"STUDY ON DIFFERENT SHAPES OF 5 LAKH LITERS CAPACITY 80M STAGING ELEVATED SERVICE RESERVOIRS"

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ABSTRACT
Elevated service reservoirs (ESR) are structures intended to accommodate water at a predetermined height. Structurally, a water tower comprises a tank, a support and a foundation. The present work is concentrated on two major aspects relating to Dynamic Analysis and Design of elevated Water reservoir for critical basic wind speed of 230 Km\hr. The first part of the present study has been focused on the development of general program to the wind load calculation of the Structure at different heights using MATLAB and the second part of the work focusing the best possible Reservoir for a height of 60m Stage of 5 Lakh liters capacity in different load combinations. Different types of Reservoir like circular with bottom dome Tank, Intze Tank and Conical Tanks have been used and its efficiency has been studied. The modeling and analysis has been done using the STAAD pro. They have been studied for different parameters for a particular capacity of the water tank. Apart from structural safety and viability the economic aspect has also been looked into, which is very much important in the civil engineering field. The present study suggests that the choice of a particular reservoir is definitely depending on the configurations of the structure.
Keywords: Elevated service reservoirs, , wind loads, Staad pro.

Introduction

Elevated water tanks or elevated service reservoirs (ESR) are quite commonly used in water distribution systems. elevated service reservoirs are generally located at higher altitude like top of the hillock; hence they are subjected to severe wind loads. An elevated tank consists of two parts:

1. Container and
2. Staging

Container can be cylindrical, rectangular, conical or intze in shape. Similarly staging which supports the container can be shaft type, or space frame type. In India, elevated tanks are generally Reinforced cement concrete (RCC).

Earlier works

From the review of earlier investigations it is found that considerable work has been done on the method of analysis and design of water towers. Attempts have also been made by various designers and research workers to give the ratio of optimized geometrical parameters for the design of container and optimized parameters for the design of staging. Very little work has been made on over all Economy of the elevated water reservoir.

Objectives of the Present Study

The importance of overhead tanks, as utility structures needs no highlighting; hence the safety of the structure is of utmost importance. The present study has been made to fulfill the various objectives such as:

1. To study the practice of design and construction of different type of water tank.
2. To study the Indian standard codal guidelines for the design of such tanks.
3. To study the suitability of different types of optimum values considering the design of such tanks in particular site conditions and height of staging for a 500 cum capacity of the different water tank.
4. To check the efficiency of a different tank with respect to economy.

Computer Program to Generate Wind loads

A ' MATLAB' Program has been Developed, which is capable of generating the Design wind Speed, Design Pressure, Solidity Ratio, Force Coefficient and Wind load for Different Height as per the Indian Standard Specifications (IS 875 (3), by Specifying the Dimension of Structure, Basic wind speed, Risk Coefficient, Terrain, Topography And type of Structure. The Generated Data's are used as input for the Analysis of structures.

Wind load calculation:

1. Wind Speed: 63.88 m/Sec

2. Probable design of structure: 100 years.

3.Terrain category: 2
4. Class of structure: C
5.Topography: Less than 3^{o}degree slope

