

“A STUDY ON 80 M STAGING ELEVATED WATER 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 of tank, support and foundation. A structure consists of a series of connected parts used to support loads. Some of the elements composing a structure are slabs, beams, and columns. 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 attempt has been made in the second part of the work focusing the best possible reservoir for a height of 80m 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 have 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. A judicious choice can be made after taking this kind of analysis, which results in the optimization of the resource and ensures safety as well.

Keywords: *Elevated service reservoirs, Staad pro, wind loads.*

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).

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° degree slope

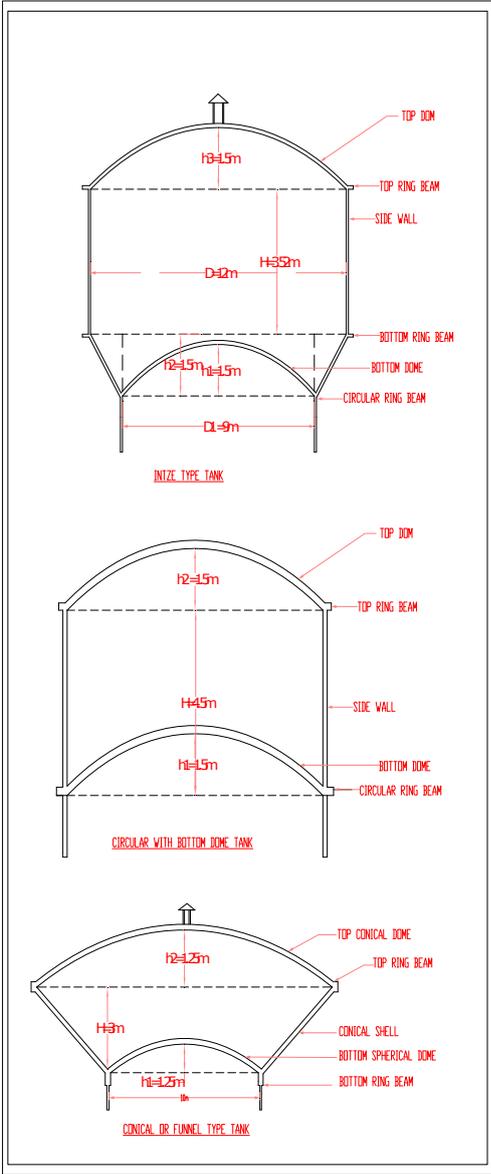


Figure 1.containers

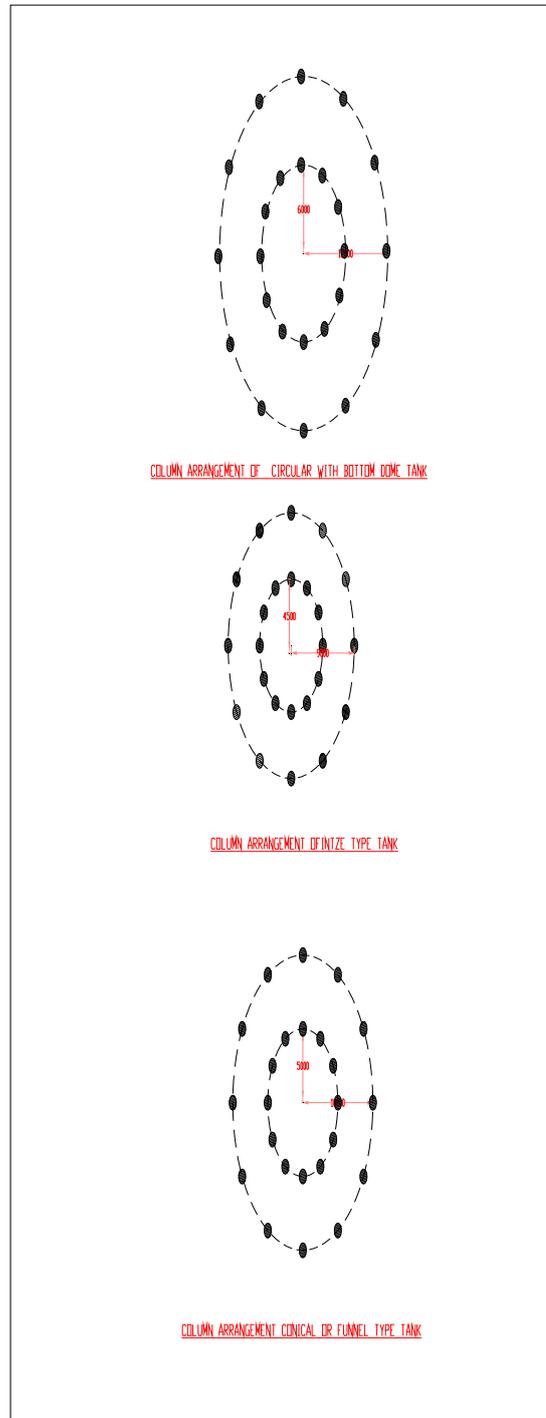
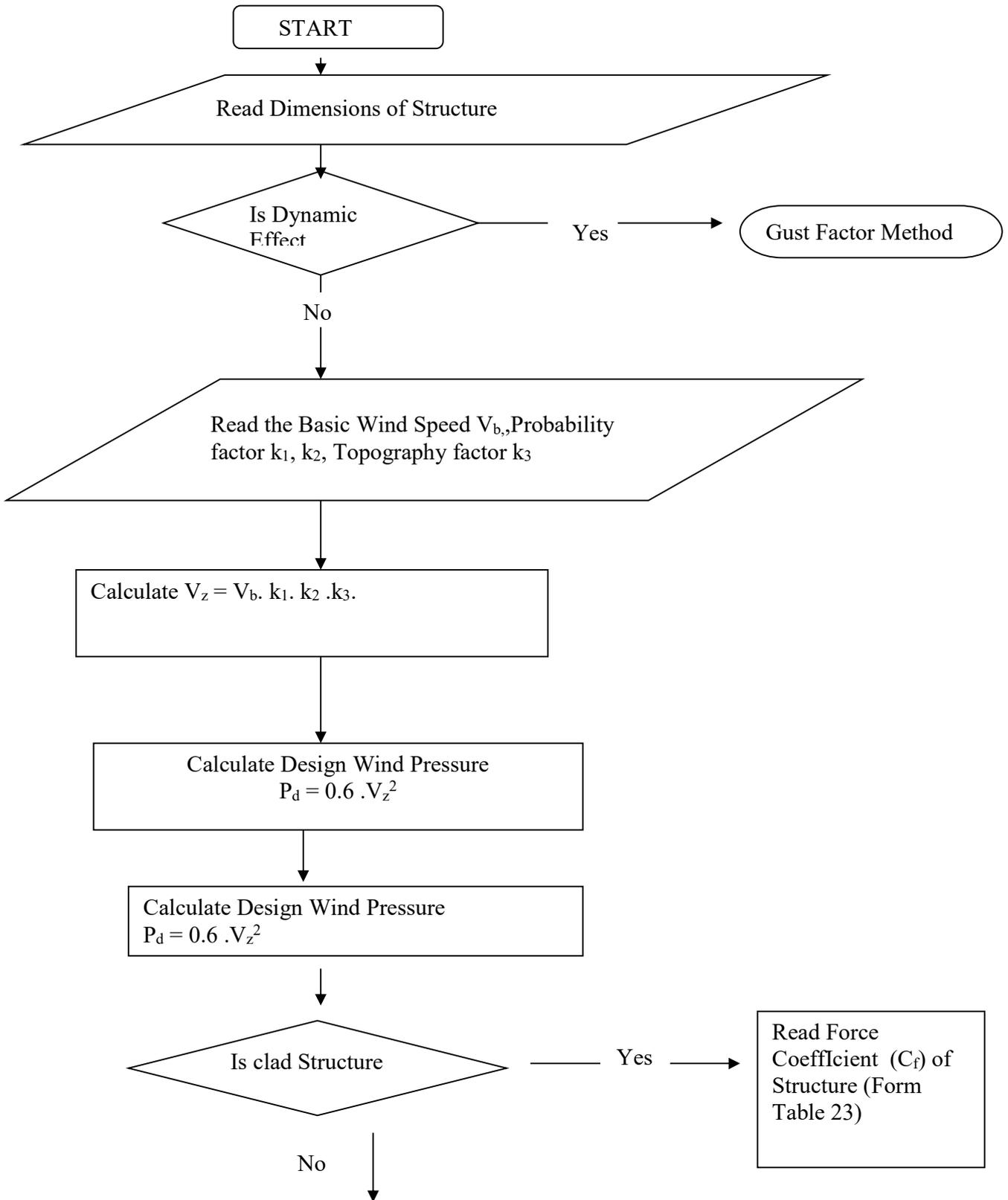
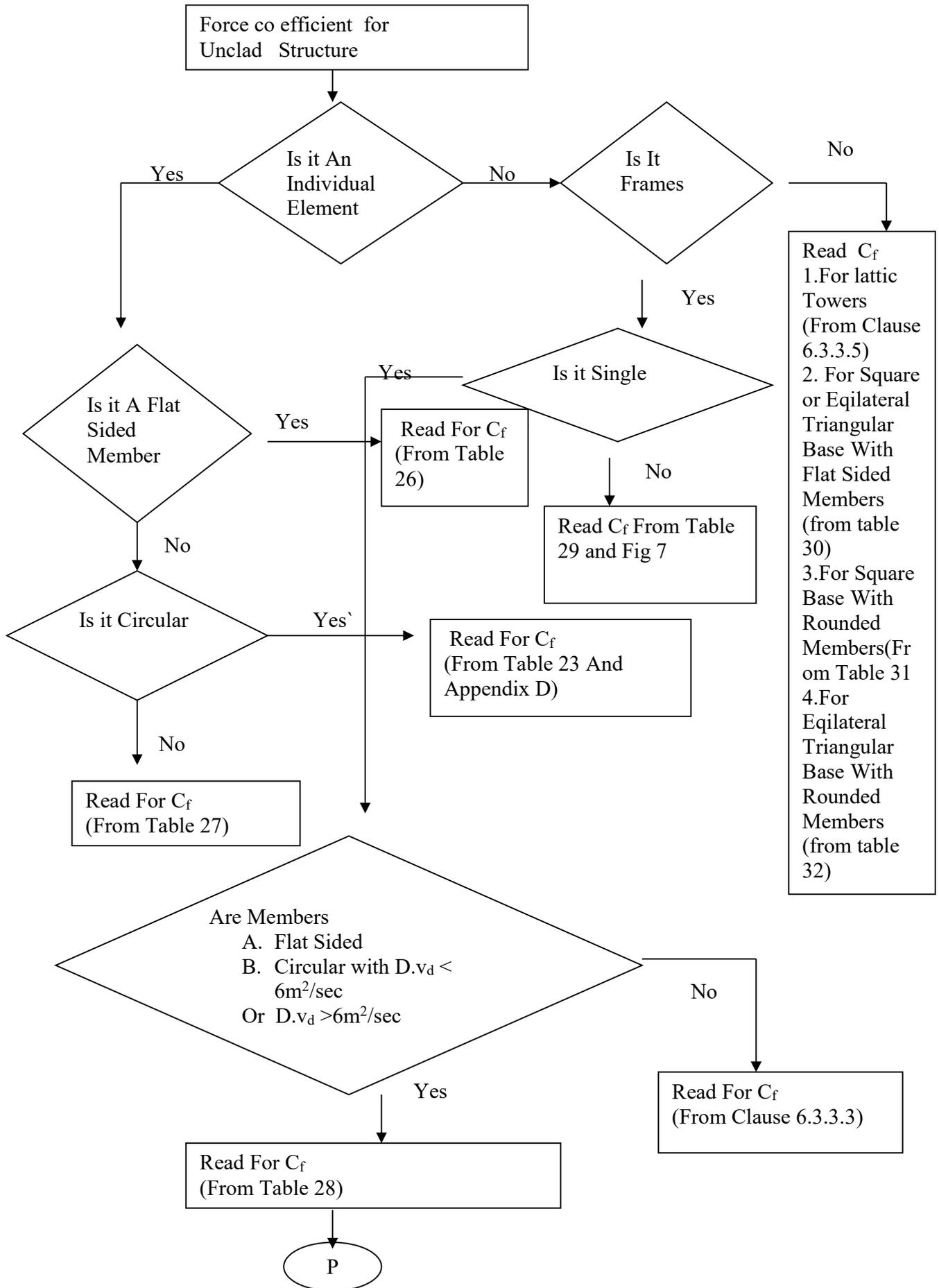
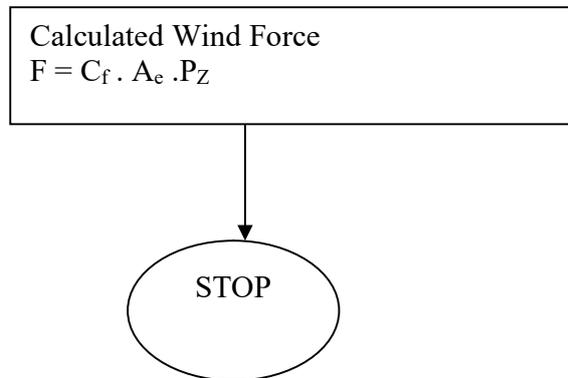


