Design And Analysis Of Underground And Elevated Service Reservoir In Single Structure

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Abstract- *The need for a service reservoir is as old civilization, to provide storage of water for use in many applications like drinking water, chemical manufacturing, etc. This paper presents analysis of single structured RCC Underground and Elevated Service Reservoir for a capacity of 1500000 litres square shaped and 900000 litres circular shaped resp. store fully treated potable water close to the point of distribution. The main concept of designing and analysing single structured service reservoir is to increase water storage capacity and improve pressure without affecting environmental and ecological assets in the area. Also to get right water pressures to both nearby and more distant residents. This paper presents the study deals with the performance Single structured UGSR and ESR to seismic and wind forces. Static and Dynamic Analysis is carried out by using STAAD Pro. Software.*

Keywords- Single structured Underground and Elevated Service Reservoir, Water storage capacity, Seismic and Wind forces, Static analysis, Dynamic analysis, STAAD Pro.

I. INTRODUCTION

Indian sub-continent is highly vulnerable to natural disasters like earthquake, draughts, floods, cyclones etc. Majority of states or union territories are prone to one or multiple disasters. These natural calamities are causing many casualties and innumerable property loss every year. Earthquake occupy first place in vulnerability. Hence, it is necessary to learn to live with these events. According to seismic code IS: 1893 (Part I):2000, more than 60% of India is prone to earthquakes. After an earthquake, property loss can be recovered to some extent however, the life loss cannot. The main reason for life loss is collapse of structures. It is said that earthquake itself never kills people; it is badly constructed structures that kill. Hence it is important to analyse the structure properly for earthquake effects. Water supply is a life line facility that must remain functional following disaster. All the tanks are designed as crack free structures to eliminate any leakage. Most of the failures of large tanks after earthquakes are suspected to have resulted from the dynamic buckling caused by overturning moments of seismically induced liquid inertia and surface slosh waves. Hydrostatic and Hydrodynamic pressures on tanks under earthquake forces play an important role in the design of the service reservoir. When the tank is in full condition, earthquake forces almost govern the design of these structures in zones of high seismic activity.

The failure of these structures may cause some hazards for the health of the citizens due to the shortage of water or difficulty in putting out fire during the earthquake golden time.Scientific wind is a critical load component while analysing and designing service reservoirs as it results in horizontal displacement. Horizontal displacement in service reservoir due to wind results in sloshing of water and additional vibrations.

II. METHODOLOGY

1. DESCRIPTION OF SINGLE STRUCTURED SERVICE RESERVOIR

In the present study single structured underground and elevated service reservoir of 1500 m^3 and 900 m^3 which is square and circular shaped respectively is analysed using staad pro. Software. The Equivalent Static Analysis and Dynamic Analysis is carried out for tank full and empty condition. Response Spectrum Method is used in dynamic analysis.

TABLE NO. 1: DIMENSIONS OF SERVICE RESERVOIR

PARTICULARS	DIMENSIONS
Size of ESR	D = 16 m, H = 4.8 m
Size of UGSR	L = 18 m, B = 18 m H = 5 m
Thickness of Top Dome	100 mm
Rise of Top Dome	2.6 m
Size of Top Ring Beam	350 mm x 350 mm
Diameter of Cylindrical Wall	16 m
Height of Cylindrical Wall	4.8 m
Thickness of Cylindrical Wall	200 mm

Diameter of Base Slab	16 m
Thickness of Base Slab	380 mm
Width of Gallery	1000 mm
Thickness of Gallery	100 mm
Size of Bottom Ring Beam	600 mm x 1000 mm
No. of Columns	8
Height of Columns	19 m
Size of Columns	450 mm x 450 mm
No. of Bracings	4
Distance between Intermediate Braces	3.5 m
Size of Bracing	400 mm x 450 mm
Thickness of Top Slab of UGSR	120 mm
Size of Beams	450 mm x 450 mm
Thickness of Square Wall	500 mm
Height of Square Wall	5 m
Thickness of Raft Slab	150 mm
Size of Raft Beams	450 mm x 1800 mm
Size of Raft Beams	450 mm x 1300 mm