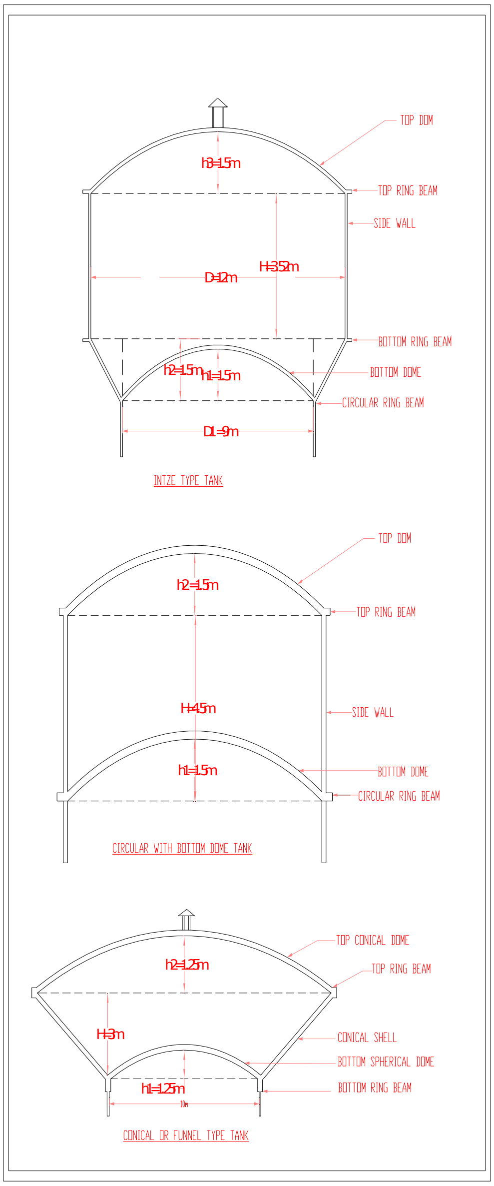

Figure 1.containers

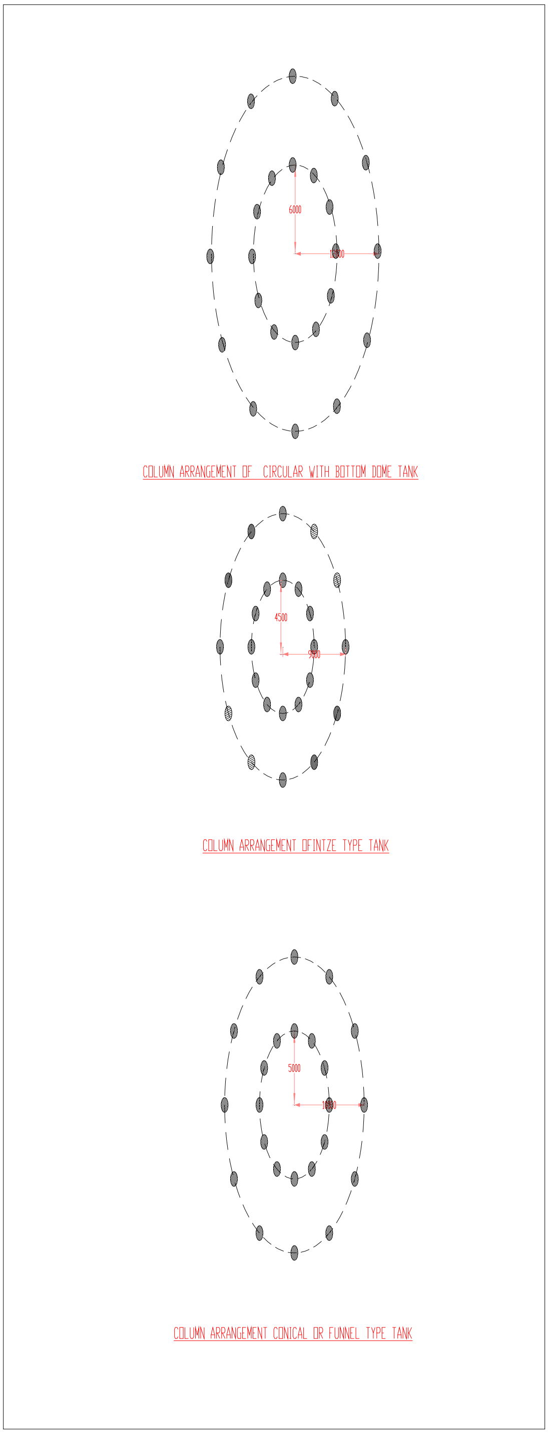

Figure 2. plan of towers

Wind load calculation 60m Staging

Table 1.wind pressure calculation

Elevation	V_b	K_1	K_2	K_3	Vz (m/sec)	Pz (KN/m^2)
10	63.88	1.08	0.67	1	46.2236	1.2820
15	63.88	1.08	0.72	1	49.6731	1.4804
20	63.88	1.08	0.75	1	51.7428	1.6064
30	63.88	1.08	0.79	1	54.5024	1.7823
50	63.88	1.08	0.85	1	58.6418	2.0633
60	63.88	1.08	0.87	1	60.0216	2.1615

