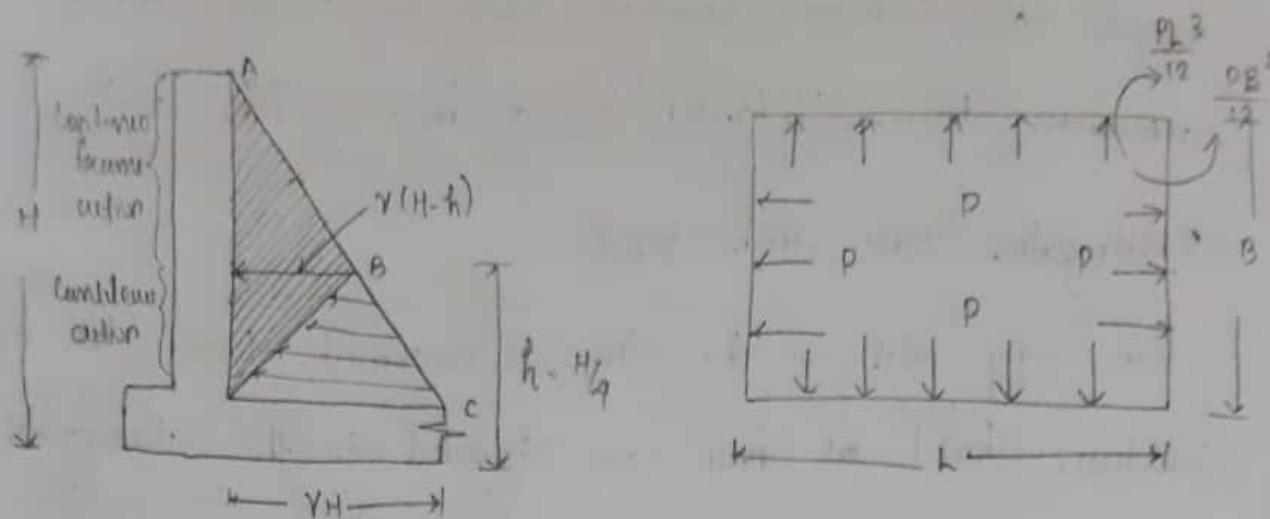
Design of rectangular water tanks

Rectangular tanks are used for small capacities. These tanks are basically divided into two categories for the purpose of design.

- Tanks with L/B ratio less than 2
- Tanks with $L/B > 2$

Design of Rectangular Tanks (with $L/B \leq 2$)

For such tanks, the tank walls are assumed to act as a continuous frame subjected to a triangular load. This frame action starts from $H/4$ or 1m distance from base making the wall to bend in horizontal plane, the wall is assumed to act like a cantilever in the bottom portion with bending in vertical plane, subjected to a load varying from 0 to VH .



For horizontal bending i.e. passive action, walls are designed for the maximum moment with pressure intensity P .

$$P = \gamma(H-h)$$

In the absence of moment distribution analysis, the BM in wall may be taken as for short wall,

$$M_{\text{center}} = +\frac{PB^2}{16}$$

$$M_{\text{corners}} = -\frac{PB^2}{12}$$

For long wall

$$+\frac{PL^2}{16} \text{ at centre}$$

$$-\frac{PL^2}{12} \text{ at corners.}$$

Similarly hoop tension on long walls $= \gamma(H-h) B/2$

In short walls $= \gamma(H-h) L/2$

The bottom position of the wall up to height $h/2$ is

designed as cantilever just like that of circular tank with maximum $B.M = \frac{1}{2}(\gamma \cdot H)h \cdot \frac{h}{3}$ at base of the wall.

4) Rectangular Tank with $h/B > 2$

- The long wall of the tank is assumed to act like a cantilever fixed at base as subjected to the triangular loading. $M = \frac{\gamma H^3}{6}$



H

$$M_{max} \text{ at base} = \frac{1}{2}(\gamma H) \cdot H \cdot \frac{H}{3}$$

The long wall is also subjected to direct tension or hoop

$$T = \gamma(H-h) \cdot \frac{B}{2}$$

- The short wall of the tank will act as cantilever up to a height h [$H/4$ or $1m$] from the base and the upper part from h to top of the wall will act like a continuous frame supported on the long walls.

$$M_{max} \text{ in cantilever position} = \frac{1}{2}(\gamma H) \cdot h \cdot \frac{h}{3}$$

Due to small volume action the max moment at centre of span

$$= \frac{V(H-h)B^2}{16}$$

The max moment at ends = $\frac{-V(H-h)B^2}{16}$

- Q. Design a rectangular tank of size $6m \times 5m \times 4m$, resting on ground, using approximate method of design. Use M25 concrete & Fe415 steel.

