UNIT - III

DESIGN OF WATER TANKS - I

* To meet daily requirements of water by industries, localities, towns and cities, various types of water tanks are used.
* Such tanks are generally classified as
  - (i) Tanks resting on ground
  - (ii) under ground tanks
  - (iii) Elevated tanks
* The tanks may be circular (or) rectangular sections.
* Apart from strength requirement another essential requirement in the design of water tank is imperviousness.
* To make water tanks impervious, wider cracks should be avoided in the concrete which may be achieved by using
  - (i) Richer concrete mix say M_{25} (or) M_{30}
  - (ii) A minimum clear cover of 25mm
  - (iii) provide smaller diameter bars at closer intervals
  - (iv) Keep the tensile stresses in concrete is low.
  - (v) To follow good construction practices like thorough mixing, good compaction and good curing.

Design requirements :-

* IS : 3370 is the Indian Code of Practice for Concrete structures for the storage of liquids.
* The Code is available in following four parts.
  (i) Part - I - General requirements
  (ii) Part - II - Reinforced Concrete structures
  (iii) Part - III - Pre stressed Concrete structures
  (iv) Part - IV - Design tables
* To avoid leakage problems, limit state method of design should not be used for design of water tanks.

Permissible stresses in Concrete :- (IS 3370, Table 1, Pg 7)

Grade of Concrete	Permissible stresses in tension (N/mm²)		Permissible stresses in shear (N/mm²)
	Direct	Bending	
M_{20}	1.2	1.7	1.7
M_{25}	1.3	1.8	1.9
M_{30}	1.5	2.0	2.2
M_{35}	1.6	2.2	2.5
M_{40}	1.7	2.4	2.7

Permissible stresses in steel :- (IS 3370, Table 2, Pg 8)

Type of stress	Permissible stress (N/mm^2)	
	Mild steel	HYSD
1. Direct tensile stress	115	150
2. Tensile stress in bending		
(a) on liquid retaining face	115	150
(b) on face away from liquid (if t< 225)	115	150
(c) on face away from liquid (if t≥ 225)	125	190
3. Compressive stress in columns subjected to direct load	125	175

Minimum Reinforcement :- (IS : 3370, cl 7.1, Pg 13)

* For thickness upto 100mm, Minimum percentage of reinforcement should be 0.3.

* For thicknesses from 100 mm to 450mm, it may be reduced linearly upto 0.2%.

* If the thickness of section is more than 225 mm, layers of bars are required in both faces, However it is enough if total steel meets minimum reinforcement.

Design of circular tanks resting on ground:-

* circular tanks have flexible base (or) rigid base. In case of flexible joints the wall is free to move out ward when internal water pressure is applied and hence the wall is subjected to hoop forces (T)

$$T = \gamma \times H \times D/2$$

where, γ = unit weight of water

H = Height of water tank

D = Diameter of water tank

Free board:-

* In all water tanks, a free board of about 200 mm is to be given.
* However ~~for~~ the design depth of water is taken as the total depth since a stagnate water upto the full height may be stored.

Working Stress Method :-

Modular Ratio, $m = \dfrac{280}{3\,\sigma_{cbc}}$

Constant, $K = \dfrac{m\,\sigma_{cbc}}{m\,\sigma_{cbc} + \sigma_{st}}$: Neutral axis factor

Lever arm factor, $J = 1 - K/3$

Balancing moment, $M = Q b d^2$ - Balanced

where $Q = \frac{1}{2} K \sigma_{cbc} J$

$M = \sigma_{st} \times A_{st} \times (d - n_a/3)$ - under

$M = \dfrac{\sigma_{cbc}}{2} \times b \times n_a \times (d - \frac{n_a}{3})$ - over

for M_{15} grade Concrete, $\sigma_{cbc} = 5\ N/mm^2$

for M_{20} " ", $\sigma_{cbc} = 7\ N/mm^2$

for M_{25} " ", $\sigma_{cbc} = 8.5\ N/mm^2$

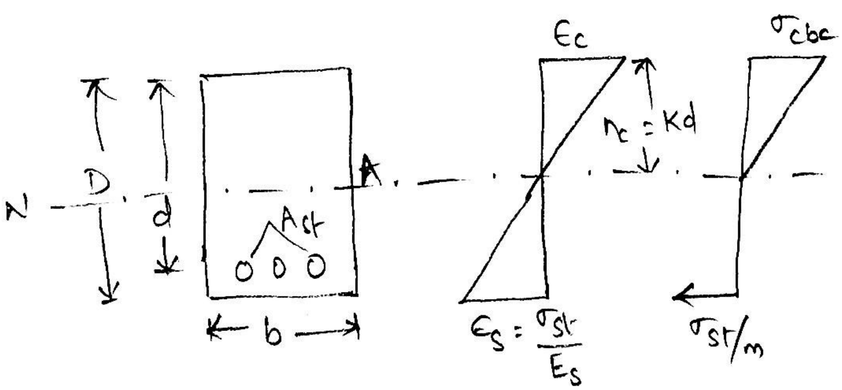
for M_{30} " ", $\sigma_{cbc} = 10\ N/mm^2$

for Fe 250 grade steel, $\sigma_{st} = 140\ N/mm^2$

for Fe 415 " ", $\sigma_{st} = 230\ N/mm^2$

For design of liquid retaining structures we dont use these values

(IS:3370-1965 values are used)



Actual neutral axis (n_a)

$$\frac{b n_a^2}{2} = m A_{st} * (d - n_a)$$

If $n_a < n_c$ - Under

If $n_a > n_c$ - Over

If $n_a = n_c$ - Balanced.

