

Analysis and Design of Clear Water Reservoir using Membrane Theory

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ABSTRACT:

As nation of close to 1.4billion,the first most populous in the world, India is maintaining a steady growth of its economy. Although it has an economy based largely on agriculture there is a trend towards rapid industrialization and urbanization. Water is a key element in all kinds of development planning. A recent estimate shows that about 70% of population lives in rural areas as against 30% in metropolitan cities and urban centers of the urban population about 25% live in slums. About 60% of the urban population is not connected to sewerage system and about 20% are without safe drinking water. The Clear water reservoir which is designed is part of water supply scheme and its capacity is 400 KL.

I. INTRODUCTION:

For storage of large quantities of liquids like water, oil, petroleum, acid and sometime gases also, containers or tanks are required. These structures are made of masonry, steel, reinforced concrete and pre stressed concrete.

Out of these, masonry and steel tanks are used for smaller capacities. The cost of steel tanks is high and hence they are rarely used for water storages. Reinforced concrete tanks are very popular because, besides the construction and design being simple, they are cheap, monolithic in nature and can be made leak proof.

Classification of RCC. tanks :

In general they are classified in three categories depending on the situation.

1. Tanks resting on ground.
2. Tanks above ground level (Elevated tanks)
3. Under ground tanks.

Tanks resting on ground:

These are used for clear water reservoirs, settling tanks, aeration tanks etc. these tanks directly rest on the ground. The wall of these tanks are subjected to water pressure from inside and the

base is subjected to weight of water from inside and soil reaction from underneath the base. The tank may be open at top or roofed.

Elevated tanks:

These tanks are supported on staging which may consist of masonry walls, R.C.C tower or R.C.C. column braced together- The walls are subjected to water pressure from inside. The base is subjected to weight of water, wt- of walls and wt. roof. The staging has to carry load of entire tank with water and is also subjected to wind and earth quake loads.

Under ground tanks :

These tanks are built below the ground level such as clarifiers, filters in water treatment plants, and septic tanks .The walls of these tanks are subjected to water pressure from inside and earth pressure from outside. The base of the tank is subjected to water pressure from inside and soil reaction from underneath. Always these are covered at top. These tanks should be designed for loading which gives the worst effect.

II. SYMBOLS USED:

MWL = Maximum water level
LWL = Lowest water level
Ly = Length of Longer span
Lx = Length of shorter span
Mu = Factored Bending moment
B = width of section
d = depth of section
SF = Shear force
BM = Bending moment

III. PROBLEM FORMULATION :

A numerical problem is taken for design.

Design criteria:

- The sump consists of circular container covered by a flat roof slab.
- Roof slab is supported by beams in both directions which are supported by 9 nos of RCC columns.
- Designs are based on Limit State method.
- The roof slab is designed for a live load of 150 kg/sqm.
- Bending moment coefficients are taken from IS 456:2000.
- Roof beams are designed as continuous beams considering a moment of $wL^2/10$
- Side wall is Designed for critical condition considering no earth outside and only water inside.
- Hoop tension values are based on IS3370 part-4: 2021, Table 4 & table 7 considering hinged Base & free top and fixed base & free top.

IV. ANALYSIS AND DESIGN OF CIRCULAR TANK : MANUAL DESIGN

Permissible Stresses :

S.no	Concrete	M30
1)	Direct Compression	80 Kg/Cm ²
2)	Bending	100 Kg/Cm ²
3)	Direct tension	15 Kg/Cm ²
4)	Bending tension	20 Kg/Cm ²

Water Retaining Members:

Tensile Stress in members under direct tension ,bending and shear	1300	kg/cm ²
Compressive stress in columns subjected to direct load	1400	kg/cm ²

Steel : Fe 500

General Purpose :

Tensile Stress / Shear Stress	2750	kg/cm ²
Compression in Columns	1900	kg/cm ²

Salient features of sump:

M.W.L = + 3.00
 L.W.L = + 0.00

Depth of Water = 3 - 0 = 3.0 M

Capacity calculations:

Diameter provided = 13.15 m
 Free board = 0.30 m
 Dead storage = 0.15 m
 Actual capacity = $0.785 \times 13.15 \times 13.15 \times 3.0$
 = 407.23 cum
 Deductions of columns = $0.30 \times 0.30 \times 3.0 \times 9$ = 2.43 cum
 Provided capacity = $407.23 - 2.43 = 404.8$
 cum > 400 KL

Design of slab 120th:

Panel size = 3.50 x 3.50 Met

$$\frac{L_y}{L_x} = \frac{3.50}{3.50} = 1.0$$

L_x

Loading :

Self Wt

Assuming 120 thick = $0.12 \times 2500 = 300$ kg/m²

Live Load = 150 kg/m²

Finishes = 100 kg/m²

 550 Kg/m²

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Refer IS:456:2000 Table 26

Condition : Interior Panel

Max +ve moment = $(0.024)(550)(3.50) \times (3.50)$
 = 141.48 Kg Met

Max -ve moment =
 $(0.032)(550)(3.50)^2(3.50) = 215.60 \text{ Kg Met}$

Uncracked depth (D) = $\sqrt{(215.60 \times 100 / (3.5 \times 100))} = 7.84 \text{ cm} < 12 \text{ cm}$