Solution

Step 1:- given data

size of tank = $6m \times 5m \times 4m$

$$\sigma_{cbc} = 8.5 \text{ N/mm}^2$$

$$\sigma_{ct} = 1.3 \text{ N/mm}^2$$

$$\sigma_{st} = 130 \text{ N/mm}^2$$

Q2:- Design constants:

$$m = \frac{\alpha_{80}}{\sigma_{cbc} \times 3} = \frac{\alpha_{80}}{8.5 \times 8.5} = \underline{\underline{11}}$$

$$K = \frac{m \cdot \sigma_{cbc}}{m \cdot \sigma_{cbc} + \sigma_{st}} = \frac{11 \times 8.5}{11 \times 8.5 + 130} = \underline{\underline{0.419}}$$

$$j = 1 - \frac{k}{3} = 1 - \frac{0.419}{3}$$

$$j = 0.86$$

$$R = \frac{1}{12} \times 8.5 \times 0.419 \times 0.86 = \underline{\underline{1.53}}$$

$$h/B = 6/5 = \underline{\underline{1.2 \angle 9}}$$

In this type of tank both long and short walls will act like a cantilever for a length of $H_{1/4} = 1m$ and for the rest of the length continuous frame action is there.

$$H_{1/4} = H/4 = 1m$$

$$\underline{h = 1m}$$

$$\therefore \text{pressure at } h = \gamma(H-h) = 10(4-h) = \underline{\underline{90 \text{ kN/m}^2}}$$

Steps:- Continuous frame action

$$P = 30 \text{ kN/m}^2$$

Fixed end moments due to this pressure

$$= -\frac{Ph^2}{12} \quad \text{or} \quad -\frac{PB^2}{12}$$

$$\text{along short wall} = \frac{PB^2}{12} = \frac{30 \times 5^2}{12} = \underline{\underline{62.5 \text{ kNm}}}$$

$$\text{along long wall} = \frac{PL^2}{12} = \frac{30 \times 6^2}{12} = \underline{\underline{90 \text{ kNm}}}$$

These moments are to be distributed in proportion of the stiffness of the walls using moment distributed method.

$$\text{Stiffness of short wall} = \frac{4EI}{5} = 0.8EI$$

$$\text{" " long wall} = \frac{4EI}{6} = 0.666EI$$

$$\therefore \text{Total Stiffness} = (0.8 + 0.666) EI = \underline{\underline{1.466EI}}$$

$$\text{Distribution factor for short wall} = \frac{0.849}{1.1662} = 0.548$$

$$\text{Distribution factor for long wall} = \frac{0.6669}{1.1662} = 0.562$$

short wall	long wall
$DF = 0.548$	$DF = 0.562$
-62.5	90
$(0.548 \times (90 - 62.5))$	$(0.548 \times (90 - 62.5))$
$= -12.43$	$= \underline{-15.0}$
-75	+7.5

∴ Design moment at the corner of the walls = 75 kNm

$$\text{Effective depth required} = \sqrt{\frac{M}{R.b}} = \sqrt{\frac{75 \times 10^6}{f_{y3} \times 1000}}$$

