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PLANNING, DESIGNING AND ESTIMATION OF ELEVATED SERVICE RESERVOIR AT KHANDERAJURI VILLAGE

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ABSTRACT

In this project, we have planned, designed and estimated an overhead circular reinforced cement concrete water tank, to cater the water requirements of khanderajuri village. the population of village is estimated as 9340 persons using population forecasting methods. For this requirement, a circular overhead water tank is planned and it further designed manually and then it also designed in staad pro software, after that total estimation of water tank had done in measurement and abstract sheet

Keywords: Population, Elevated Storage Reservoir, Manual Design, Staad Pro, Estimation.

I. INTRODUCTION

The water tanks are liquid storage containers, they usually store water for human consumption, irrigation, fire, agricultural, farming etc. water is important for day-to-day life work so it is necessary to store water. The main objectives of design of water tanks are to provide safe drinkable water after storing for long time, optimizing cost strength, service life and performance during special situations like earthquakes. Also, other objectives include to prevent growth of microorganisms and to maintain the pH of water. A design of water tanks should not harm to the water. Design of reinforced concrete water tank is based on IS code. this design is based on the location of water tank i.e., on the ground or underground or overhead water tanks. So basically, water tanks are classified into two types based on position and shape of tanks. Based on location water tanks are classified into three ways-

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

Also, the water tanks are classified based on shapes: -

1. Circular tanks
2. Rectangular tanks
3. Intze tanks
4. Circular tanks with conical bottom
5. Square tanks

The Khanderajuri village is in Sangli district, which is situated on sloping ground. Overhead water tank is preferred in village so that supply water can be done under gravity. Overhead water tank is usual water storage tank as its name stands itself these tanks are placed over the head that is built on certain height. water supply is non uniform throughout the village and houses which are newly constructed on the upper side are facing difficulties to accomplish their daily water need.so under this project we had decided the location of water tank and we had designed the water tank structure.

II. METHODOLOGY

Population Forecasting:

As per Government of India manual on water supply engg, for growing village or developing village, geometrical increase method is adopted.so forecasted population of khanderajuri village at 2050 is 9340 persons

Table -1: Population Forecasting

Sr. No.	Year	Population	Increase in Population	%increase in Population
1	1981	3250	-	-
2	1991	3782	532	16.36%
3	2001	5253	1471	38.89%
4	2011	5506	253	4.81%

As per GOI manual, r can be computed by geometric mean,

$r = (r_1 r_2 r_3 ....)^{1/m}$

$= (16.36 \times 38.89 \times 4.81)^{3.9}$

$= 14.51\%$

General expression is, $Pn = P_0 (1+r/100)^n$

Population at 2050,

$P_{2050} = 5506(1 + 14.51/100)^{3.9}$

= 9340 Persons

Calculation of Water Demand:

According to IS1172:1993 and GOI manual per capita water demand assumed as 270 lpcd, then by finding out maximum daily demand we found coincident demand for 9340 persons. So total water demand for forecasted population is 4.548MLD As per GOI manual on water supply, various water demands are as follows-

a. Domestic demand = 135 lpcd
b. Industrial demand =50 lpcd
c. Institutional & commercial = 20 lpcd
d. Public use demand =10 lpcd
e. Losses and thefts = 55 lpcd

So, Total q = 270 lpcd

Per capita demand for 9340 persons = 270 x 9340 = 2.52 MLD

Coincident demand = Maximum Daily Demand + Fire Demand

Fire demand = $3182\sqrt{P}$

$= 3182\sqrt{9.3}$

$= 9703.79 = 9.703 \times 10^{-3}$ MLD

Coincident demand = $1.8 \times 2.52 + 9.703 \times 10^{-3}$

= 4.548 MLD

So, Total demand is 4.548 MLD

Capacity of water tank:

Capacity of water is calculated by using mass curve method so capacity of water tank is $216 m^3$