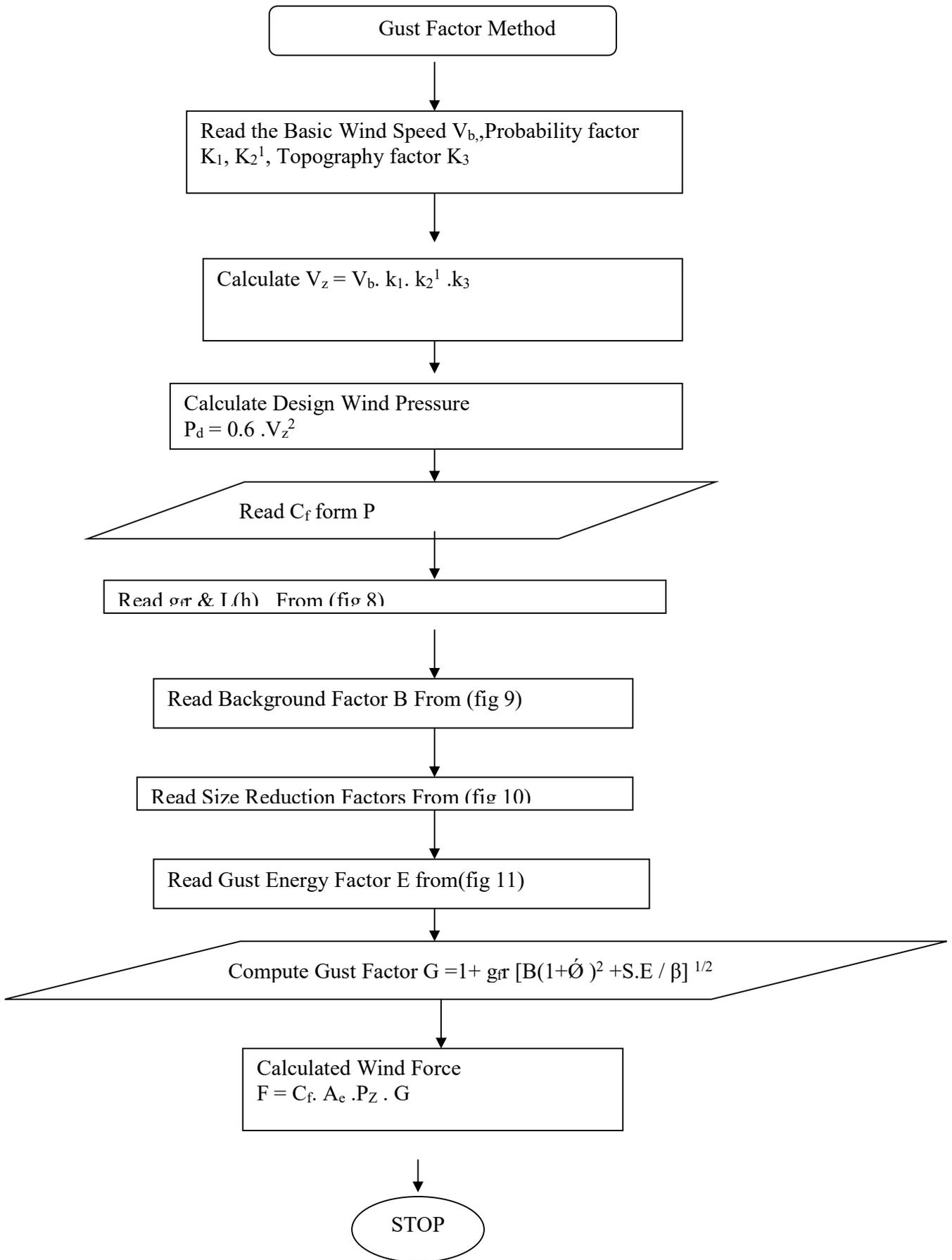
Figure 2. plan of towers

FLOW CHART FO WIND LOAD CACULATION









Wind load calculation 80m Staging**Table 1. wind pressure calculation**

Elevation	V_b	K_1	K_2	K_3	V_z (m/sec)	P_z (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
80	63.88	1.08	0.89	1	61.4015	2.2621

Table 2. Solidity ratio & C_f calculation

ITEM	Solidity Ratio	C_f
Circular	0.615	1.25
Intze	0.499	1.09
Conical	0.46	1.11

Table 3. Wind force obtained for Circular Tank Tower

Elevation (m)	Wind force(KN/m ²)
F ₁₀	3.13
F ₁₅	3.68
F ₂₀	4.04
F ₃₀	4.52
F ₅₀	5.3
F ₈₀	5.88

Table 4. Wind force obtained for Intze tank Tower

Height	Wind force(KN/m ²)
F ₁₀	3.072
F ₁₅	3.61
F ₂₀	3.96
F ₃₀	4.4
F ₅₀	5.198
F ₈₀	5.767

Table 5. Wind force obtained for Conical Tank Tower

Height	Wind force (KN/m ²)
F ₁₀	3.09
F ₁₅	3.52
F ₂₀	3.98
F ₃₀	4.45
F ₅₀	5.22
F ₈₀	5.80

Table 6. wind pressure calculation for Circular Container

Elevation	V _b	K ₁	K ₂	K ₃	V _z (m/sec)	P _z (KN/m ²)
86	63.88	1.08	0.88	1	60.71	2.21

Table 7. Solidity ratio & C_f 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 ₈₆	3.712

Table 9. wind pressure calculation for Intze Container

Elevation	V _b	K ₁	K ₂	K ₃	V _z (m/sec)	P _z (KN/m ²)
86.52	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 _{86.52}	3.902

Table 11. wind pressure calculation for Conical Container

Elevation	V _b	K ₁	K ₂	K ₃	V _z (m/sec)	P _z (KN/m ²)
86.52	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 _{84.5}	3.61