$$= \underline{222 \text{ mm}}$$

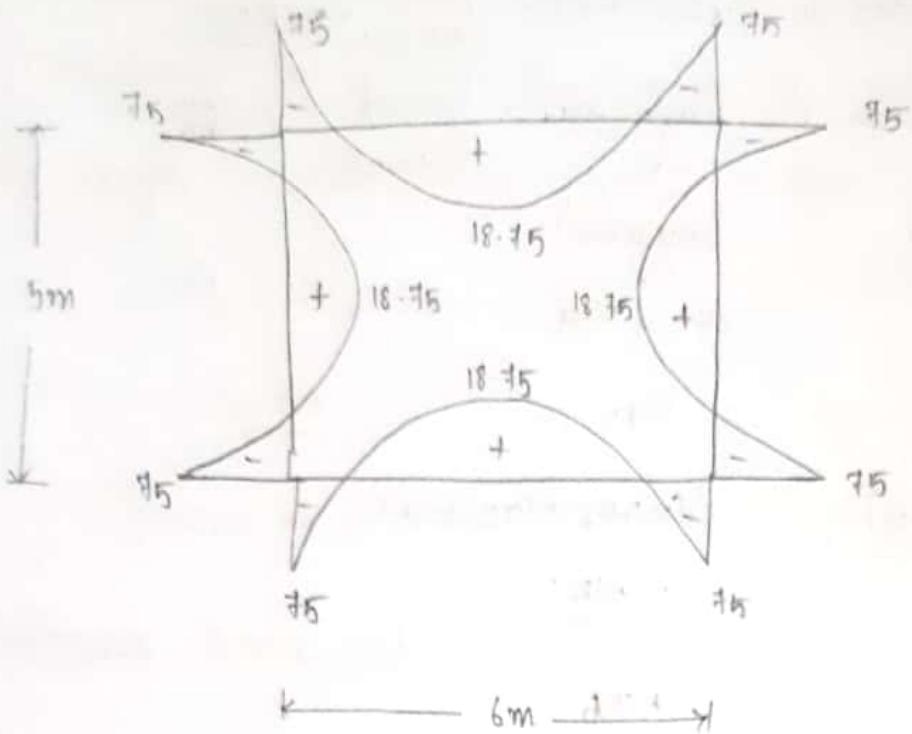
Hence adopting a total depth of 300mm and 40mm effective cover,

$$d = 300 - 40 = 260 \text{ mm.}$$

$$\text{BM at centre of long wall} = \frac{Ph^2}{8} - \text{end moment}$$

$$= \frac{30 \times 5^2}{8} - 75$$

$$= \underline{18.75 \text{ kNm}}$$



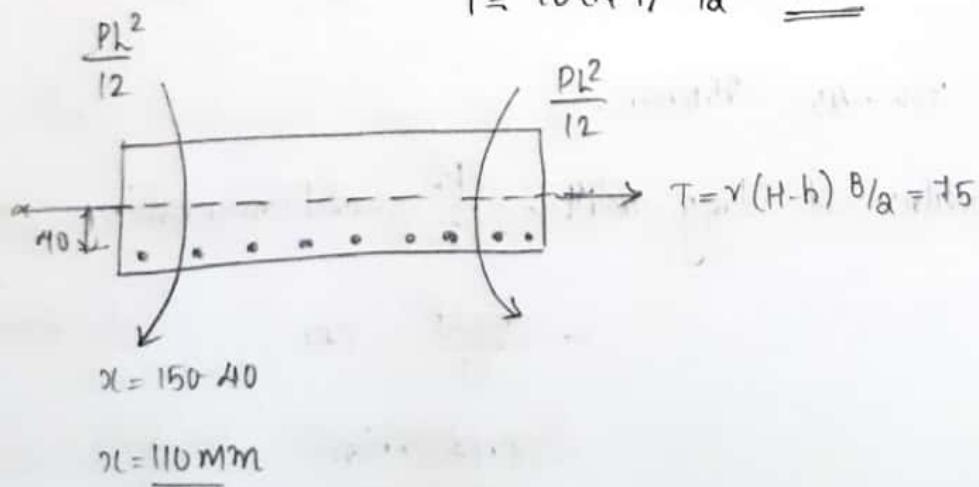
Ques:- Design of long wall.