1) Design a circular water tank with flexible base resting on ground to store 50,000 litres of water. The depth of water tank may be kept 4 m. Use M_{25} grade Concrete and Fe 415 steel.

Sol:- Given data :-

Capacity of tank = 50,000 lt = $50 m^3$

Depth of tank = 4m

volume = $\pi/4 \, D^2 H \Rightarrow \pi/4 \times D^2 \times 4 = 50$

$\Rightarrow D = 3.98$ m

Provide 4m dia, Take free board = 200 mm = 0.2m

Total height of tank = 4 + 0.2 = 4.2m

Unit weight of water, $\gamma = 9.81 \, KN/m^3$

Permissible tensile stress in Concrete (M_{25}) = $1.3 \, N/mm^2$

Permissible tensile stress in Fe 415 steel = $150 \, N/mm^2$

Maximum hoop tension (T) = $\frac{1}{2} \times \gamma \times H \times D$

$= \frac{1}{2} \times 9.81 \times 4.2 \times 4$

$= 82.32 \, KN/m$ at base.

Area of steel in hoop tension, $A_{SH} = \frac{82.32 \times 1000}{150}$

$= 548.8 \, mm^2$

Using 12 mm dia bars, spacing $S = \frac{\pi/4 \times 12^2}{548.8} \times 1000 = 206.1$ mm

Provide 12 mm dia bars @ 200 mm c/c

$A_{SH_{Prov}} = \pi/4 \times 12^2 \times \frac{1000}{200} = 565.56 \, mm^2/m$ height.

Increase the spacing to 300 mm at a height of 1.5m from base.

Thickness of wall :-

Maximum hoop tension $(T) = 82.32$ KN/m length

Modular ratio, $m = \frac{280}{3\sigma_{cbc}} = \frac{280}{3 \times 8.5} = 10.98 \approx 11$

$(\because \sigma_{cbc}$ of M_{25} Concrete $= 8.5\ N/mm^2)$

If 't' is the thickness of wall, equivalent area of Concrete per meter height $= 1000\,t + (m-1)\,A_{SH}$

$$\sigma_c = \frac{T}{1000\,t + (m-1)\,A_{SH}}$$

$$1.3 = \frac{82.32 \times 1000}{1000\,t + (11-1) \times 565.5}$$

$$1300t + 7352.28 = 82.32 \times 10^3$$

$$\Rightarrow t = 57.66\ mm$$

Provide thickness of wall = 100mm

Vertical steel :-

$Ast_{min} = 0.3\%$ gross c/s area

$= \frac{0.3}{100} \times 1000 \times 100 = 300\ mm^2$

Using 8 mm dia bars, spacing $= \frac{\pi/4 \times 8^2}{300} \times 1000$

$= 167$ mm

Provide 8 mm dia bars @ 150 mm c/c.

Design of base slab :-

A base slab will be laid on a 75 mm lean mix bed covered with tarfelt, since the load gets transfered to ground directly,

(tarfelt ↓ for water proofing)

a nominal thickness of 150 mm may be provided with minimum reinforcement in both directions.

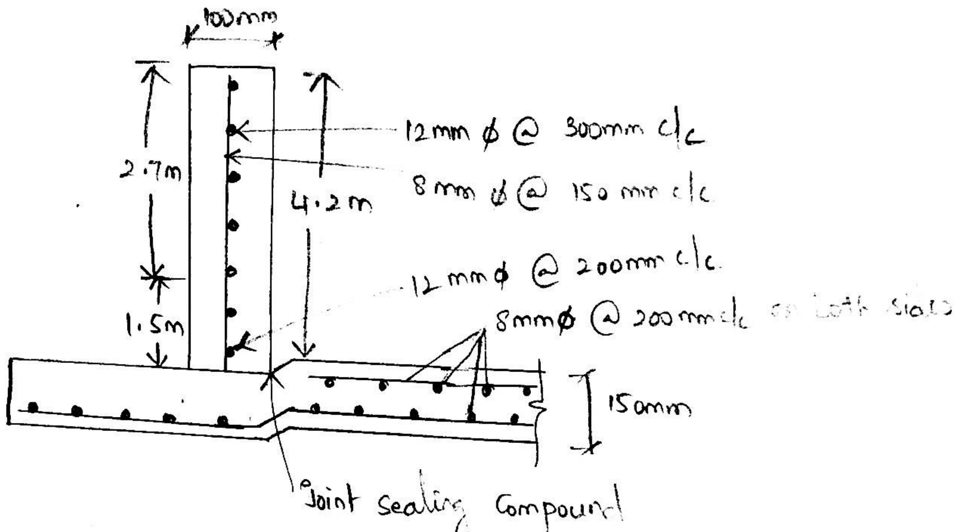
$$A_{st\,min} = 0.3\%\ \text{gross c/s area}$$

$$= \frac{0.3}{100} \times 1000 \times 150 = 450\,mm^2$$

Providing Half the reinforcement near each face, $A_{st} = 225\,mm^2$

Using 8 mm dia bars, spacing $= \frac{\pi/4 \times 8^2}{225} \times 1000 = 223\,mm$

Provide 8 mm dia bars @ 220mm c/c. on both faces in both directions.