Table 2.Solidity ratio & Cf calculation

ITEM	Solidity Ratio	C_f
Circular	0.43	1.1
Intze	0.451	1.159
Conical	0.472	1.177

Table 3.Wind force obtained for Circular Tank Tower

Elevation (m)	Wind force(KN/m^2)
F_{10}	3.37
F_{15}	3.95
F_{20}	4.39
F_{30}	4.95
F_{50}	5.84
F_{60}	6.24

Table 4.Wind force obtained for Intze tank Tower

Height	Wind force(KN/m^2)
F_{10}	3.53
F_{15}	4.13
F_{20}	4.59
F_{30}	5.19
F_{50}	6.12
F_{60}	6.58

Table 5.Wind force obtained for Conical Tank Tower

Height	Wind force (KN/m^2)
F_{10}	3.58

F_{15}	4.18
F_{20}	4.65
F_{30}	5.25
F_{50}	6.2
F_{60}	6.672

Table 6.wind pressure calculation for Circular Container

Elevation	V_b	K_1	K_2	K_3	Vz (m/sec)	Pz (KN/m^2)
66	63.88	1.08	0.88	1	60.71	2.21

Table 7. Solidity ratio & Cf calculation for Circular Container

ITEM	C_f
Circular	0.7
Intze	0.7
Conical	0.7

Table 8.Wind force obtained for Circular Tank Container

Height	Wind force(KN/m^2)
F_{66}	3.65

Table 9. wind pressure calculation for Intze Container

Elevation	V_b	K_1	K_2	K_3	Vz (m/sec)	Pz(KN/m^2)
66.52	63.88	1.08	0.882	1	60.84	2.221

Table 10.Wind force obtained for Intze Container

Height	Wind force KN/m^2
$F_{66.52}$	3.68

Table 11.wind pressure calculation for Conical Container

Elevation	V_b	K_1	K_2	K_3	Vz (m/sec)	Pz(KN/m^2)