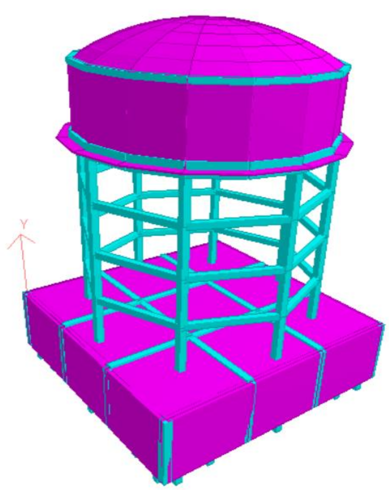

FIGURE NO. 1: 3D MODEL OF SERVICE RESERVOIR

II. LOADING DETAILS

A. Dead Load:

Self Weight of Structure = 1 KN/m^2

B. Live Load:

Live load for roof slab and walking gallery taken as 1.5 KN/m^2

C. Water Pressure:

a) **Elevated Service Reservoir**

Water pressure on Bottom Slab = (9.81 x 4.5) + (0.38 x 25) = 54 KN/m^2

Water pressure on Tank Wall = γ x H = 9.81 x 4.5 = 45 KN/m^2

b) **Underground Service Reservoir**

Water pressure on Bottom Slab = γ x H = 9.81 x 4.7 = 46 KN/m^2

Water pressure on Tank Wall = γ x H = 46KN/m^2

Soil Pressure on Bottom Slab = Ka x γ_sx H = 0.33 x 16.8 x 5 = 28 KN/m^2

Soil Pressure on Tank Wall = Ka x γ_sx H = 0.33 x 16.8 x 5 = 28 KN/m^2

D. Wind Load:

Wind loads are calculated as per IS 875 Part III (1987).
Design wind speed, Vz = Vb (K1 x K2 x K3)
The basic wind speed (Vb) = 39 m/s For Satara
Structure is considered Exposed open terrain with few or no obstructions and in which the average height of any object surrounding the structure is less than 1.5 m.
Terrain Category- 1, Class- A
K1 = Probability factor = 1.05
K2 = Terrain, height and size factor
K3 = Topography factor = 1
Pressure Intensity = 0.6 Vz^2
So we calculated the pressure intensity at different heights of structure from the above relation.
Pressure Intensity = 1.05 KN/m2 at 10 m
1.09 N/m2 at 15 m
1.12 N/m2 at 20 m
1.139 KN/m2 at 26.402 m

E. Seismic Load:

Seismic load is calculated for tank empty ad full condition as per IS 1893:2002

TABLE NO. 2: CONSTANTS FOR SEISMIC LOAD

CONSTANT	VALUES	REMARKS
Z	0.24	Structure in zone IV
I	1.5	Importance Factor
R	4	Response Reduction Factor

3. Analysis

Seismic analysis of service reservoir involved two types of analysis,

a) Equivalent Static analysis of service reservoir:

Equivalent static analysis of service reservoir is the conventional analysis based on the conversion of seismic load in equivalent static load. IS: 1893- 2002 has provided the method of analysis of elevated water tank for seismic loading. Historically, seismic loads were taken as equivalent static accelerations which were modified by various factors, depending on the location's seismicity, its soil properties, the natural frequency of the structure, and its intended use. Service reservoir can be analyzed for both the condition i.e. tank full condition and tank empty condition. For both the condition, the tank can be idealized by one- mass structure. The response of elevated water tanks obtained from static analysis shows the high scale value.

Time period for Static Equivalent Method
Fundamental Natural Period: (Ta) = $0.075\ h^{0.75}$
Where, h = Height of Structure
d= Base dimension of the structure at the plinth level, in m, along the considered direction of the lateral force.
So, $T_x = 0.075\ h^{0.75} = 0.8735$ sec
$T_Z = 0.075\ h^{0.75} = 0.8735$ sec

b) Dynamic response of service reservoir:

Dynamic response of elevated water tanks is hard to define, as a behaviour of tank is unpredictable. Dynamic analysis of liquid storage tank is a complex problem involving water- structure interaction. Based on numerous analytical, numerical and experimental studies, simple spring- mass models of tank- liquid system have been developed to calculate the hydrostatic and hydrodynamic forces. During the earthquake, water contained in the tank exerts forces on tank wall as well as bottom of the tank.