Table -2: capacity calculation

Time	Supply	Demand	Cumulative supply	Cumulative demand	Cs-cd
12-6 am	1.137	1	1.137	1	0.137
6-12 am	1.137	1.353	2.274	2.353	-0.079
12-6 pm	1.137	1.095	3.585	3.448	0.137
6-12 pm	1.137	1.1	4.548	4.548	0

Min volume of Balancing reservoir = ∑ Max. Ordinates difference between CS and CD curves

Vmin = 0.137+0.079

= 0.216MlD

Capacity of water tank = 216 m^3

Site selection - For selection of site we carried out total station survey and then decided location of water tank based on RLs

Manual RCC design of overhead circular water tank:

Design of overhead circular water tank with top slab dome shaped and bottom slab flat,

Grade of concrete = M25 and Grade of steel = Fe415

i) Diameter of tank-

$$V = \frac{\pi}{4} X\ d^2 X h = \frac{\pi}{4} X\ d^2 X 4 = 216$$

d = 8.29 m; h = 4 m; H = h + FB = 4 + 0.5 = 4.5m

ii) Diameter of ring beam-

D_{RB} = 0.75 times diameter of water tank= 0.75X8.29 = 6.21 m

Radius a= 4.14m; Radius b= 3.10m

iii) Design of top dome

Rise = $\frac{1}{7} X\ D = \frac{1}{7} X$ 8.29 = 1.184 Say 1.2 m

(2R- h) h = $\frac{D}{2} x \frac{D}{2}$ = (2R -1.2)1.2 = $(4.14)^2$

2.4R - 1.44 = 17.139; R = 9.28 = 9.3 m Semi central angle,

$\Theta = \cos^{-1}(\frac{R-h}{R}) = \cos^{-1}(\frac{9.3-1.2}{9.3}) = 29.428^0$

Assuming thickness of dome = 75 mm

Self-weight of dome = 0.075 x 1 x 1 x 25 = 1.875 KN/m^2

Live load = 1.5 KN; Finishing load = 1 KN

W=4.375 KN/m^2

Maximum meridional thrust (T1) (using the membrane theory of shell)

$T_1 = \frac{WR}{1+COS\theta} = \frac{4.375X9.3}{1+COS29.428}$ = 21.746 KN/m

Maximum circumferential force (T_2)

$T_2 = WR\ (\cos\theta - \frac{1}{1+\cos\theta}) = 4.375x9.3(\cos29.428 - \frac{1}{1+\cos29.428})$ = 13.691 KN/m

Maximum stress= 0.289 MPa

Permissible stress in M25 concrete in compression = 6 N/mm^2; Hence Safe.

So, Provide only nominal reinforcement of 8mm dia. at 180 mm c/c in both circumferential and meridional directions.

iv) Design of top ring beam

Hoop tension = $T_1\cos\theta\frac{D}{2}$ = 21.746cos29.428x4.14= 78.412 KN

Using 16mm diameter bars,

Ast = $\frac{T}{\sigma st} = \frac{78.412X10^3}{150}$=522.746 mm^2

Provide, 6 bars of 12 mm diameter,

Ast provided = 6 x $\frac{\pi}{4}$ x $(12)^2$ = 667.584 mm^2

Modular ratio = $\frac{280}{3X\sigma cbc} = \frac{280}{3X8.5}$ = 10.98

Area of concrete required is given by,

T = m. Ac + m. Ast

$\sigma ct = \frac{T}{Ac+mAst} = \frac{78.412X10^3}{Ac+10.98X667.584} = 1.3$

$A_c = 52986.850\ mm^2$

Provide, 250 mm x 300 mm top ring beam with 6 bars of 12 mm diameter main reinforcement. Nominal stirrups of 6mm at 225 mm c/c are to be provided in the beam.

v) Design of tank wall-

Depth of water in tank = 4; Diameter of water tank = 8.29 m

Max hoop tension in the wall = $\frac{rhD}{2}$ = 182.9

Ast = $\frac{T}{\sigma st} = \frac{182.981X10^3}{150}$ = 1219.873; Ast on each face = $\frac{1219.873}{2}$ = 609.936mm²

Use 12mm diameter bars,

Spacing required is, S = $\frac{ast}{Ast}$ x 100 = $\frac{\frac{\pi}{4}X\,12^2}{609.936}$ x 1000 = 185.42 mm²

Provide, 12mm diameter bars at 180 mm c/c near base, on each base.