66.52	63.88	1.08	0.878	1	60.57	2.201

Table 12.Wind force obtained for Conical Container

Height	Wind force (KN/m^2)
$F_{64.5}$	3.64

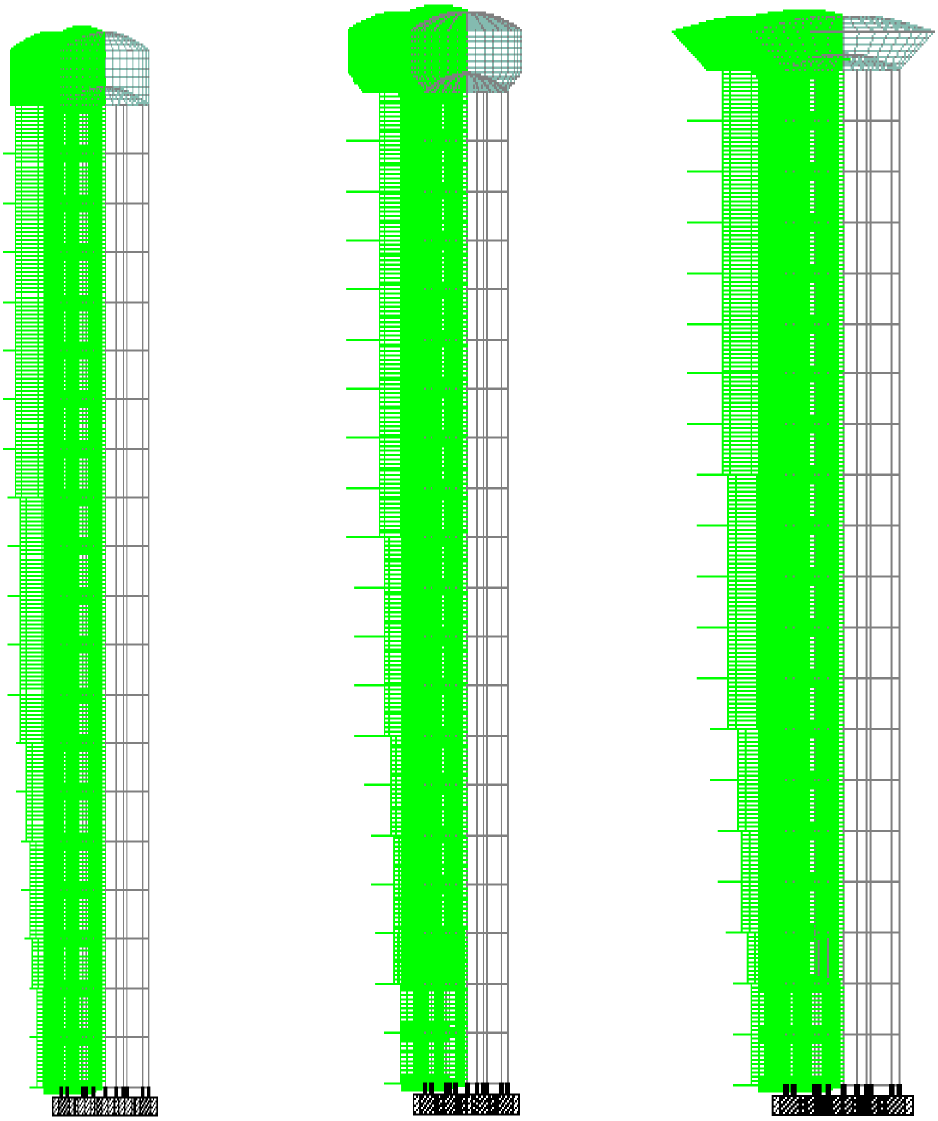

Figure 3.Circular Tank Intze tank, Conical Tank subjected to wind Load

Results and discussion

Table 13. Force and section obtained for Circular Container

SL NO	Item	Meridian stress N/mm^2	Circumferential Stress N/mm^2	Hoop Tension KN	Hoop Stress N/mm^2	A_{st} mm^2
1	Top dome (100 mm thk)	0.352	0.194	-	-	300
2	Top Ring Beam (300 x400 mm)	-	-	178.87	-	1192.48
3	cylindrical wall (160 mm thk)	-	-	235.2	-	1568
4	Bottom Dome (200 mm thk)	1.1327	-	-	0.5091	600
		Max(-) Bending moment KN-m	**Max (+)bending moment KN-m**	**Torsional moment KN-m**	**Shear force at support Section KN**	**Area of steel A_{st} mm^2**
5	Bottom Ring Girder (1500 x800 mm)	827.42	413.71	43.17	374.55	3600

Table14.Force and section obtained for Intze Container

SL NO	Item	Meridian stress N/mm^2	CircumferentialStress N/mm^2	Hoop Tension KN	Hoop Stress N/mm^2	A_{st} mm^2
1	Top dome (100 mm thk)	0.352	0.194	-	-	300
2	Top Ring Beam (300 x400 mm)	-	-	178.87	-	1192.48
3	cylindrical wall (160 mm thk)	-	-	241.047	-	1609.81
4	Bottom Ring Beam (300 x400 mm)	-	-	573.18	-	3821.2
5	conical Dome (250 mm thk)	1.460	-	191.35	-	1275.694
6	Bottom Dome (200 mm thk)	0.867	-	-	0.389	600
		Max(-) Bending moment KN-m	**Max (+)bending moment KN-m**	**Torsional moment KN-m**	**Shear force at support Section KN**	**Area of steel A_{st} mm^2**
7	Bottom Ring Girder (1200 x600 mm)	748.59	504.49	39.058	451.8244	3338.193