Reinforcement Details

2) Design a circular water tank with rigid base resting on the ground to store 50,000 lts water. The depth of tank may be kept 4m. use M_{25} grade concrete and Fe_{415} grade steel.

Sol:- Design Constants :-

$$\text{Modular ratio, } m = \frac{280}{3\sigma_{cbc}} = \frac{280}{3 \times 8.5} = 10.98$$

$$K = \frac{m\sigma_{cbc}}{m\sigma_{cbc} + \sigma_{st}} = \frac{10.98 \times 8.5}{10.98 \times 8.5 + 150} = 0.38$$

$$J = 1 - K/3 = 1 - \frac{0.38}{3} = 0.87$$

$Q = \frac{1}{2} \times K \times \sigma_{cbc} \times J$

$= \frac{1}{2} \times 0.38 \times 8.5 \times 0.87 = 1.41$

Design of cantilever action:-

The height 'h' above base upto which cantilever action exists is given by $h = H/3 = 4.2/3$ (or) 1m which ever is more.

$= 1.4m$

Total height (H) of water tank with free board of 0.2m

$H = 4 + 0.2 = 4.2m$

Cantilever moment $= \frac{1}{2} \times \gamma \times H \times h \times h/3$

$= \frac{1}{2} \times 9.81 \times 4.2 \times 1.4 \times 1.4/3 = 13.46$ KNm

Depth from balanced section, $d = \sqrt{\frac{M}{Qb}}$ $(M = Qbd^2)$

$= \sqrt{\frac{13.46 \times 10^6}{1.41 \times 1000}} = 97.7$ mm

To keep the section sufficiently under reinforced,

Let $d = 4/3 \times 97.7 = 130.27$ mm

Let us keep effective depth $d = 130$ mm and total thickness of 165mm

$A_{st} = \frac{M}{\sigma_{st} J d} = \frac{13.46 \times 10^6}{150 \times 0.87 \times 130} = 793.4 \text{ mm}^2$

Using 10mm dia bars, spacing $s = \frac{\pi/4 \times 10^2}{793.4} \times 1000 = 99$ mm

Provide 10mm dia bars @ 95 mm c/c near inner face keeping clear cover of 30mm.

Let us provide 10 mm dia bars @ 95 mm c/c at base and curtail alternate bars at a height of 1.4m. So that a spacing of 190mm is available in top 2.8 m height.

Design of Section for Hoop action:-

For hoop action, reinforcement is to be provided in horizontal direction. Maximum hoop tension is to be considered at a height of

$h = 1.4m$

Hoop tension is given by $T = \gamma \times (H-h) \times D/2$

$= 9.81 \times (4.2-1.4) \times 4/2$

$= 54.94 \text{ KN/m}$

(Volume of tank $= V = \pi/4 \, D^2 H = 50 \, m^3$

$\Rightarrow \pi/4 \times D^2 \times 4.2 = 50 \Rightarrow D = 4m$)

$$A_{SH} = \frac{T}{\sigma_{st}} = \frac{54.94 \times 10^3}{150} = 366.24 \text{ mm}^2$$

using 10 mm dia bars, spacing $S = \frac{\pi/4 \times 10^2}{366.24} \times 1000$

$= 214 \text{ mm}$

Provide 10 mm dia bars @ 200mm c/c

For bottom 1.4m above base, the spacing of 200 mm may be maintained. In the remaining portion, it may be raised to 300 mm c/c.

Distribution steel :-

$A_{st\,min} = 0.3\%$ gross c/s area

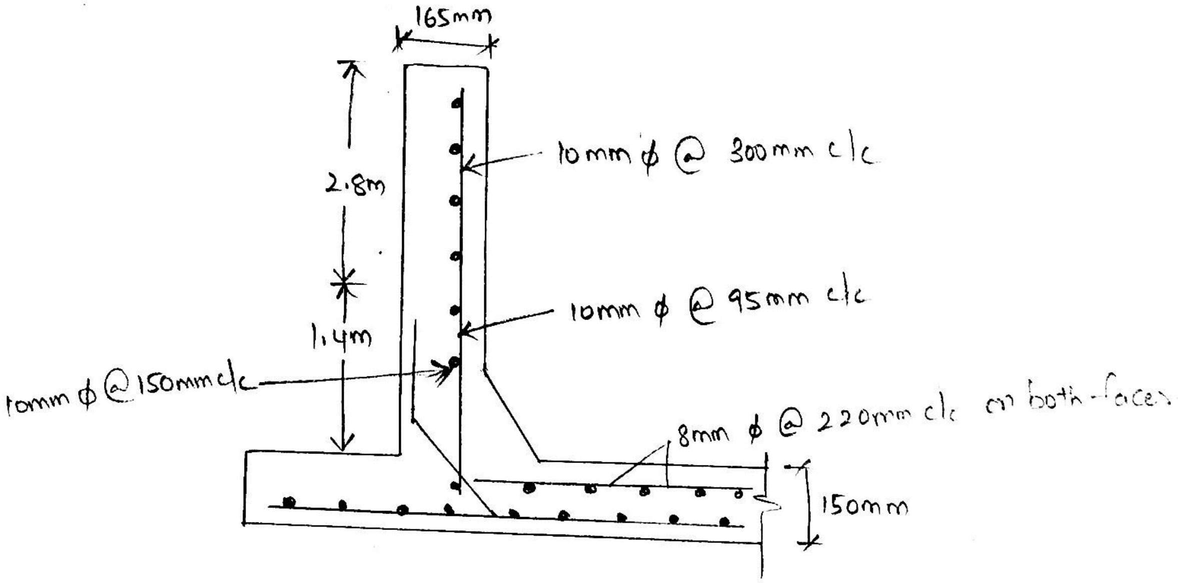
$= \frac{0.3}{100} \times 1000 \times 165 = 495\ mm^2$

