International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 08 Aug. 2024, pp: 101-106 www.ijaem.net ISSN: 2395-5252

Analysis and Design of Clear Water Reservoir using Membrane Theory

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Date of Submission: 01-08-2024 Date of Acceptance: 08-08-2024

ABSTRACT:
As nation of close to 1.4 billion,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 is400 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 my 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.

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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 & table7considering 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 x 13.15x13.15x3.0 = 407.23 cum
Deductions of columns = 0.30x0.30x3.0 x9 = 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

$\frac{Ly}{Lx}$ = 3.50/3.50 = 1.0

Loading :

Self Wt
Assuming 120 thick = 0.12 x2500 =300 kg/m2

Live Load = 150 kg/m2

Finishes = 100 kg/m2
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550 Kg/m2
=====

Refer IS:456:2000 Table 26

Condition : Interior Panel

Max +ve moment= (0.024)(550)(3.50)*(3.50) =141.48 Kg Met

Max –ve moment = (0.032)(550)(3.50)*(3.50)=215.60 Kg Met

Uncracked depth (D) = sqrt(215.60 x100 /(3.5 x100) = 7.84 cm < 12 cm

Factored +ve moment = 1.5 x 141.48 = 212.22 kgm

Factored _ve moment = 1.5 x 215.60 = 323.4kgm

Effective depth = 120 –(45+8/2) = 71 mm

Mu/bd^2 for _ ve moment is = 323.4 x1000x10/(1000 x (71)^2 = 0.64say 0.65

Percentage of steel from Table 4of SP:16 forMu/bd^2 =0.65 and Fe 500 = 0.153

Area of steel required= 0.153 x 1000x71 /100 =108.63 sqmm

Minimum steel = 0.12/100 x1000x71 = 85.2 sqmm

Provide dia of bar = 8 mm

Spacing requied = 50 /108.63 *1000 =460.27 mm

Provide at bottom8tor @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 x350
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 mm
Slab load on Beam = 2 x (WLx / 3)
2 x (550x3.5/3) = 1283.33 kg/m

Self Wt. of Beam =0.30x (0.35-0.12) x2500 =172.5 kg/m
Total Load= 1455.8Say 1500 kg/m
Max S.F =1500 x3.5 /2= 2625 kg
Max B.M =1500 x3.5^2 /10= 1837.5 kgm
Factored bending moment = 1.5 x1837.5 = 2756.25

Mu/bd^2 for _ ve moment = 2756 x1000x10/(300 x(299)^2 = 1.02 say1.05

Percentage of steel from Table 4 of SP:16 forMu/bd^2 =1.05 and Fe 500 = 0.252

Area of steel required = 0.252 x 300 x299 /100 =226.04 sqmm

Minimum steel = 0.85 x 300 x299/500 = 152.49 sqmm
Provide at top and bottom 3-12 tor through
% of Steel Provided = 100 x3.39 / (30 x 29.9) =0.37 say 0.50
Factored Max S.F =1.5 x2625 = 3937 kg
Nominal shear stress = 3937 /(30 x29.9) =4.38 kg/sqcm
Permissible shear stress as per table 19 of IS: 456:2000corresponding topercentage of steel 0.50 and M30concrete is 0.5 N/ sqmm or 5 Kg/sqcm
Permissible shear stress is more than nominal shear stress. Hence minimum shear reinforcement required.
Provide 8tor @ 200 c/c stirrups

Column inside Container : 300 x 300
Size of the Column = 300 x300
Axial load = 4 x RB1 = 4 x2625 =10500 kg
Height of Column = 3.45 m
Self wt Of Column = 0.30 x0.30 x3.45 x2500 = 539.06 kg
Total Load = 10500 +539.06 = 11039.06 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 x 300 x300 = 720 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 kg
Area of Footing Required = sqrt(12100/20000)
Side of footing Required = 0.77
Provide Footing of 1mt x1 m t
Provided Area of Footing = 1.0 sqmt
Net upward Pressure = 11000/1x1 = 11000 kg/sqm < 20000 kg/sqm
S.F =11000 x1 x(1-0.30)/2 = 3850 kg
B.M =3850 x 1/2 ((1-0.30)/2) = 673.75 kgm

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Factored bending moment = 1.5 x673.75 = 1010.62 kgm
Effective depth = 250-50-10/2 = 190 mm
Mu/bd^2 = 1160.14 x1000 x10 /(1000 x(190)^2 = 0.32 say 0.35

Percentage of steel from Table 4 of SP:16 forMu/bd^2 =0.35 and Fe 500 = 0.082

Area of steel required= 0.082 x 1000x190 /100 = 155.8 sqmm

Minimum steel = 0.35/100 x1000x250 = 875 sqmm

Provide dia of bar = 12 mm

Spacing required = 113 /875 *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 be200 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 = (Coefficient) WHR = 0.5989 x1000 x3.45x 13.15/2
= 13585 kg

Area of steel required = 1.5 x 13585x 10 /(0.55 x500) = 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 x1000 x 200 = 480 sqmm