Table 15. Force and section obtained for Conical Container

SL NO	Item	Meridian stress N/mm^2	Circumferential Stress N/mm^2	Hoop Tension KN	Hoop Stress N/mm^2	A_{st} mm^2
1	Top dome (100 mm thk)	0.3982	-	-	0.7495	300
2	Top Ring Beam (500 x400 mm)	-	-	309	-	2060
4	Inner shaft (100mm thk)		-	-	0.307	300
5	conical Dome (250 mm thk)	0.518	-	248.132	-	1653.33
6	Bottom Dome (150 mm thk)	0.99	-	-	0.307	450
		Compressive stress				A_{st} mm^2
7	Bottom Ring Beam (500 x400 mm)	748.59	-	-	-	600

Staging Details

The configuration shown in fig is subjected to wind load analysis of the top level. Deflection is limited to H/500. The design of the structure is done using Gust Factor Method. The same model is subjected to Gust load and design output for beams and columns are obtained.

Table 16.Member force on columns for Circular 60m Staging

Height	Axial load(P_u) ,KN	Moment (M_z) ,KN-m	Moment (M_y), KN-m	Area of steel (A_{st}) mm^2
0- 20 m	4116.36	579.1	13.64	9249
20-40 m	3794.06	343.06	42.82	6032
40 – 60 m	3044.39	228.82	48.26	4021

Table 17. member forces on braces for Circular 60m Staging

Item	AXIAL	SHEAR Y	SHEAR Z	TORSION	MOM Y	MOM Z	A_{st} mm^2
Outer	49176	218.178	9.174	1.28	13.992	331.475	2746.231
	-12.009	-218.17	-9.174	-1.28	-4.495	-325.695	
Intermediate	73.438	255.05	15.693	2.54	27.801	375.444	3392.821
	-9.13	238.06	-15.693	-2.54	-27.80	-370.622	
Inner	79.301	664.213	36.143	4.163	26.836	511.67	5202.661
	49.808	664.213	36.143	-4.163	-29.48	514.68	

Table.18. Member force on columns for Intze 60m Staging

Height	Axial load(P_u),KN	Moment (M_z),KN-m	Moment (M_y), KN-m	Area of steel (A_{st}) mm^2
0- 20 m	4108.15	514.61	11.25	8847
20-40 m	3792.83	301.98	34.41	6032
40 – 60 m	3037.86	186.71	39.38	4021

Table 19. Member forces on braces for Intze 60m Staging

Item	AXIAL	SHEAR Y	SHEAR Z	TORSION	Moment in Y	Moment in Z	A_{st} mm^2
Outer	44.536	223.043	7.861	0.957	8.977	256.539	2910.144
	-9.747	-223.04	-7.861	0.957	-9.334	252.655	
Intermediate	72.597	250.83	13.424	2.961	17.763	278.416	3280.67
	-50.038	243.062	-13.424	-2.961	-17.76	-275.93	
Inner	57.694	689.389	31.791	3.875	19.386	401.572	5360.66
	-40.20	689.377	31.792	3.875	-17.64	-401.225	

Table 20.Member force on columns for conical 60m Staging

Height	Axial load(P_u) ,KN	Moment (M_z) ,KN-m	Moment (M_y), KN-m	Area of steel (A_{st}) mm^2
0- 20 m	3954.33	530.12	12.04	9249
20-40 m	3639.61	312.54	37.18	6434
40 – 60 m	2894.45	198.65	42.75	4423