Factored +ve moment = $1.5 \times 141.48 = 212.22 \text{ kgm}$

Factored -ve moment = $1.5 \times 215.60 = 323.4 \text{ kgm}$

Effective depth = $120 - (45 + 8/2) = 71 \text{ mm}$

μ/bd^2 for -ve moment is = $323.4 / (1000 \times 10 / (1000 \times (71)^2)) = 0.64$ say 0.65

Percentage of steel from Table 4 of SP:16 for $\mu/bd^2 = 0.65$ and Fe 500 = 0.153

Area of steel required = $0.153 \times 1000 \times 71 / 100 = 108.63 \text{ sqmm}$

Minimum steel = $0.12 / 100 \times 1000 \times 71 = 85.2 \text{ sqmm}$

Provide dia of bar = 8 mm

Spacing required = $50 / 108.63 \times 1000 = 460.27 \text{ mm}$

Provide at bottom 8 tor @ 200 c/c both ways alternate bar bent up @ L/5 from support

Extra top over support - 8 tor @ 400 c/c upto L/4

Design of Beam : 300 x 350

Span = 3.5 m

Width of Section = 300 mm

Depth of Section = 350 mm

Clear Cover = 45 mm

Effective Depth = $350 - 45 - (12/2) = 299 \text{ mm}$

Slab load on Beam = $2 \times (W_L \times l / 3)$

$2 \times (550 \times 3.5 / 3) = 1283.33 \text{ kg/m}$

Self Wt. of Beam = $0.30 \times (0.35 - 0.12) \times 2500 = 172.5 \text{ kg/m}$

Total Load = 1455.8 Say 1500 kg/m

Max S.F = $1500 \times 3.5 / 2 = 2625 \text{ kg}$

Max B.M = $1500 \times 3.5^2 / 10 = 1837.5 \text{ kgm}$

Factored bending moment = $1.5 \times 1837.5 = 2756.25$

μ/bd^2 for -ve moment = $2756 / (1000 \times 10 / (300 \times (299)^2)) = 1.02$ say 1.05

Percentage of steel from Table 4 of SP:16 for $\mu/bd^2 = 1.05$ and Fe 500 = 0.252

Area of steel required = $0.252 \times 300 \times 299 / 100 = 226.04 \text{ sqmm}$

Minimum steel = $0.85 \times 300 \times 299 / 500 = 152.49 \text{ sqmm}$

Provide at top and bottom 3-12 tor through

% of Steel Provided = $100 \times 3.39 / (30 \times 29.9) = 0.37$ say 0.50

Factored Max S.F = $1.5 \times 2625 = 3937 \text{ kg}$

Nominal shear stress = $3937 / (30 \times 29.9) = 4.38 \text{ kg/sqcm}$

Permissible shear stress as per table 19 of IS: 456:2000 corresponding to percentage of steel 0.50 and M30 concrete is 0.5 N/sqmm or 5 Kg/sqcm

Permissible shear stress is more than nominal shear stress. Hence minimum shear reinforcement required.

Provide 8 tor @ 200 c/c stirrups

Column inside Container : 300 x 300

Size of the Column = 300 x 300

Axial load = $4 \times \text{RB1} = 4 \times 2625 = 10500 \text{ kg}$

Height of Column = 3.45 m

Self wt Of Column = $0.30 \times 0.30 \times 3.45 \times 2500 = 539.06 \text{ kg}$

Total Load = $10500 + 539.06 = 11039.06 \text{ kg}$

L/D = $3450 / 300 = 11.5 < 12$

Hence it is short column

Design Load = 10909 say 11000 kg

Minimum Area of Steel = $0.8 / 100 \times 300 \times 300 = 720 \text{ sqmm}$

Provide 8 x 12 tor main bars (904 sqmm)

Provide 8 dia links @ 150 c/c

Design of Column Footing : 1000x1000 x250 mm

Load coming from Column = 11000 kg

Assume safe bearing capacity of soil = 20000 kg/sqm

Self Wt of footing = 10% of Load coming from column

= 1100 kg

Total Load = $11000 + 1100 = 12100 \text{ kg}$

Area of Footing Required = $\sqrt{(12100 / 20000)}$

Side of footing Required = 0.77

Provide Footing of 1m x 1m

Provided Area of Footing = 1.0 sqm

Net upward Pressure = $11000 / 1 \times 1 = 11000 \text{ kg/sqm} < 20000 \text{ kg/sqm}$

S.F = $11000 \times 1 \times (1 - 0.30) / 2 = 3850 \text{ kg}$

B.M = $3850 \times 1/2 \times ((1 - 0.30) / 2) = 673.75 \text{ kgm}$

Factored bending moment = $1.5 \times 673.75 = 1010.62$ kgm

Effective depth = $250 - 50 - 10/2 = 190$ mm

$\mu/bd^2 = 1160.14 \times 1000 \times 10 / (1000 \times (190)^2) = 0.32$ say 0.35

Percentage of steel from Table 4 of SP:16 for $\mu/bd^2 = 0.35$ and Fe 500 = 0.082

Area of steel required = $0.082 \times 1000 \times 190 / 100 = 155.8$ sqmm

Minimum steel = $0.35/100 \times 1000 \times 250 = 875$ sqmm

Provide dia of bar = 12 mm

Spacing required = $113 / 875 \times 1000 = 129.14$ mm

Provide 12 - tor @ 120 c/c both ways at bottom.