It may be gradually increased to 300mm,

Spacing at = $\frac{S\,X\,h}{300} = \frac{180\,X\,4.5}{300}$ = 2.7m below the top, in the span of 2.7 m maintain 300mm spacing Ast provided at base = $\frac{\frac{\pi}{4}X\,12^2}{180}$ x 1000 = 628.318 mm²

Let, thickness of wall (t), to keep direct compression in wall within limiting value,

$\sigma ct = \frac{T}{1000Xt+mAst} = \frac{182.981X10^3}{1000t+10.98X628.318} = 1.3$

t = 133.85 mm =150 mm, Provide 150 mm wall thickness

vi) Vertical Steel

Bottom = $\frac{4.5}{3}$ = 1.5 m is under cantilever moment

Cantilever moment = $\frac{rHh^2}{6} = \frac{9.81\,X\,4.5\,X\,1.5^2}{6}$ = 16.55 KN-m

For M25 Concrete and Fe 415 Steel,

M = 10.98; σcbc = 8.5 N/mm²; σct = 1.3 N/mm²; σst = 150 N/mm²

$K = \frac{m\sigma cbc}{m\sigma cbc+\sigma st} = \frac{10.98X8.5}{10.98X8.5+150} = 0.383$

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

Effective depth = thickness – clear cover = 150-35 =115 mm

$Ast = \frac{M}{\sigma stXJXd} = \frac{16.55X10^6}{150X0.87X115} = 1102.781\ mm^2$

Use of 10 mm diameter bars,

$S = \frac{\frac{\pi}{4}X\,12^2}{1102.781}$ x 1000 = 102.55 mm = 100mm

Minimum steel provided in vertical direction; Ast min = 0.3% of gross c/s area,

= $\frac{0.3}{100}$ x (bxt) = $\frac{0.3}{100}$ x (1000x150) = 450 mm²

Minimum steel on each face = $\frac{450}{2}$ =225 mm²; Use 10 mm diameter bars,

$S = \frac{\frac{\pi}{4}X\,10^2}{225}$ X1000 = 349.06 m

Hence, provide 10mm diameter bars at 70 mm c/c in the lower 1.5m on inner face, curtail alternate bars on outer face provide 10mm diameter @ 300 mm c/c

vii) Design of base slab-

Total load from dome = T_1sinθ x 2π$\frac{D}{2}$ = 21.746sin29.428 x 2π x 4.14 = 277.928 KN

Weight of ring beam = 0.25 x 0.3 x 2π x 4.14 x 25 = 48.832 KN

Weight of wall = dx (H-0.3) x 2π x (8.59/2) x 25 = 0.115 x (4.5-0.6) x 2π x 4.29 x 25

= 302.231 KN

Total weight = 277.928 + 48.832 + 302.231= 628.991 KN

Weight of water = rHπ $(\frac{D^2}{4})$= 9.81 x 4.5 x π x $\frac{8.29^2}{4}$ = 2382.760 KN