Time period for Response Spectrum Analysis

Time period for impulsive mode = $T_i = 2\pi \sqrt{\frac{mi + mc}{ks}}$ = 5.11sec

Time period for impulsive mode = $T_c = Cc \sqrt{\frac{D}{g}}$ = 5.36sec

III. RESULTS

Equivalent static analysis and Response spectrum analysis is carried out for the service reservoir with empty and full condition. The obtained results are noted down in wind analysis, base shear, storey shear, natural frequency and time period, plate stress values.

A. Result for wind Analysis

Wind analysis is carried out for load combination of 1.2(DL+LL+WP+WLX)

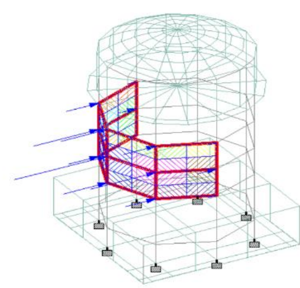

FIGURE NO. 2: WIND EFFECT IN X DIRECTION

TABLE NO. 3: DISPLACEMENT DUE TO WIND LOAD

	DISPLACEMENT (mm)	
	Empty Condition	Full Condition
Column (567)	12.644	8.118
Bracing (278)	11.313	7.654

B. Result for Base Shear

Table shows the comparison between static and dynamic analysis for empty and full condition.

TABLE NO. 4: BASE SHEAR VALUES

	DISPLACEMENT (mm)	
	Empty Condition	Full Condition
Column (567)	12.644	8.118
Bracing (278)	11.313	7.654

C. Results For Frequencies And Period

TABLE NO. 5: MODAL FRQUENCIES AND PERIOD

MODE	FREQUENCY (Cycles/sec)		PERIOD (Sec)	
	Empty Condition	Full Condition	Empty Condition	Full Condition
1	0.359	0.358	2.78647	2.78994
2	0.359	0.358	2.78647	2.78994
3	0.468	0.467	2.13776	2.14064
4	2.569	2.568	0.38929	0.38934
5	2.569	2.568	0.38929	0.38934
6	2.739	2.739	0.36513	0.36513
7	2.739	2.739	0.36509	0.36509
8	3.045	3.045	0.32838	0.32842
9	4.321	4.321	0.23143	0.23145
10	4.339	4.339	0.23045	0.23045
11	4.339	4.339	0.23044	0.23044
12	5.467	5.467	0.18290	0.18290

D. Result For Peak Storey Shear

TABLE NO. 6: PEAK STOREY SHEAR VALUES

STOREY	LEVEL (m)	IMPULSIVE		CONVECTIVE	
		Empty Condition	Full Condition	Empty Condition	Full Condition
6	19.0	24044.46	24086.73	35842.75	35842.96
5	15.5	27151.91	27190.13	40474.77	40475.11
4	12.0	28174.45	28211.24	41999.28	41999.27
3	8.50	29379.72	29415.17	43795.95	43795.95
2	5.0	29479.72	29415.17	43795.95	43795.98
1	2.50	29459.35	29494.73	43917.66	43914.70
Base	0.0	29459.35	29494.73	43914.66	43914.70

E. Result for Plate Stress

Plate stress refers to the bending of plate due to application of loads o the plates results in the deflection of plates.

The stresses in plate can be calculated from these deflections. Once the stresses coming on plates are known, then failure theories can be applied to determine whether these plates will fail under a given load or not.

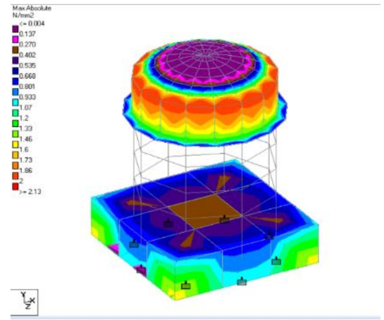

FIGURE NO. 3: PLATE STRESS

Below figure shows the maximum absolute pressure values of bottom slab and wall of service reservoir.