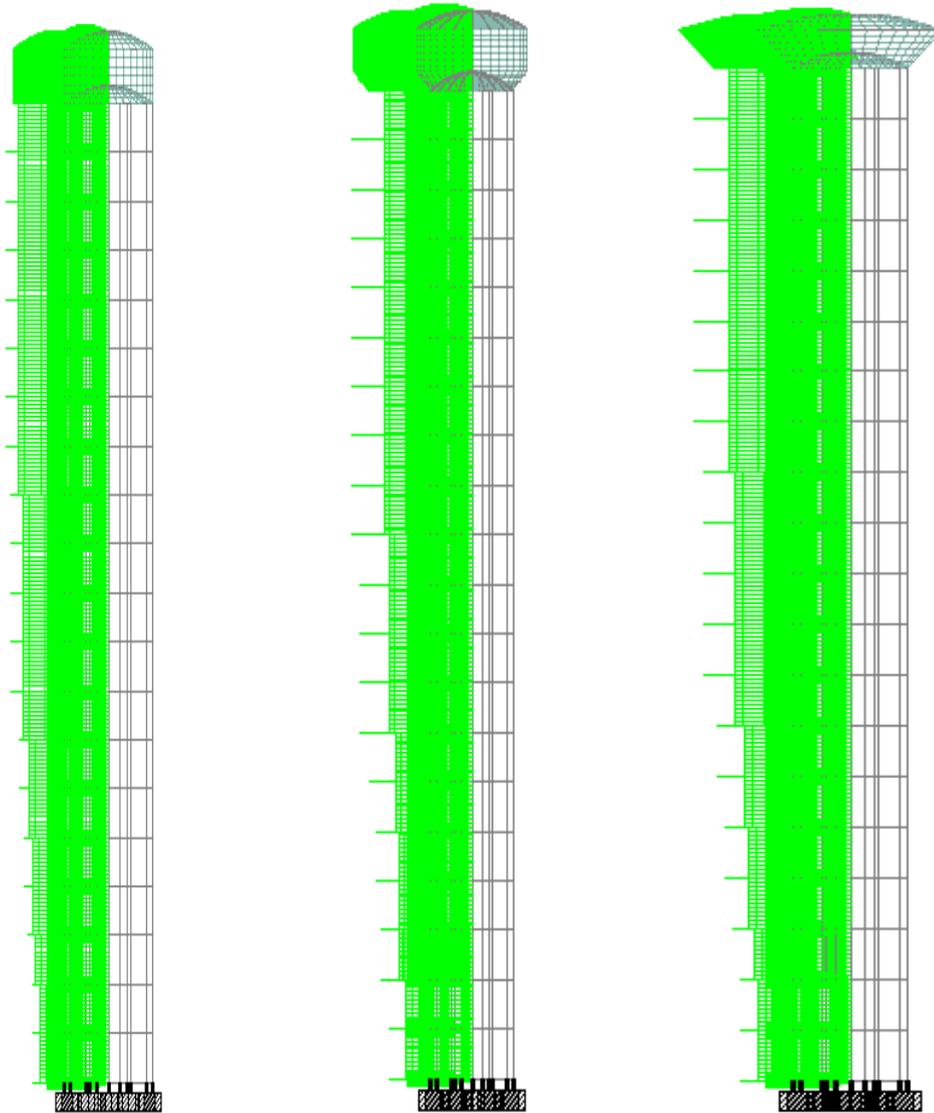


Figure 3. Circular Tank Intze tank, Conical Tank subjected to wind Load

Results and discussion**Table 13. Force and section obtained for Circular Container**

SL NO	Item	Meridian stress N/mm²	Circumferential Stress N/mm²	Hoop Tension KN	Hoop Stress N/mm²	A_{st} mm²
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 neg BM KN-m	Max pos BM KN-m	Tor moment KN-m	S F at sup KN	A_{st} mm²
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	Circumferenti al 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)	-	-	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 at support Section, KN	Area of steel (A_{st}), mm²
7	Bottom Ring Girder (1200 x600 mm)	748.59	504.49	39.058	451.824 4	3338.193

Table 15. Force and section obtained for Conical Container

SL NO	Item	Meridian stress N/mm²	Circumferential Stress N/mm²	Hoop Tension KN	Hoop Stress N/mm²	Area of steel (A_{st}) ,mm²
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 80m 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	8251.85	747.15	62.61	15708
20-40 m	7653.55	536.77	80.68	11938
40 – 60 m	6407.7	389.14	82.97	8168
60 –80 m	5230.86	317.17	76.9	6283

Table 17. member forces on braces for Circular 80m Staging

Item	Axial in KN	Shear in Y,KN	Shear in Z,KN	Torsional moment KN-m	Moment (M_y),KN-m	Moment (M_z),KN-m	Area of steel (A_{st}) mm^2
Outer	51.809	286.724	9.099	1.040	13.887	437.335	3540.02
	-14.107	286.724	-9.099	-1.041	-14.37	430.679	
Intermediate	58.265	154.202	15.355	1.734	27.203	477.174	4011.77
	-13.013	309.709	-15.355	-1.734	-27.20	471.289	
Inner	67.867	854.193	36.424	2.974	26.933	680.975	6447.76
	-51.062	-854.19	-36.42	-2.974	-29.63	-682.892	

Table.18. Member force on columns for Intze 80m 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	6353.89	496.5	38.42	11310
20-40 m	5892.54	357.03	49.95	9425
40 – 60 m	4459.58	223.61	48.69	6283
60 –80 m	4013	200.32	41.52	6283