using 10mm dia bars, spacing $= \frac{\pi/4 \times 10^2}{495} \times 1000 = 158.68mm$

Provide 10mm dia bars @ 150mm c/c.

Design of base slab :- (similar to pb 1)

Provide a nominal thickness of 150 mm with nominal reinforcement of 8mm dia bars @ 220mm c/c in both directions.



Reinforcement Details

Rectangular tanks resting on ground :-

* Let us consider a rectangular tank of size L × B × H

where, L = length of the tank

B = Breadth of the tank

H = Height of the tank

* In approximate methods, such tanks are divided into two categories.

(i) Tanks with $L/B < 2$

(ii) Tanks with $L/B \geq 2$

(i) Design of tanks with $L/B < 2$:-

* This is similar to the design of circular tanks, here also lower part is assumed to have predominantly cantilever action and upper portion to have resistance by horizontal action.

$$h = H/4 \text{ (or) } 1m \text{, which ever is more.}$$

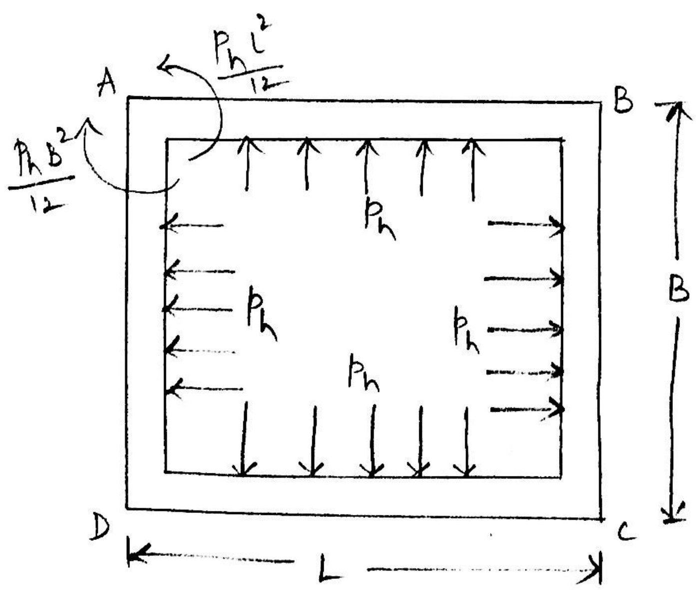


Fig (b)

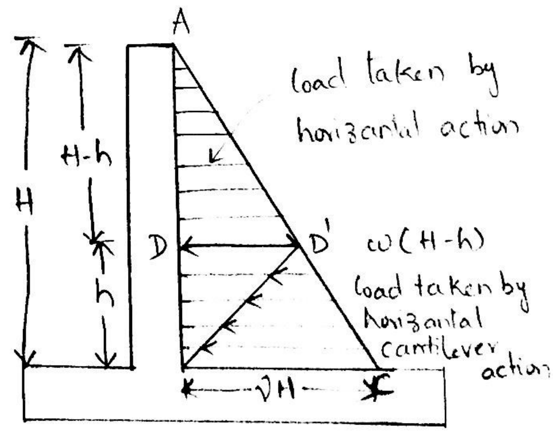


Fig (a)

* Maximum cantilever moment on the wall = $\frac{1}{2} \gamma H h \times h/3$

* For horizantal action, maximum pressure is at (H - h) metres below top. Hence $P_h = \gamma(H-h)$

* The fixed end moments at 'A' are $\frac{P_h B^2}{12}$ and $\frac{P_h L^2}{12}$. Using moment distribution method the moments may be balanced.

$$T_L = \gamma(H-h) \times B/2$$

$$T_B = \gamma(H-h) \times L/2$$

* The effect of horizantal tensile forces is to reduce the net moment in walls to an extent $T \times x$

where 'x' is the distance of tensile reinforcement from the centre of wall. Final Horizantal design moment = $M - Tx$

(ii) Design of tanks with $L/B \geq 2$:-

* In this case long walls behave like cantilevers of height 'H'.
* Thickness of walls may be decided on the basis of cantilever moments in long walls.
* The horizantal steel required in the long wall is to resist direct tension $T_L = \gamma(H-h) \times B/2$

$$T_B = \gamma(H-h) L/2$$

1) Design a rectangular water tank of size 5 m × 4 m × 3 m deep resting on firm ground. Use M_{25} grade concrete and mild steel reinforcement.