On edge of slab, Self-weight of slab,

Assuming slab thickness = $\frac{8.29}{35}$ = 0.236 = 300 mm

Self-weight of slab = 0.3x1x1x25 = 7.5 KN/m^2

Total self-weight = 7.5x$\frac{\pi}{4}$x8.59 = 434.647 KN

Finishing load = 0.6x$\frac{\pi}{4}$x8.29^2 =32.385 KN

Total downward load = 628.991 + 2382.760 + 434.647 + 32.385 = 3478.783 KN

Now, the slab may be treated as freely supported by walls and subjected to,

1) Uniformly distributed downward load of q = $\frac{2849.739}{\frac{\pi}{4}X8.59^2}$ = 49.173 KN/m^2

2) Upward beam load = 3478.783 KN

So, for Case I loading, a = 4.29 m, r = radius at any point slab,

$$M_r = \frac{3q}{16}(a^2 - r^2) = \frac{3X49.173}{16}(4.29^2 - r^2)$$

$$M_\theta = \frac{3q}{16}a^2 - \frac{qr^2}{16} = \frac{3X49.173}{16}4.29^2 - \frac{49.173r^2}{16}$$

Moments at critical path,

Table-3: Moment's calculation

r in m	0	1.554	3.108	4.29
M_r	169.684	147.419	80.623	0
M_θ	169.684	162.262	139.997	113.123

In case II

For r < 3.108

$M_r = M_\theta = \frac{W}{8\pi}[2\log\frac{a}{b} + 1 - \left(\frac{b}{a}\right)^2]$; for r > 3.108

$M_r = \frac{W}{8\pi}[2\log\frac{a}{r} - \left(\frac{b}{a}\right)^2 + \left(\frac{b}{r}\right)^2]$, $Mr = \frac{W}{8\pi}[2\log\frac{a}{r} - \left(\frac{b}{r}\right)^2 + 2 - \left(\frac{b}{a}\right)^2]$

Noting that a = 4.29; b = 3.108

Moments at critical point are listed below (Note- W upward. Hence may be taken as -ve)

Table-4: Moment's calculation

r in m	0	1.554	3.108	4.29
M_r	-104.51	-104.51	-104.51	0
M_θ	-104.51	-104.51	-104.51	-92.78

Net moment in the slab is given below,

Table-5: Net moment calculation

r in m	0	1.554	3.108	4.29
M_r	65.174	42.909	-23.887	0
M_θ	65.174	57.752	35.487	20.343

Design moment = 65.174 KN-m

$$d = \sqrt{\frac{65.174X10^6}{1.423X1000}} = 214 \text{ mm; Provide d = 215mm; t = 250mm}$$

Ast = $\frac{65.174X10^6}{150X0.87X250}$ = 1999.67 mm^2

Using 25 mm bars, S = $\frac{\frac{\pi}{4} X\, 25^2}{1999.67}$ x 1000= 245.47 mm

25 mm diameter bars @240mm c/c is required at top slab in radial direction at the edge,

Mθ = 65.174 KN-m hogging, d = 250-25 = 225mm

Ast = $\frac{65.174X10^6}{150X0.87X225}$= 2219.634 mm^2

Use 20 mm diameter bars, S = $\frac{\frac{\pi}{4}x20^2}{2219.634}$x1000 = 141.728 mm = 140 mm

Provide 20mm diameter bars @140 mm c/c at top of slab in circumferential direction at the outer edges of slab, 2 m x 2 m grid mesh at center.

viii) Design of beam: B =350 mm; D = 600 mm; BM = 925 KN-m; use M25 grade concrete Fe415 grade steel; Assume cover of 50 mm; d= 550 mm; Q = 0.138 x 25 = 3.45

Designed factored BM = 1.5 x 925 = 1387.5 KN- m

MR of limiting section; Mu lim = QBd^2 = 3.45 x 350 x 55 = 365.26 KN-m

BMu > Muim i.e., 1387.5>365.26; design the doubly reinforced section,

Part 1) Ast $_1$ = $\frac{\text{Mulim}}{0.87\text{fyjd}}$ = $\frac{365.26x10^6}{0.87x415x(1-0.42x0.48)x550}$ = 2303.835 mm^2