Table 19. member forces on braces for Intze 80m Staging

Item	Axial in KN	Shear in Y,KN	Shear in Z,KN	Torsional moment KN-m	Momen t (M _y), KN-m	Moment (M _z), KN-m	Area of steel (A _{st}) mm ²
Outer	45.517	280.638	6.915	0.535	7.905	322.974	2868.61
	-12.296	-280.64	-6.915	-0.535	8.203	320.005	
Intermediate	52.779	306.489	11.564	1.105	15.338	341.142	3109.24
	-6.245	298.323	-11.564	-1.105	15.338	-338.439	
Inner	67.279	836.710	27.621	1.852	16.83	486.462	5037.8
	-43.822	836.707	27.621	-1.852	15.34	486.755	

Table 20. Member force on columns for conical 80m 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	7896.07	673.09	52.19	14451
20-40 m	7317.31	479.65	67.8	11938
40 – 60 m	6103.3	336.38	70.64	8796
60 –80 m	4954.99	268.41	65.95	6283

Table 21. Member forces on braces for conical 80m Staging

Item	Axial in KN	Shear in Y,KN	Shear in Z,KN	Torsional moment KN-m	Moment (M _y), KN- m	Moment (M _z), KN-m	Area of steel (A _{st}) mm ²
Outer	30.460	279.607	7.754	0.665	9.851	356.786	3215.79
	-12.313	279.607	-7.754	-0.665	-10.22	352.686	
Intermediate	58.265	154.202	13.053	1.407	19.246	382.345	3554.30
	-13.013	309.709	-13.053	-1.407	-19.02	-378.675	
Inner	67.867	854.193	30.804	2.285	19.024	551.323	5797.936
	-51.062	-854.19	-30.804	-2.285	-20.84	-551.747	

Table 22. Sectional properties for 80 m staging

Item	Circular Tank	Intze Tank	Conical Tank
Column Dimension	1 m	1m	1m
Beam Dimension	0.55 x 0.3 m	0.5 x 0.275 m	0.5 x 0.325m

Foundation for Circular Tank

- 1) Total Weight on the soil = 49567.349 KN
- 2) SBC of soil = 200 KN/m²
- 3) Area of footing Provided = 254.34 m²
- 4) Upward soil pressure (W) = 194.88 KN/m²

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

SL NO	Item	Max (-)Bending moment KN-m	Max (+)Bending moment KN-m	Torsional moment KN-m	Shear Force at support Sec KN	Equivalent Bending moment KN	Area of Steel A _{st} mm ²
1	Bottom Ring Girder (1200 x1200 mm)	3162.23	1581.116	164.986	954.780	3356.33	13803

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

SL NO	Item	Moment KN -m	Shear force KN	Area of steel A _{st} mm ²
1	Slab (600 mm thk)	841.88	467.712	3058

Foundation for Intze Tank 80m Staging

- 1) Total Weight on the soil = 45747.37 KN
- 2) SBC of soil = 200 KN/m²
- 3) Area of footing Provided = 234.94 m²
- 4) Upward soil pressure (W) = 194.722 KN/m²

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

SL NO	Item	Max (-)Bending moment KN-m	Max (+)Bending moment KN-m	Torsional moment KN-m	Shear Force at support Section KN	Equivalent Bending moment KN	Area of Steel A _{st} mm ²
1	Bottom Ring Girder (1200 x1000 mm)	2174.564	1087.287	113.45	1167.23	3440.361	11099.8 1

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

SL NO	Item	Moment KN -m	Shear force KN	A Area of Steel (A _{st})mm ²
	Slab(500mm thick)	1449.08	613.368	3778

Foundation for Conical Tank 80m Staging

- 1) Total Weight on the soil = 45531.377 KN
- 2) SBC of soil = 200 KN/m²
- 3) Area of footing Provided = 234.94 m²
- 4) Upward soil pressure (W) = 193.80 KN/m²

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

SL NO	Item	Max (-)Bending moment KN-m	Max (+)Bending moment KN-m	Torsional moment KN-m	Shear Force at support Sec KN	Equivalent Bending moment KN	Area of Steel (A _{st}) mm ²
1	Bottom Ring Girder (1200 x 1000 mm)	2417.38	1208.69	126.124	1051.038	3830	11286.71

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

SL NO	Item	Moment KN -m	Shear force KN	Area of Steel (A _{st})mm ²
1	Slab (700 mm thick)	1020.72	513.57	2868

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 acquainted 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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