Design of Elevated Level Storage Reserviour

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***Abstract*: Without water survival is impossible. Water is one of the most important substances on earth. All plants and animals must have water to survive. If there was no water there would be no life on earth. As water is very precious and due to the scarcity of drinking water in day to day life one has to take care of every drop.A water tank is used to store water to tide over the daily requirement. In the construction of concrete structure for the storage of water and other liquids the imperviousness[1] of concrete is most essential. Overhead water tank is the most effective storing facility used for domestic or even industrial purpose. By considering all the requirements which are essential for economical[2] construction, in this project an overhead tank is designed for AITS college population of around 4,419 members by manually and using software. The complete design of the elevated structure is given in the project by using LIMIT STATE METHOD from IS: 3370-2009[3].**

Key words: Imperviousness, economical, IS:3370-2009

1 INTRODUCTION

Without water survival is impossible. Water is one of the most important substances on earth. All plants and animals must have water to survive. If there was no water there would be no life on earth. As water is very precious and due to the scarcity of drinking water in day to day life one has to take care of every drop. A water tank is used to store water for daily requirements like drinking, washing etc. An elevated water tank is a large water storage container constructed for the purpose of holding water supply at certain height to provide sufficient pressure in the water distribution system. Liquid storage tanks are used extensively used by municipalities and industries for storing water, inflammable liquids and other chemicals. These tanks have various types of support structures like RC braced frame, steel frame, RC shaft, and even masonry pedestal. The most commonly used staging in practice is the frame type. The main components of this type of staging are columns and braces. The staging acts like a bridge between the overhead container and foundation to transfer loads acting on the tank. Thus Water tanks are very important for public utility and for industrial structure and also to withstand more design forces. The frame support of the ELSR should have adequate strength to resist axial loads, moment and shear force due to lateral loads. These forces depend upon total weight of the structure, which varies with the amount of water present in the tank container.

1.1 TYPES OF WATER TANKS

The water tanks are majorly classified into water tank resting on ground, under the ground and the water tank about the ground. Based on the shape, water tanks are majorly circular rectangular and triangular shape. Elevated tanks are supported on staging which may consist of masonry walls, R.C.C. tower or R.C.C. columns braced together. The walls are subjected to water pressure. The base has to carry the load of water and tank load. The staging has to carry load of water and tank. The staging is also designed for wind forces. From design point of view the tanks may be classified as per their shape- rectangular tanks, circular tanks, intz type tanks. Spherical tanks conical bottom tanks and suspended bottom tanks. A circular shaped ELSR is adopted in this project for AITS College, Boyanpalli, Rajampeta, in Kadapa district in Andrapradesh.

1.2 METHODOLOGY

Limited cracking in the structure designed by working stress method was the main reason why the Indian Standard IS: 3370 (1965) did not adopt the limit state design method even after adoption by IS; 456 – 1978.However, with the following advantages of Limit State Design method, IS:3370 adopted Limit State Design Method in 2009.

i) Limit State Design Method considers the materials according to their properties

ii) Limit State Design Method considers the load according to their nature

iii) The structures also fails mostly under limit state and not in elastic state

iv) Limit State Method also checks for serviceability

IS: 3370-2009 Part (I-IV) adopts Limit State Design Method with precautions. It adopts the criteria for limiting crack width when the structures are designed by considering ultimate limit state and restricts the stresses to 130MPa in steel so that cracking width is not exceeded. These precaution ensures cracking width to be less than 0.2 mm i.e. fit for liquid storage. This also specifies clearly how a liquid storage structure differs with other structures.

1.3 DESIGN METHODS USED

As per discussion above, the three water tank design problems are designed by the following four design methods.

1. Working stress method in accordance IS 3370 (1965).
2. Working stress method in accordance IS 3370 (2009).

3. Limit state design method with crack width calculations and check in accordance IS 3370 (2009).
4. Limit state design method deemed to satisfy (limiting steel stresses) in accordance IS 3370 (2009).