Sol: <u>Given data</u> :-

$L = 5m$, $B = 4m$, $H = 3m$

~~$f_{ck} = 25\ N/mm^2$, $f_y = 250\ N/mm^2$~~

Modular ratio, $m = \frac{280}{3\sigma_{cbc}} = \frac{280}{3 \times 8.5} = 10.98$

$K = \frac{m\,\sigma_{cbc}}{m\,\sigma_{cbc} + \sigma_{st}} = \frac{10.98 \times 8.5}{10.98 \times 8.5 + 115} = 0.448$

$J = 1 - K/3 = 0.85$

$Q = \frac{1}{2} K \sigma_{cbc} J = \frac{1}{2} \times 0.448 \times 8.5 \times 0.85 = 1.61$

The ratio $L/B = 5/4 = 1.25 < 2$

∴ Both long walls and short walls resist the load by cantilever action for a height $h = 1m$ and by horizontal action resist the load in that of $H - h = 3 - 1 = 2m$. In such water tanks moment due to horizontal action is considerable and it governs the selection of thickness of walls. Hence horizontal frame action is first considered.

<u>Horizontal frame action</u> :-

The critical section is at a height of $h = H/4$ (or) 1m - which is greater

$h = H/4 = 0.75m$ (or) 1m ⇒ $h = 1m$

Horizontal pressure $P_H = \gamma(H - h) = 9.81(3 - 1) = 19.62\ kN/m^2$

Fixed end moments are $\frac{P_H L^2}{12}$, $\frac{P_H B^2}{12}$

$= \frac{19.62 \times 5^2}{12}$, $\frac{19.62 \times 4^2}{12}$

$= 40.87$ KNm , 26.16 KNm

Since thickness of short and long walls are maintained same, distribution factors at joints are shown below.

member	Stiffness	Total Stiffness	Distribution factor $\left(\frac{S}{\Sigma S}\right)$
long wall	$\frac{4EI}{5} = 0.8EI$	1.8 EI	0.444
short wall	$\frac{4EI}{4} = EI$		0.556

Due to symmetry one balancing will take of moment distribution as shown in table below.

	short wall	long wall
	0.556	0.444
$(-26.16+40.87) \times 0.556$	-26.16	40.87
	-8.178	-6.53
	-34.338	34.34
	-0.0011	-0.00088
	-34.34	34.34

Corner moment = 34.34 KNm , Tensioned out side

Effective thickness required for balanced section is

$M = Qbd^2$

$34.34 \times 10^6 = 1.61 \times 1000 \times d^2 \Rightarrow d = 146$ mm

Section is to be kept sufficiently under reinforced. Let us keep overall thickness of 200mm with effective cover of 35 mm.

Effective depth, $d = 200 - 35 = 165$ mm

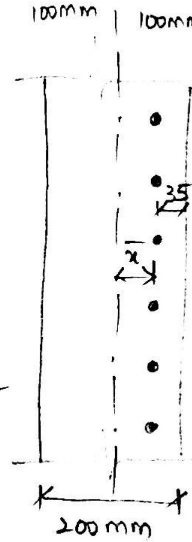
Direct Pull on long wall and short wall are given by

$T_L = P_h \, B/2$ $\quad\quad$ $T_B = P_h \, L/2$

$= 19.62 \times 4/2 = 39.24$ kN $\quad\quad$ $= 19.62 \times 5/2 = 49.05$ kN

Eccentricity of reinforcement from centre of wall

$x = \frac{200}{2} - 35 = 65$ mm



Design moment at Corner $= M - Tx$

$= 34.34 - 39.2 \times 0.065 = 31.79$ kNm

Horizantal reinforcement at corner

$A_{st_1} = \frac{M}{\sigma_{st} \, J d} = \frac{31.79 \times 10^6}{115 \times 0.85 \times 165} = 1971 \text{ mm}^2$

For direct tension $A_{st_2} = \frac{39.24 \times 10^3}{115} = \frac{T}{\sigma_{st}}$

$= 340.8 \text{ mm}^2$

Total $A_{st} = 1971 + 340.8 = 2311.8 \text{ mm}^2$

Using 20mm dia bars, spacing $S = \frac{\pi/4 \times 20^2}{2311.8} \times 1000 = 136$ mm

Provide 20 mm dia bars @ 130mm c/c. It is to be provided on water face.

Reinforcement at middle of Long walls:-

Bending moment $= \frac{P_H \, L^2}{8}$ − moment at Corner

$= \frac{19.62 \times 5^2}{8} - 34.34 = 26.97$ kNm

Design moment $= M - T_L x$

$= 26.97 - 39.2 \times 0.065 = 24.42$ kNm

$$A_{st_1} = \frac{M}{\sigma_{st} J d} = \frac{24.42 \times 10^6}{115 \times 0.85 \times 165} = 1514 \text{ mm}^2$$

From direct tension, $A_{st_2} = \frac{T}{\sigma_{st}} = \frac{39.2 \times 10^3}{115} = 340.8 \text{ mm}^2$

Total $A_{st} = 1514 + 340.8 = 1854.8 \text{ mm}^2$

Using 20 mm dia bars, spacing $S = \frac{\pi/4 \times 20^2}{1854.8} \times 1000 = 169 \text{ mm}$

Provide 20 mm dia bars @ 130 mm c/c. These are provided at outer face.