Design of Side wall 200th

Thickness of Sump Wall $t = 200$ mm

Diameter of Sump = 13.15 m

Top of Wall = 3.65

Bottom of Wall = -0.15

M.W.L = + 3.0

L.W.L = + 0.0

Condition: Only Water inside & No Earth out side
The side wall is designed for max values of hoop tension for hinged base free top.

$H = 3.45$ mt ; Diameter = 13.15 mt. $H^2/Dt = 4.52$

Let the thickness of Wall be 200 mm uniform.

Hoop Tension:

Max Hoop Tension for side wall is considered to be Hinge bottom and free top Table 4 - IS 3370 (PART-IV)-2021

Hoop tension $T = (\text{Coefficient}) \text{WHR} = 0.5989 \times 1000 \times 3.45 \times 13.15/2$

=

13585 kg

Area of steel required = $1.5 \times 13585 \times 10 / (0.55 \times 500) = 741$ sqmm

As per IS:3370 part2:2021 table 5

Minimum reinforcement of 0.24% up to 14 m dia
0.36 % > 14 m dia

Minimum steel = $0.24/100 \times 1000 \times 200 = 480$ sqmm

Dia of bar = 12 mm

Spacing required is = $113/7741 \times 1000 = 152.4$ mm

Provide 12tor@ 150 c/c throughout.

Vertical steel:

Max Bending moment for side wall is occurred Wall is considered to be fixed bottom and free top Table 7 - IS 3370 (PART-IV)-2021

Max Bending Moment = (Coefficient) WH3
= $0.0244 \times 1000 \times 3.45^3 = 1001.95$ kgm

Factored bending moment = $1.5 \times 1001.95 = 1502.92$ kgm

Effective depth = $200 - 45 - 12/2 = 149$ mm

$\mu/bd^2 = 1502.92 \times 1000 \times 10 / (1000 \times (149)^2) = 0.67$ say 0.70

Percentage of steel from Table 4 of SP:16 for $\mu/bd^2 = 0.70$ and Fe 500 = 0.166

Area of steel required = $0.166 \times 1000 \times 200 / 100 = 332$ sqmm

Minimum steel = $0.24/100 \times 1000 \times 200 = 480$ sqmm

Provide 10 tor@ 200 c/c throughout

Design of wall footing : 1500 wide x350 thick

Let Width of Footing = 1500 mm

Let Depth of Footing = 350 mm

Clear Cover = 50 mm

Effective Depth = 300 mm

Wt of wall = $3.8 \times 0.2 \times 2500 = 1900$ kg/m

Roof Slab = $550 \times 3.5/2 = 962.5$ kg/m

kg/m

Footing = $1.5 \times 0.35 \times 2500 = 1312$ kg/m

Water = $3.45 \times 1000 \times 0.625 = 2156$ kg/m

Total Load = 6330 kg/m

Net BM = $1001.95 - 2156 (0.2 + 0.625)/2$

= 112.6 kg/m

$e = M/P = 112.6/6330 = 0.017$

$6e = 0.102$

$P_{max} = (6330 - 1312) / 1.5 + (6 \times 0.017 / 1.5) = 3345 + 0.068 = 3345.06$ kg/m < 20,000

Shear force = $3345 \times 0.625 = 2090$ kg

Bending Moment = $2090 \times 0.625 = 1306$ kg/m

Effective depth = $350 - 50 - 10/2 = 295$ mm

$Mu/bd^2 = 1306 \times 1000 \times 10 / (1500 \times (295)^2) = 0.10$ say 0.30
 Percentage of steel from Table 4 of SP:16 for $Mu/bd^2 = 0.30$ and Fe 500 = 0.070
 Area of steel required = $0.070 \times 1000 \times 350 / 100 = 245 \text{ sqmm}$
 Minimum steel = $0.24/100 \times 1000 \times 295 = 708 \text{ sqmm}$
 Provide 10 tor@ 150 c/c both ways at bottom

Design of Floor Slab :

Water table at the Proposed site is assumed to be far below and further the tank is directly resting on ground.
 Provide 200 mm thick R.C.C floor slab with 8 tor @ 200c/c both ways at top.

V. CONCLUSIONS

Liquid storage tanks are commonly used in domestic water supply scheme.

The Clear water reservoir, which is designed, is part of water supply scheme and its capacity is 400 KL designed with M30 Concrete.
 An attempt is made to design the clear water reservoir Manually stepwise from Basic concept .

REFERENCES

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