1.4 FLEXIBLE BASE CIRCULAR WATER TANK

For smaller capacities rectangular tanks are used and for bigger capacities circular tanks are used .In circular tanks with flexible joint at the base tanks walls are subjected to hydrostatic pressure .so the tank walls are designed as thin cylinder. As the hoop tension gradually reduces to zero at top, the reinforcement is gradually reduced to minimum reinforcement at top. The main reinforcement consists of circular hoops. Vertical reinforcement equal to 0.3% of concrete are is provided and hoop reinforcement is tied to this reinforcement.

1.5 PERMISSIBLE STRESSES IN CONCRETE

Table: 1: Stress for different grades of concrete

GRADE OF CONCRETE	DIRECT PERMISSIBLE STRESS IN KN/M^2 TENSION	BENDING PERMISSIBLE STRESS IN KN/M^2 TENSION	SHEAR
M15	1.1	1.5	1.5
M20	1.2	1.7	1.7
M25	1.3	1.8	1.9
M30	1.5	2.0	2.2
M35	1.6	2.2	2.7
M40	1.7	2.4	2.9

2 DESIGN OF OVER HEAD WATER TANK

The water tank is designed for the AITS college population of 4,475. Based on the per capita demand for institutional buildings the capacity of the water tank is reached as 100KL. The salient features of the overhead water tank is as tabulated below.

Table: 2: Salient features of water tank

Grade of Concrete	:	M_{20}
Capacity of water tank	:	100KL
Staging of over head tank	:	16m
Number of columns	:	6
Number of braces	:	3
Inner diameter of tank	:	6 m
Height of cylindrical walls	:	4 m
Rise of dome	:	1.2 m
Thickness of dome	:	0.1 m
Thickness of cylindrical walls	:	0.18 m
Dimensions of columns	:	0.45 x 0.45m
Dimensions of braces	:	0.40 x 0.35m
Top ring beam size	:	0.2 x .2 m
Bottom ring beam size	:	0.3 x 0.2 m
Thickness of floor slab	:	0.1 m
SBC of soil	:	31.5t/m^2
Depth of footing	:	1.37 m

STRENGTH PARAMETERS

Concrete Grade
: M_{20}

Permissible stresses (from IS 3370{ part-2}:2009)

Direct tensile stress : 2.8 KN/m^2
Direct compressible stress : 5 N/mm^2
Bending compressive stress (σcbc) : 7 KN/m^2
Characteristic compressive stress (fck) :20 N/mm^2
Grade (for staging and sub structure)
:H.Y.S.D Fe415

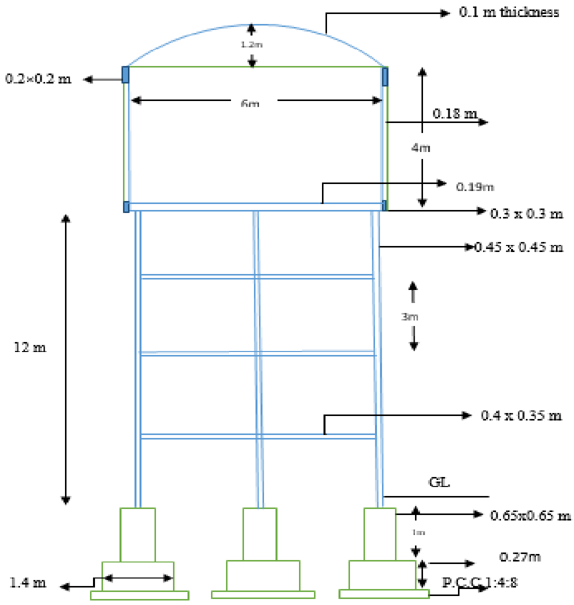

Fig: 1: Circular shaped ELSR

2.1: POPULATION FORECASTING:

Different methods of population forecasting are
1. Arithmetic method
2. Geometric method
3. Incremental method
4. Logistic method
5. Graphical method

By using geometric method population forecasted to 4,475. The total capacity of water required for the population is calculated as 100KL included with the fire demand.
For the capacity obtained size of the tank is decided as
Radius of the overhead tank: 3m
Height of the overhead tank: 4m

2.2: Design of dome:

Minimum dome thickness must not be less than 100mm. Hence thickness of dome is assumed as 100mm.
Meridional Thrust $T_1=(WR/(\cos\theta+1))$
Meridional stress $=T_1/(bXd)$
Hoop stress $=\frac{w\times R}{t}\times\left(\cos\theta-\frac{1}{1+\cos\theta}\right)$

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Meridional and hoop stresses developed in the spherical dome are 0.19N/mm^2 and 0.04N/mm^2 respectively. The obtained stresses are within the permissible stresses are the dome is safe against the stresses.
Total load on the dome is calculated as: 5 KN/m^2
Factored load on the dome : 7.5 KN/m^2
Providing minimum percentage of steel in the dome: A_{st}= 0.3% (cross sectional area)

=300mm^2
Hence provided reinforcement: 8mm Ø bars of 190mmc/c

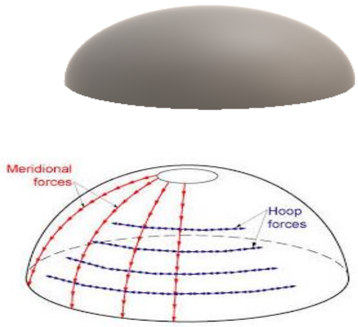


Fig : 2 : Meridional and hoop stresses in spherical dome.

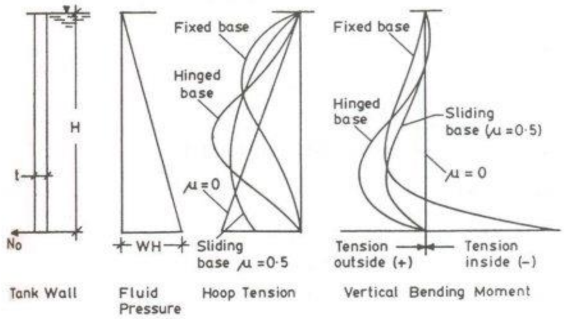
2.3: DESIGN OF TOP RING BEAM:

Horizontal components of thrust(Ht) = T_1xcosΘ
Hoop tension in ring beam(Ft) = Ht x(D/2)

$$\text{Tensile stress} = \frac{Ft}{Ac+(m-1)\times Ast}$$

Area of concrete calculated as 607mm^2
Hence provided a ring beam of size 200X200mm
Total load on top ring beam = 7.5 KN/m^2
Reinforcement provided as 4 no's of 20mm Ø bars.

2.4: DESIGN OF CYLINDRICAL WALL:



Hoop Tension and Bending Moments in Cylindrical Tank Walls

The reinforcement details of the cylindrical side wall with a hoop tension of 76.1KN was given as tabulated below

Table: 3: Reinforcement details in cylindrical side wall

Height above floor slab(m) (H^2/Dt)	Height below (M.W.L)	Hoop coefficient	Hoop tension (KN)	Area (mm^2) Both faces	Reinforcement on each face		Proposed area (mm^2)
					No .of bars	spacing	
4	0.0H	0.0002	0.152	0.1	10	200	392
3.6	0.1H	0.0989	7.526	49.87	10	200	785
3.2	0.2H	0.1991	15.15	100	10	200	785
2.8	0.3H	0.3042	22.14	153	10	150	1046
2.4	0.4H	0.4137	31.48	209	10	140	1611
2	0.5H	0.5318	40.46	268	10	130	1740
1.6	0.6H	0.6408	48.76	323	10	130	1740
1.2	0.7H	0.6849	52.12	345	10	120	1884
0.8	0.8H	0.5779	39.41	261	10	120	1884
0.4	0.9H	0.2620	19.93	132	10	120	1884

2.4: DESIGN OF BOTTOM RING BEAM:

Horizontal thrust, H $= T_1 \cos\alpha$

$$= \frac{V_1}{\sin\alpha} x \cos\alpha$$

$= V_1 \cot\alpha$

Tension due to vertical loads H_g = HD/2

$$\text{Hoop tension due to water pressure } H_W = \frac{WhXdXD}{2}$$

Total load on bottom ring beam = 7.5KN
Total factored load = 114.75 KN/m
Total Hoop tension on bottom ring beam=hoop tension due to vertical loads+ hoop tension due to water pressure = 389 KN
The main reinforcement provided as 8no's of 20mmØ @ 120mm c/c.