Dia of bar = 12 mm
Spacing required is = 113/7741 x1000 = 152.4 mm
Provide 12 tor@ 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 x1000x3.45^3
= 1001.95 kgm

Factored bending moment = 1.5 x 1001.95 = 1502.92 kgm

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

Mu/bd^2 = 1502.92 x1000 x10 /(1000 x(149)^2 = 0.67 say 0.70

Percentage of steel from Table 4 of SP:16 forMu/bd^2 =0.70 and Fe 500 = 0.166

Area of steel required= 0.166 x 1000x200 /100 = 332 sqmm

Minimum steel = 0.24/100 x1000x200 = 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*0.2*2500 = 1900 kg/m
Roof Slab = 550*3.5/2 = 962.5 kg/m
Footing = 1.5*0.35*2500 = 1312 kg/m
Water = 3.45*1000*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

Pmax = (6330 -1312)/1.5 + (6 x 0.017/1.5) = 3345+ 0.068 = 3345.06 kg/m < 20, 000
Shear force=3345 *0.625 = 2090 kg
Bending Moment=2090 *0.625 = 1306 kg/m
Effective depth = 350-50 -10/2 =295 mm

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Mu/bd^2 = 1306x1000 x10 /(1500 x(295)^2 = 0.10 say 0.30
Percentage of steel from Table 4 of SP:16 forMu/bd^2 =0.30 and Fe 500 = 0.070
Area of steel required= 0.070 x 1000x350 /100 = 245 sqmm
Minimum steel = 0.24/100 x1000x295 = 708 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.
Provide200 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 .

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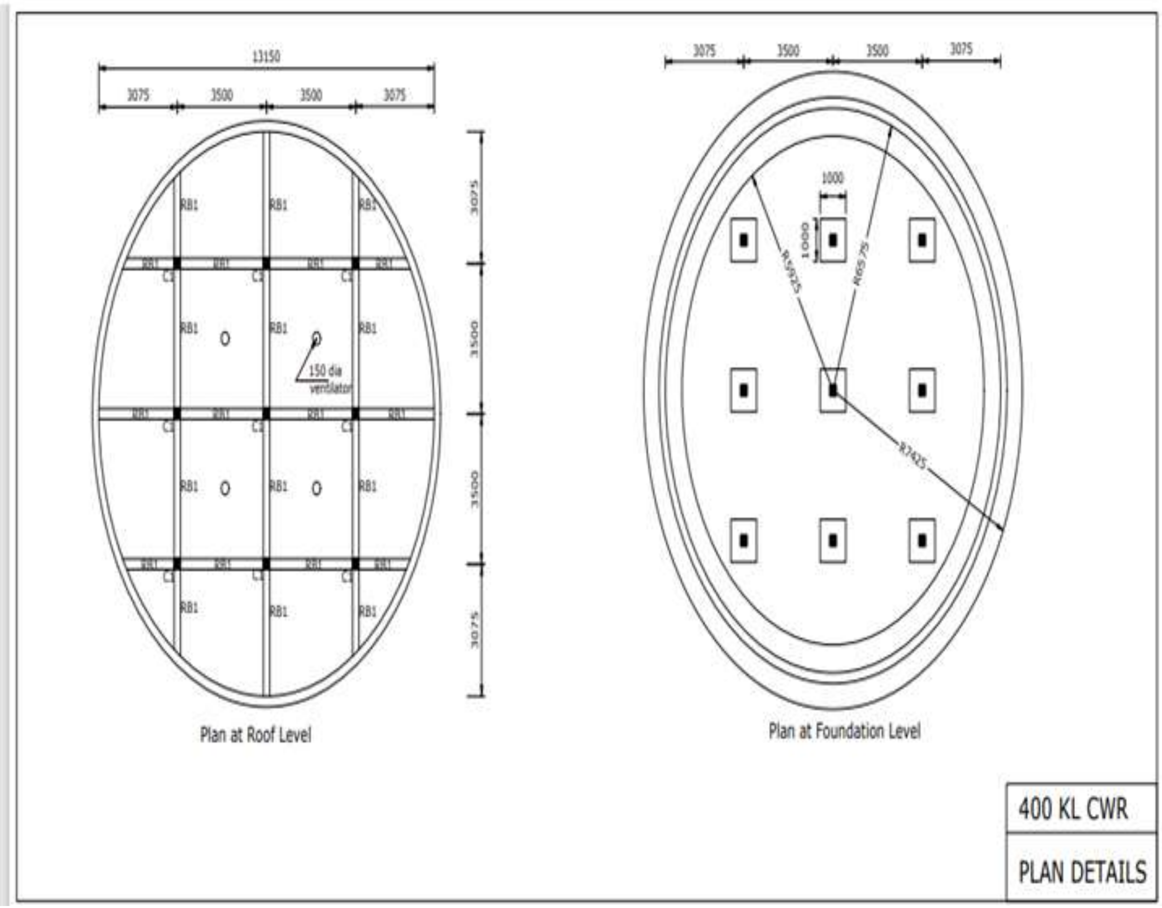