-ve moments at corners = 75 kNm

+ve " at mid span = 60 kNm

Pinned tension in long wall = $\gamma(H-h) B/2$

$$T = 10(4-1)^{5/2} = \underline{\underline{75 \text{ kN}}}$$



Design moment at corner of the long wall

$$M_d = M(-ve) - Txr. = 75 - 75 \times \frac{110}{1000} = 66.75 \text{ kNm}$$

Area of steel required for design moment (Ast)

$$A_{st_1} = \frac{M_{el}}{\sigma_{st} j d} = \frac{66.75 \times 10^6}{130 \times 0.87 \times 260} = \underline{\underline{2270 \text{ mm}^2}}$$

Area of steel required for direct tension (Ast₂)

$$A_{st_2} = \frac{T}{\sigma_{st}} = \frac{75 \times 10^3}{130}$$

$$A_{st_2} = \underline{\underline{577 \text{ mm}^2}}$$

Total area of steel required = Ast

$$= A_{st_1} + A_{st_2} = 2270 + 577 = \underline{\underline{2847 \text{ mm}^2}}$$

Choosing column dia bars, $A_\phi = 314 \text{ mm}^2$

$$\text{Spacing required} = \frac{314 \times 1000}{2847} = \underline{\underline{107.71}} \approx 110 \text{ mm}$$

Hence provide column dia bars @ 110 mm C/c at supports on inner face and curving half of the bars from ab a distance of 1.0 m from support.

$$\text{Design B.M. at mid span} = M - T \cdot x = 60 - \frac{75 \times 110}{1000}$$

Area of steel required for design moment = $\underline{\underline{51.75 \text{ kNm}}}$

moment = $\sigma_{st} \cdot I$

$$\sigma_{st} = 180 \text{ N/mm}^2$$

$$A_{st_1} = \frac{51.75 \times 10^6}{130 \times 0.87 \times 260} = \underline{\underline{1760 \text{ mm}^2}}$$

$$\text{Area of steel required at mid span} = 1760 + 5 \text{ ft}^2 \\ = 2337 \text{ mm}^2$$

Provide 8mm dia bars at 130mm c/c at mid span.

Step 5:- Design for cantilever action

$$\text{Moment at base} = (Y_2 Y_{H-h}) \frac{h}{3} \\ = \frac{1}{2} \times 10 \times 4 \times 1 \times Y_3 = 6.67 \text{ kNm}$$

Area of vertical steel required

$$= \frac{6.67 \times 10^6}{130 \times 0.87 \times 240} = 246 \text{ mm}^2$$

Min. steel = 0.35% of x-sectional area

$$= \frac{0.35 \times 1000 \times 150}{100} = 525 > 246 \text{ mm}^2$$

Providing 10 mm dia bars @ 140mm c/c on both faces of wall

Step 6:- Design of short wall

Moment at the corner of short wall = 75 kNm

Moment at the centre of short wall = $\nu(H-h) \cdot \frac{h}{2}$

$$= 10(14-7) \cdot \frac{6}{2}$$

$$= 90 \text{ kN}$$

Design moment at corner of the short wall = $M - T \alpha r$

$$= 75 - \frac{90 \times 110}{2} = 65.1 \text{ kNm}$$

$$\text{Design moment at mid span of the short wall} = M - T \cdot x \\ = 18.75 - \frac{90 \times 110}{1000} = 8.85 \text{ kNm}$$

Area of steel required at the corner of the short wall

$$= \frac{65.1 \times 10^6}{130 \times 0.87 \times 260} = \underline{\underline{2214 \text{ mm}^2}}$$

$$\text{Area of steel required for direct tension} = \frac{90 \times 10^3}{130}$$

$$\underline{\underline{A_{st2} = 649 \text{ mm}^2}}$$

$$\text{Total area of steel} = A_{st1} + A_{st2}$$

$$= 2214 + 649 = \underline{\underline{2863 \text{ mm}^2}}$$

Hence providing 20mm dia bars @ 100mm 1/c ab supports
on inner face.

$$\text{Area of steel required at the mid span} = \frac{8.85 \times 10^6}{130 \times 0.87 \times 260} \\ = 301 \text{ mm}^2$$

$$\text{Area of steel required for direct tension} = \frac{90 \times 10^3}{130} \\ = 693 \text{ mm}^2$$

$$\text{Total steel required} = 301 + 693 \\ = 994 \text{ mm}^2 < A_{st \min}$$

Hence providing 12mm bars @ 100mm 1/c ab outer face.

Step 7:- Base slab

The tank is resting on the ground providing minimum thickness of 150mm of slab over a lean concrete base. The area of steel may be provided as 8mm dia bars @ 180mm c/c.

Ans :- Detailing