2.5: DESIGN OF CIRCULAR SLAB:

For every of the elevated water tank options, the base slab characteristic serviceability uniformly distribute load in kN/m per meter was the sum of its dead load, self-weight concrete and its finishing loads , and its live load, that is, the weight of water to be contained. And the serviceability point load in kN / meter, acting on each of the base slabs, at the extremes of the overhangs was derived by adding up the wall dead load that is the base projection weight and a calculated fraction of the top slab load. But some notice difference may be experience in the calculations of the fractions of the loads from the circular water tank top slabs.
Thickness of circular slab =100mm
Clear span of the slab = 6m
Total load on the slab = 43.5 KN/m^2
Total factored load on the slab = 62.25KN/m^2

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Moment $\mathbf{M_u}$ = $(Wa^2/6)$
A_{st} provided as $412mm^2$
The reinforcement provided in the slab was 10mm Ø @ 190mm c/c

2.6: DESIGN OF COLUMNS:

Size of the column = 450X450mm
Total vertical load on column =445.46 KN
Wind intensity = 1.5 KN/m^2
Number of columns = 6
Moment at column base = 13.5 KN/m
Reinforcement provided was 6no's of 20mm Ø @ 300mm c/c

2.7: DESIGN OF BRACINGS:

Number of bracings = 6
Size of bracings = 400X350mm
Provide 4 bars of 16 mm diameter.

2.8: DESIGN OF FOOTINGS:

Soil bearing capacity for the soil was $31.5t/m^2$
Total load on the footing = 396KN
Total factored load = 594KN
Size of the footing was decided as 1.4X1.4m
Provide 5no's of 12mm Ø @ 220mm c/c.

2.9: ESTIMATION OF OVERHEAD WATER TANK

Unit	Description	Rate	Total amount
	Rate for 100KL ELSR	20.50	
	Rate for 500 KL ELSR	18.27	
	Rate for 1000KL ELSR	15.10	
	Rate for 100 KL ELSR		20.50
	For 16Mts Staging		
	For staging more than 15 Mt , the Rate shall be increased by Rs.0.10 Paisa on basic rate per every meter increase in staging		0.10
	For SBC of 14.0 T/sq m		
	For every decrease of 2.50 T/Sq m of SBC the rate shall be increased by 2.5%bon basic rate and for every increase of 2.5 T/Sq m of SBC the rate shall be decreased by 0.1% on basis rate		-0.70
	Wind pressure		
	The above rate are applicable for wind pressure up to 350Kgs/Sq m for every 100 Kg/Sq m decrease in wind pressure the rate is to be decreased by 5% (PH SSR item No. 43 (11)) formula = Basis		-1.51
	Cement variation		
	The above rate shall be increased / decreased due to increase/decrease in cost of cement by basic rate * (6400-4000)*0.00007(PH SSR item No.43(7))		2.54
	Steel variation		
	The above rate shall be increased / decreased due to increase/decrease in cost of steel by basic rate (42000-46500)*0.00002		-1.36
	Note : For every 1 m increase/decrease in length of compound wall the increase / decrease in basic rate of capacities from 500 to2500 KL as follows. 500KL=0.086% , 1000KL = 0.047%		0.00
			20.88
	Add contractors profit @ 13.615%		2.02
	Total rate		
Provision Towards VAT @ 5%			0.84
Provision Towards Labor Cess@1%			0.17

TOTAL RATE : 23.91 PER LITRE
Total rate for 100 KL ELSR=23.91*100*100/10000
RS.23.91 Lakhs

3. CONCLUSION:

Elevated water tanks provide head for supply of water. When water has to be pumped into the distribution system at high heads without any pumps for supply however pumps are necessary for pumping only till tank is filled. Once it is stored in tank the gravity creates the pressure for free, unlike pumps. We need pressurized water to fledge and make taps eject water at an appropriate rate. Elevated tanks do not require continuous operation of pump, as it will not affect the distribution system since the pressure is maintained by gravity. Strategic location of tank can equalize water pressure in the distribution system. The design of overhead tank is designed manually and a rough estimation for the proposed water tank is included.

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