Reinforcement for short wall :-

Corner moment = 34.34 KNm

Design moment $= M - T_B x = 34.34 - 49.05 \times 0.065$

$= 31.15$ KNm

$$A_{st_1} = \frac{M}{\sigma_{st} J d} = \frac{31.15 \times 10^6}{115 \times 0.85 \times 165} = 1931 \text{ mm}^2$$

For direct tension, $A_{st_2} = \frac{T_B}{\sigma_{st}} = \frac{49.05 \times 10^3}{115} = 426.52 \text{ mm}^2$

Total $A_{st} = 1931 + 426.52 = 2357 \text{ mm}^2$

Using 20 mm dia bars, spacing $S = \frac{\pi/4 \times 20^2}{2357.52} \times 1000 = 133 \text{ mm}$

Provide 20 mm dia bars @ 130 mm c/c.

Reinforcement at centre of wall :-

Bending moment at centre of wall $= \frac{P_H B^2}{8}$ − Moment at corner

$= \frac{19.62 \times 4^2}{8} - 34.34 = 4.9$ KNm

Design moment $= 4.9 - 49.05 \times 0.065$

$= 1.71$ KNm

It is quite small, it is taken care by minimum reinforcement.

Bent alternate bars provided for end moment at a distance $B/4 = 1m$ from each end and continue remaining half through out. Hence at centre of wall consists of 20mm dia bars @ 260 mm c/c.

Reinforcement in vertical direction:-

Cantilever moment $= \gamma \times H \times h^2/6$

$= 9.81 \times 3 \times 1^2/6 = 4.9$ KNm

$$A_{st_1} = \frac{M}{\sigma_{st} J d} = \frac{4.9 \times 10^6}{115 \times 0.85 \times 165} = 304 \text{ mm}^2$$

$A_{st_{min}} = 0.3\%$ gross c/s area

$$= \frac{0.3}{100} \times 1000 \times 200 = 600 \text{ mm}^2$$

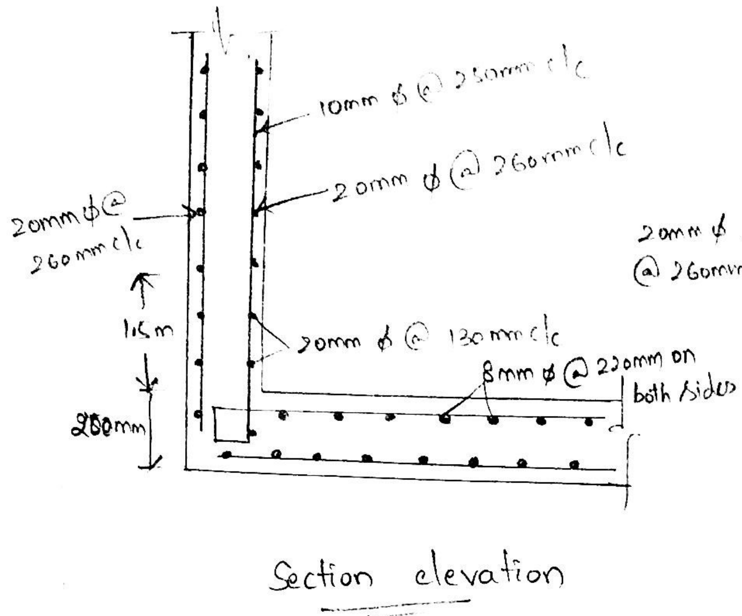
Provide 300 mm^2 area on each face, so that required distribution steel is also available.

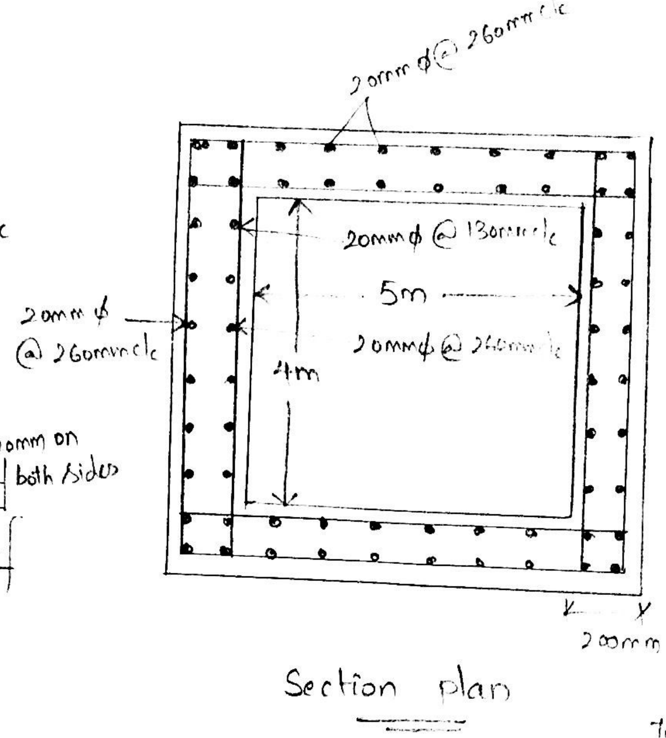
Using 10mm dia bars, spacing $S = \frac{\pi/4 \times 10^2}{300} \times 1000 = 261$ mm

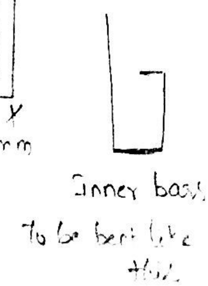
Provide 10 mm dia bars @ 250 mm c/c.