Part 2) Ast$_2$ = $\frac{\text{Bmu}-\text{mulim}}{0.87\text{fy}(d-dc)}$ = $\frac{1022.24x10^6}{0.87x415x(550-50)}$ = 5662.595 mm^2

Total Ast = Ast$_1$+ Ast$_2$ = 7966.43 mm^2

Provide 8 No. 36mm diameter bars, Asc = $\frac{904.18x10^6}{(fsc-0.45fck)(d-dc)}$;

Assume, fsc 353 N/mm^2; Asc = $\frac{904.18x10^6}{(353-0.45x25)(550-50)}$ = 5982.385 mm^2

Staad pro design and analysis

The ESR of capacity 216 m^3 with above dimensions designed and analyzed in staad pro software

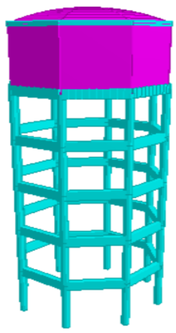

Fig-1:3D rendering view

The following are the images from staad pro design

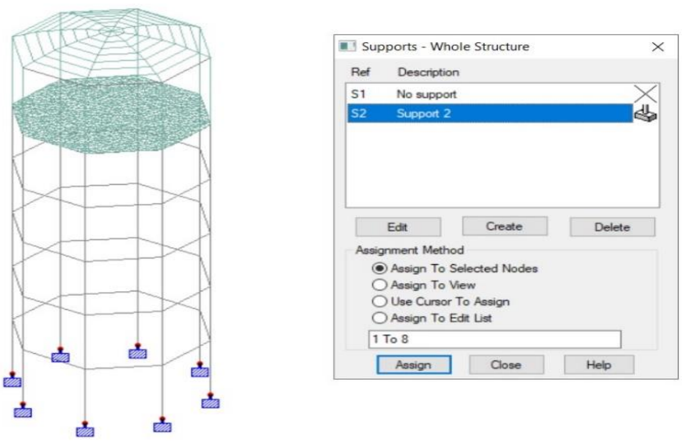

Fig-2: Assigning supports

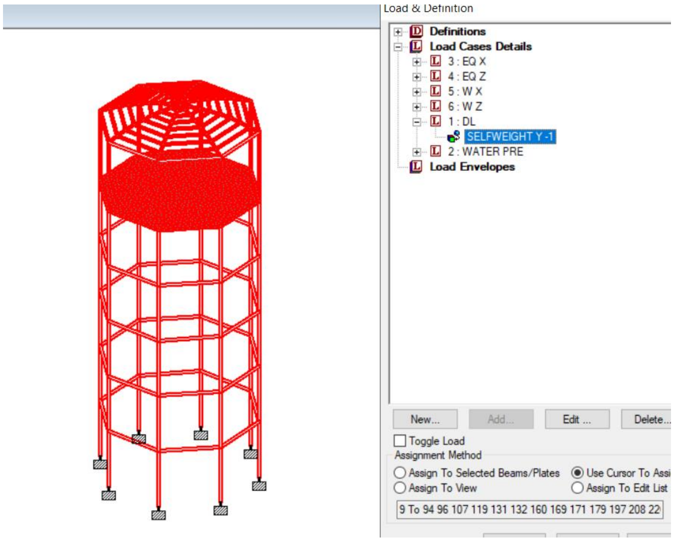

Fig-3: Assigning dead load

Estimation

After designing all the component of water tank, Estimate was prepared using MS Excel. The total estimated cost of ESR is Rs 36,66,928/-

III. CONCLUSION

1. The proposed tank in khanderajuri village is designed manually as well as in staad pro software.
2.Fluid density must be considered in design
3.Design in staad pro reduces total steel and concrete quantity, so it is economical
4.Total station survey was carried out which shows that old location is correct on basis of elevations
5.Design of ESR in staad pro reduces time and gives more accuracy than manual design

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