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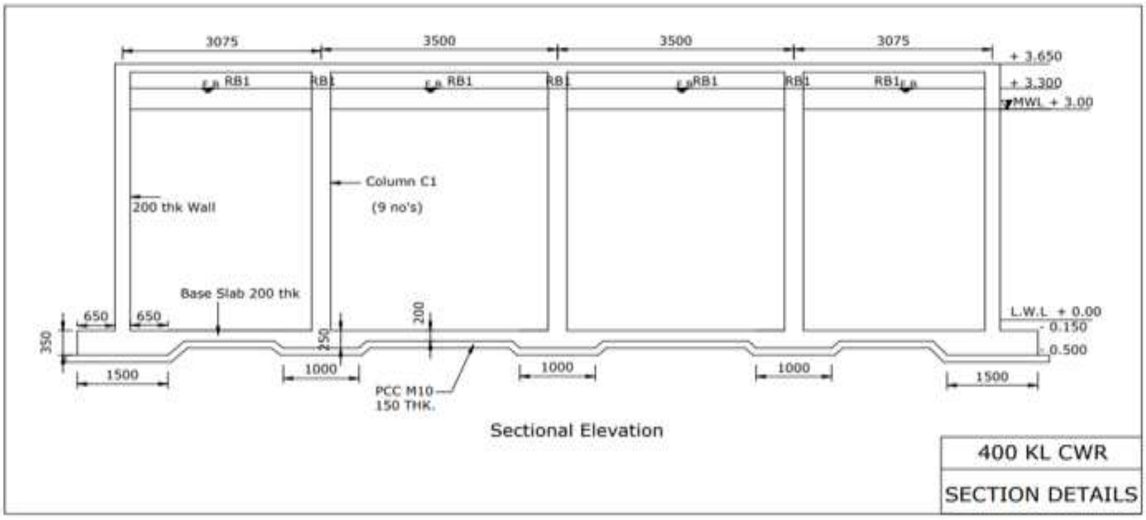

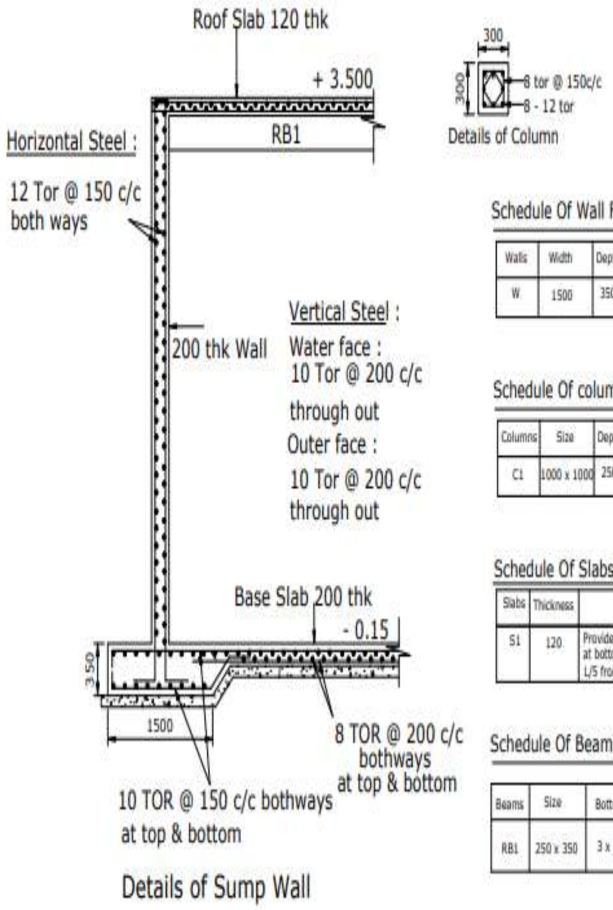

Schedule Of Wall Footings

Walls	Width	Depth	Main Bars	Distribution	Remarks
W	1500	350	10 tor @ 150 c/c at top & bottom.	10 tor @ 150 c/c at top & bottom.	M30

Schedule Of column Footings

Columns	Size	Depth	Main Bars	Remarks
C1	1000 x 1000	250	10 tor @ 150 c/c bothways at bottom.	M30

Schedule Of Slabs

Slabs	Thickness	Main Bars	Extra top Over Support	Distribution	Remarks
S1	120	Provide 8 tor @200 c/c bothways at bottom , alternate bar bent up @ L/5 from Support	8 tor @ 400 c/c up to L/4	Provide 8 tor @200 c/c bothways at bottom , alternate bar bent up @ L/5 from Support	M30

Schedule Of Beams

Beams	Size	Bottom Str	Extra at Bottom	Top Str	Extra top Over Support	Stirrups	Remarks
RB1	250 x 350	3 x 12 tor	NIL	3 x 12 tor	1 x 12 tor	Support to 900 , 8 tor @ 100 c/c 900 to centre , 8 tor @ 200 c/c	M30

400 KL CWR

REINFORCEMENT DETAILS