Design of base slab:-

Provide nominal base slab of thickness 150 mm with 8mm dia bars @ 220 mm c/c in both directions at top and bottom of slabs. A lean concrete bed of 100 mm may be provided on which bottom slab can rest.







2) Design an open rectangular tank of size 3×8×3m deep resting on a firm ground. Use M_{25} grade of concrete and Fe_{415} reinforcement. Approximate method may be used for the analysis.

Sol: Given data:-

$L = 8m, \; B = 3m, \; H = 3m$

~~$f_{ck} = 25 N/mm^2$~~, ~~$f_y = 415 N/mm^2$~~

Design constants:-

$$m = \frac{280}{3\sigma_{cbc}} = \frac{280}{3 \times 8.5} = 10.98$$

$$k = \frac{m\sigma_{cbc}}{m\sigma_{cbc} + \sigma_{st}} = \frac{10.98 \times 8.5}{10.98 \times 8.5 + 150} = 0.383$$

$$J = 1 - k/3 = 1 - \frac{0.383}{3} = 0.87$$

$$Q = \tfrac{1}{2} k J \sigma_{cbc} = \tfrac{1}{2} \times 0.383 \times 0.87 \times 8.5 = 1.416$$

The ratio of $L/B = 8/3 = 2.67 > 2$

Hence long wall predominantly act as a cantilever of height $H = 3m$

Design of long wall:-

Moment $M = \gamma \times \frac{H^3}{6} = 9.81 \times 3^3/6 = 44.145$ kNm

For balanced section, $M = Qbd^2$

$44.145 \times 10^6 = 1.42 \times 1000 \times d^2$

$\Rightarrow d = 176.31$ mm

Provide overall thickness of 220 mm with an effective cover of 35mm.

Effective depth $d = 220 - 35 = 185$ mm

(i) Reinforcement for cantilever action:-

$$A_{st} = \frac{M}{\sigma_{st} J d} = \frac{44.145 \times 10^6}{150 \times 0.87 \times 185} = 1826.65 \text{ mm}^2$$

Using 16 mm dia bars, spacing $= \frac{\pi/4 \times 16^2}{1826.65} \times 1000 = 110.2$ mm

Provide 16mm dia bars @ 110mm c/c in vertical direction near inner face of tank.

(ii) Reinforcement in long wall in horizontal direction:-

Direct tensile force transfered by short wall and long wall

$T_L = \gamma (H-h) B/2 = 9.81 (3-1) \times 3/2 = 29.43$ kN

Horizontal reinforcement required $= \frac{T_L}{\sigma_{st}} = \frac{29.43 \times 10^3}{150} = 196 \text{ mm}^2$

Ast_{min} = 0.3% gross c/s area

$= \frac{0.3}{100} \times 1000 \times 220 = 660 \text{ mm}^2$

Hence 330 mm² area may be Provided on each face. using

8 mm dia bars, spacing $= \frac{\pi/4 \times 8^2}{330} \times 1000 = 152$ mm

Provide 8 mm dia bars @ 150mm c/c near each face in horizantal direction.

Design of short wall :-

(i) Reinforcement in vertical direction :-

Moment $= \gamma \times H \times h^2/6 = 9.81 \times 3 \times 1^2/6 = 4.9$ KNm

moment is very low. Provide a minimum reinforcement of 8mm dia bars @ 150mm c/c near each face.

(ii) Reinforcement in horizantal direction :-

water pressure at h = 1m above base, $P_H = \gamma(H-h)$

$P_H = 9.81(3-1) = 19.62 \text{ KN/m}^2$

Bending moment at ends may be taken as $P_H B^2/12$

$= 19.62 \times 3^2/12 = 14.71$ KNm

Actual tension due to 1m length of long wall,

$T_B = \gamma(H-h) \times 1 = 19.62$ KN

$Ast_1 = \frac{M}{\sigma_{st} J d} = \frac{14.71 \times 10^6}{150 \times 0.87 \times 185} = 609.5 \text{ mm}^2$

$$A_{st_2} = \frac{T}{\sigma_{st}} = \frac{19.62 \times 10^3}{150} = 130.8 \text{ mm}^2$$

Total $A_{st} = 609 + 130 = 739 \text{ mm}^2$

Using 12 mm dia bars, spacing $= \frac{\pi/4 \times 12^2}{739} \times 1000 = 153 \text{ mm}$

Provide 12 mm dia bars @ 150 mm c/c near interface at ends.