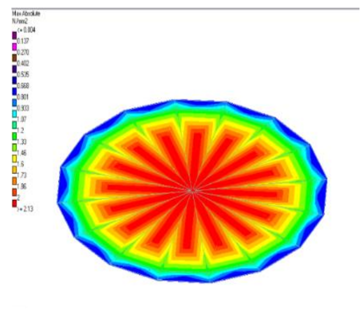

FIGURE NO. 4: PLATE STRESS IN BOTTOM SLAB OF ESR

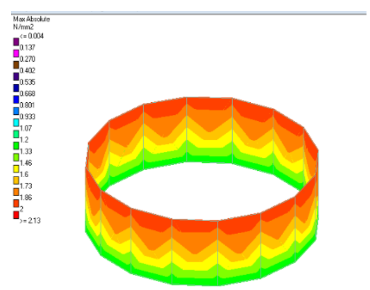

FIGURE NO. 5:PLATE STRESS ON WALL OF ESR

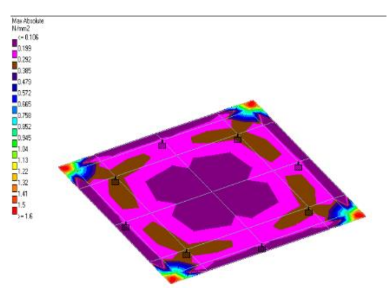

FIGURE NO. 6:PLATE STRESS IN BOTTOM SLAB OF UGSR

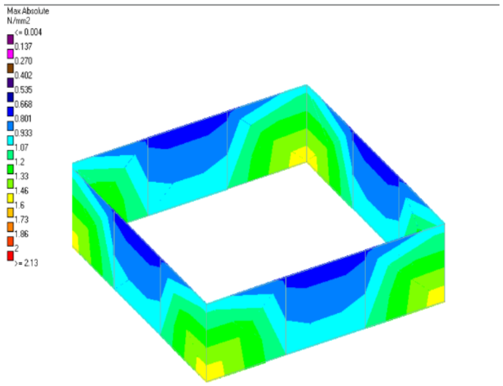

FIGURE NO. 6:PLATE STRESS IN TANK WALL OF UGSR

IV. CONCLUSION

1. Horizontal displacement in service reservoir due to wind is critical as they result in sloshing of water and additional displacement.
2. Base shear for empty condition is more compared to full condition. Because service reservoir is empty hence no water pressure from inside, only earthquake forces are acting from outside.
3. The natural frequency of structure decreases with an increase in water storage.
4. Time period varies in empty and full condition. This is due to effect of sloshing and hydrostatic pressure. Time period increases as water level increases.
5. Peak storey shear values increases in full condition for both impulsive and convective mode.
6. The pressure exerted by the water on the boundaries of tank due to excitation is to be taken stresses on the walls and base slab of tank.
7. Provision of free board helps water in the tank to oscillate freely which reduces pressure on the boundaries of service reservoir.
8. The stresses as seen in the above figure, has a clear understanding that it is dependent on the parameters like intensity of external excitation i.e., earthquake, its time period, free board provision, slosh intensity which varies with water fill.

REFERENCES

[1] V, Subbalakshmi, Naveen Kumar “Innovative Construction of Combined Ground and Elevated level Service Reservoir in Single Structure” IJAST/ Vol. 29/ No. 02/ 2020.
[2] Issar Kapdia, Purva Patel “Design, Analysis and Study of Combined Rectangular Water Tank: Combination of the Rectangular Overhead Water Tank and the Rectangular Ground Water Tank BY using STAAD PRO Software” IJCR/ Vol. 10/ Issue 04/ April 2018.
[3] Kulvendra Patel “Wind and Seismic Analysis of Elevated Tank using STAAD Pro” IRJET/ Vol. 05/ Issue 10/ Oct 2018.
[4] Aleemuddin Tirandaz, Shameena Khannavar, M.H.Kolhar "Response Spectrum Analysis of Elevated Water Tank" IJRET/ Vol. 05/ Issue 08/ August 2018
[5] Kode V. L. Swarupa, Er. R. Ramakrishna " Performance of Elevated Circular Water Tank in Different Wind Zones" IJSETR/Vol.06/Issue 11/March 2017