Table 21. Member forces on braces for conical 60m Staging

Item	AXIAL	SHEAR Y	SHEAR Z	TORSION	Moment in Y	Moment in Z	A_{st} mm^2
Outer	35.507	219.658	8.09	0.930	10.275	279.594	2754.25
	-10.529	-219.65	-8.09	-0.930	-10.66	-276.137	

Intermediate	63.67	123.90	13.825	2.149	20.386	307.634	3196.94
	-12.396	249.703	-13.825	-2.149	-20.38	304.692	
Inner	62.843	671.11	31.515	3.420	19.547	432.98	5023.966
	42.034	671.11	-31.515	-3.420	-21.38	-433.910	

Table 22. Sectional properties for 60 m staging

Item	Circular Tank	Intze Tank	Conical Tank
Column Dimension	0.8 m	0.8 m	0.8 m
Beam Dimension	0.5 x 0.3 m	0.4x 0.35 m	0.5 x 0.3m

Foundation for Circular Tank

1) Total Weight on the soil = 49567.349 KN

2) SBC of soil = 200 KN/m^2

3) Area of footing Provided = 254.34 m^2

4) Upward soil pressure (W) = 194.88 KN/m^2

Table 23.Forces and sections on Circular girder for circular tank

SL NO	Item	Max (-)Bending moment KN-m	Max (+)Bending moment KN-m	Torsoinal moment KN-m	Shear Force at support Sec KN	Eqiuvent Bending moment KN	Area of Steel A_{st} mm^2

1	Bottom Ring Girder (1000 x900 mm)	2225.25	1112.64	116.10	671.88	2691.94	8285.45

Table 24. Forces and sections on raft slab for circular tank

SL NO	Item	Moment KN -m	Shear force KN	A_{st} mm^2
1	Slab (300 mm)	99.27	155.71	1040

Foundation for Intze Tank

1) Total Weight on the soil = 45747.37 KN

2) SBC of soil = 200 KN/m^2

3) Area of footing Provided = 234.94 m^2

4) Upward soil pressure (W) = 194.722 KN/m^2

Table 25. Forces and sections on Circular girder for Intze tank

SL NO	Item	Max (-)Bending moment KN-m	Max (+)Bending moment KN-m	Torsoinal moment KN-m	Shear Force at support Sec KN	Eqiuvent Bending moment KN	Area of Steel A_{st} mm^2
1	Bottom Ring Girder (1000 x800 mm)	1564.661	782.33	81.634	839.861	2472.32	8561.06

Table 26. Forces and sections on raft slab for Intze tank

SL NO	Item	Moment KN -m	Shear force KN	Area of Steel A_{st} mm^2
	Slab(500mm)	451.335	348.875	3200

Foundation for Conical Tank 80m

1) Total Weight on the soil = 45531.377 KN

2) SBC of soil = 200 KN/m^2

3) Area of footing Provided = 234.94 m^2

4) Upward soil pressure (W) = 193.80 KN/m^2

Table 27. Forces and sections on Circular girder for Conical tank

SL NO	Item	Max (-)Bending moment KN-m	Max (+)Bending moment KN-m	Torsoinal moment KN-m	Shear Force at support Sec KN	Eqiuvent Bending moment KN	Area of Steel A_{st} mm^2
1	Bottom Ring Girder (1000 x900 mm)	1788	840	93.286	777.388	2833.45	9344.02

Table 28. Forces and sections on raft slab for Conical tank

SL NO	Item	Moment KN -m	Shear force KN	A_{st} mm^2
1	Slab (600mm)	483.599	348.54	2520

Conclusions:

From the present study it can be clearly seen that Elevated water reservoirs are affected by its structural configuration and analysis of the frame type structures is quite complex than the other type of structures. The developed wind load calculation program can help future researchers in this field to get aquatinted with the working of high-rise structures, as well as to use them for solving practical problems affected by wind. Among these three types of elevated water reservoirs the intze type elevated water tank is the most economical than the other types of elevated water reservoir for the Staging height of 80m and having Sound in structural systems, serviceability and durability.

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