In the middle portion, moment $M = P_H \times B^2/24$

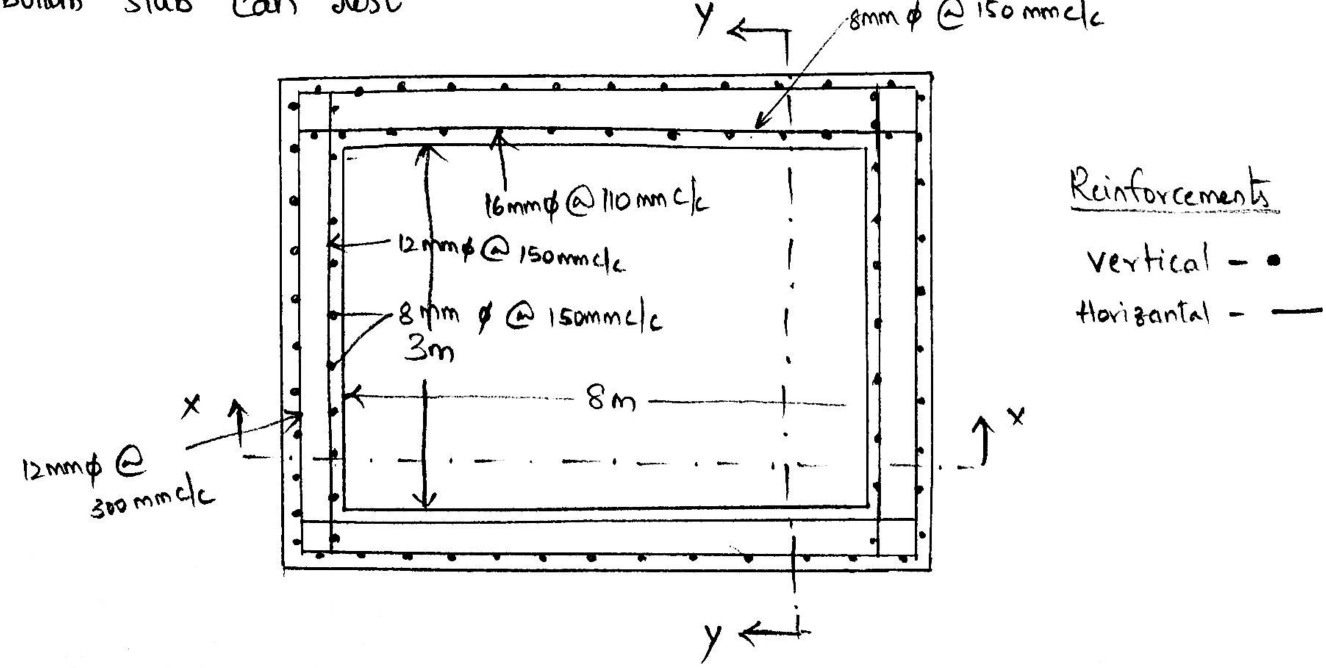
$$= 19.62 \times 3^2/24 = 7.35 \text{ KNm}$$

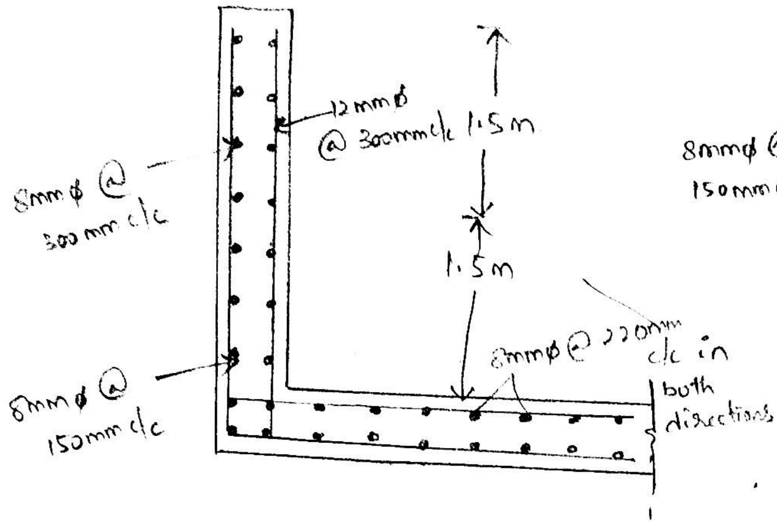
$$A_{st_1} = \frac{7.35 \times 10^6}{150 \times 0.87 \times 185} = 304 \text{ mm}^2$$

Provide 12mm dia bars @ 300mm c/c.

Design of base slab:-

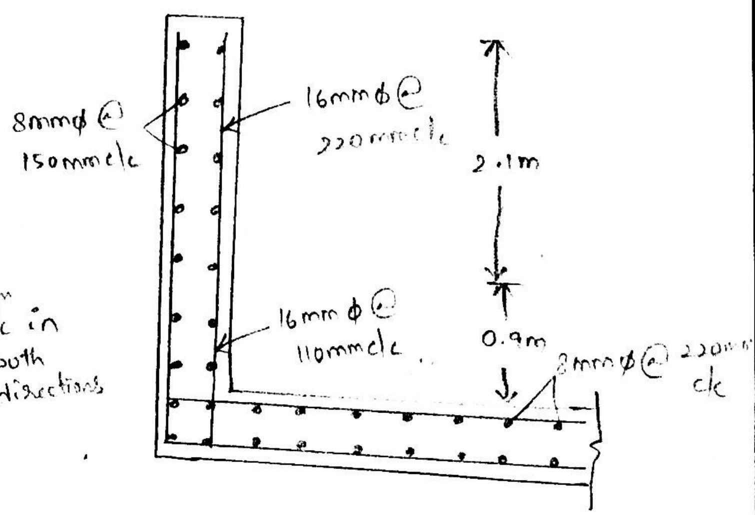
Provide nominal base slab of thickness 150mm with 8mm dia bars @ 220mm c/c in both directions at top and bottom of slab. A lean concrete bed of 100 mm may be provided on which bottom slab can rest.





Section through short wall

(Section x-x)



Section through long wall

(Section y-y)