Seismic Analysis of Intze Water Tanks Under Different Zones Using Staad. Pro

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Abstract - Elevated water tanks are one of most important lifeline structures. Intze tank is most commonly used water tank to supply water to society for drinking and washing purpose and also for firefighting purpose or any other emergency situation; therefore, it is necessary to find out the behavior of intze tank under one of the most vulnerable natural disaster i.e., earthquake. Earthquake occupy first place in vulnerability. In major cities and also in rural areas elevated water tanks forms an integral part of water supply schemes. In this study, intze tank is analyzed under the effect of earthquake forces using software STAAD. Pro. The parameters considering are capacity of tank with different geometries under different earthquake zones of India. Various parameters on the basis of which results are analyzed are maximum stress and maximum deflection. Based on these results, salient conclusions are drawn.

Keywords - Elevated water tanks, Reinforced cement concrete, Seismic analysis, STAAD Pro.

1. INTRODUCTION

Water tank is a distinctive type of liquid retaining structures. It has been developed near about 80 years ago and recognized as efficient, economic and well-designed structure for residential as well as commercial use. Water tank is an unavoidable part of water supply system and widely used for storage and processing of various types of liquids. The most important terms in elevated water tanks are strength and durability and leakages can be avoided by good construction practice. But, the reality is that, these structures do not last as long as they are designed for. Generally, distress in elevated water tanks has been observed in 9 to 10 years of service life due to problems like structural aspects, over intensity of earthquake in earthquake prone areas. During the past earthquakes, tanks have suffered varying degree of damages, which include: buckling of ground supported slender tanks, rupture of steel tank shell at the location of joints with pipes, collapse of supporting tower of elevated tanks, cracks in the ground supported RC tanks, etc. The main purpose of this paper is to study the response of intze tank under seismic forces for filled and empty conditions.

2. LITERATURE REVIEW

Shailja Upadhyay and Chirag N. Patel (2015) performed the analysis on response of elevated water tank subjected to near-fault and far- field earthquake motion. They attempted to analyze the elevated water tank subjected to near-fault and far- field earthquake, and assess the distinctions in the seismic reaction in regards to the same. Geometry of the tanks should be such that extensive mass is concentrated at the top and that builds the seismic weakness of these structures, particularly if the tank is in close by region of the earthquake epicenter likelihood of high harm or fall is high. **Chirag N. Patel and H. S. Patel (2012)** studied the behavior and suitability of supporting system of reinforced concrete elevated/overhead tanks during vulnerable force events like earthquake. The aim of this study was to know the effectiveness of supporting systems of elevated tanks with different alteration and considerable change in seismic behavior of elevated tanks with consideration of responses like displacement, base shear, base moment, sloshing, torsional vulnerability etc. **Suchita Hirde and Manoj Hedaoo (2011)** studied the seismic performance of the elevated water tank for various seismic zones of India for various heights and capacity of elevated water tanks for different soil conditions. The effects of height of water tank, earthquake zones and soil conditions on earthquake forces were presented in this paper with the help of analysis of 240 models of various parameters. **Gareane A. I. Algreane, S. A. Osman and O. A. Karim (2008)** studied the soil and water behavior of elevated water tank under seismic load. They have chosen seven cases to make comparisons with direct nonlinear dynamic analysis, mechanical models with and without soil structure interaction (SSI) for single degree of freedom (SDOF), two degree of freedom (2DOF), and finite element method (FEM) models. **R. Livaoglu and A. Dogangun (2007)** found the effects of supporting systems on the seismic response of elevated tanks considering the fluid-structure interactions. Finite elements in the frame type support system were modeled as frame elements and truncated cone and container walls were modeled with shell elements. Also shaft supporting system was modeled with shell elements. In order to characterize, fluid-elevated model (FEM) was considered for the elevated tank-fluid system. To determine the seismic behavior of the system, transient dynamic analysis was carried out using the FEM analysis program. **R K Ingle (1999)** performed the design of elevated water tank structure using P-DELTA effect. As per IS: 456 the final design forces shall include the effect of deformation (P-DELTA effect). As per IS: 11682 evaluate the effective length of column and calculate these forces due to its slenderness ratio. According to the ATC code consideration of P-DELTA effect, it is necessary if the stability index is more than 0.1 which depend upon drift ratio, story height, vertical and horizontal forces.

3. METHODOLOGY

This study is related to comparative study of behavior of intze tank under different variable parameters like diameter of tank, height of tank, capacity of tank and earthquake zones. A comparison in analysis results such as maximum stresses and maximum deflection have been made. The analysis on various cases of intze tank has been carried out by using software STAAD. Pro. Cases of intze tank which will be analyzed under earthquake loading for earthquake zones II, III, IV and V are given in Table 1.

Table 1: Cases for earthquake analysis

TYPE OF TANK →	FILLED CONDITION	EMPTY CONDITION
CAPACITY ↓		
50kL	4 SEISMIC ZONES	4 SEISMIC ZONES
100kL	4 SEISMIC ZONES	4 SEISMIC ZONES
150kL	4 SEISMIC ZONES	4 SEISMIC ZONES
200kL	4 SEISMIC ZONES	4 SEISMIC ZONES
250kL	4 SEISMIC ZONES	4 SEISMIC ZONES

Details of geometry considered for the analysis are given in Table 2.

Table 2: Geometry of tanks for different capacities

CAPACITY →	50kL	100kL	150kL	200kL	250kL
GEOMETRY ↓					
Height of cylindrical wall (H)	2 m	3.5 m	4.5 m	5.3 m	5.8 m
Diameter of cylindrical wall (D)	5 m	5.5 m	6 m	6.5 m	7 m
Diameter at bottom ring beam (D_o)	3 m	3.5 m	4 m	4.5 m	5 m
Height of conical dome (h_o)	1.5 m	1.55 m	1.6 m	1.65 m	1.7 m
Radius of conical dome (R_2)	1.625 m	1.983 m	2.368 m	2.776 m	3.204 m
Rise of conical bottom (h_2)	1 m	1.05 m	1.1 m	1.15 m	1.2 m

Details of section property considered for the analysis are given in Table 3.

Table 3: Sectional property of different elements for different capacities

CAPACITY →	50kL	100kL	150kL	200kL	250kL
ELEMENTS ↓					
Top dome (mm)	100	100	100	100	100
Cylindrical wall (mm)	110	155	185	209	224
Conical bottom (mm)	200	200	230	230	260
Bottom dome (mm)	150	150	170	170	190
Top ring beam (mm)	300 x 250	300 x 250	320 x 270	320 x 270	340 x 290
Middle ring beam (mm)	600 x 350	600 x 350	650 x 400	650 x 400	700 x 450
Bottom ring beam (mm)	700 x 400	700 x 400	750 x 420	750 x 420	800 x 440
Circular column (mm)	400	400	450	450	500
Bracing (mm)	600 x 400	600 x 400	600 x 450	600 x 450	650 x 500

4. MODELLING OF TANKS

The intze water tank has been modeled using 4 nodded plate elements. Number of elements in bottom dome and top dome for all 5 cases are 360. Number of elements in conical bottom for all 5 cases are 216. Number of members in ring beams for all 5 cases are 36. Number of elements in cylindrical wall varies from 144 to 432 in the 5 cases. Different models used in the study for filled and empty conditions are given in Table 4.

Table 4: Model generation

S.NO.	Capacity of Tank (kL)	Height of cylindrical wall (m)	Diameter of cylindrical wall (m)	Divisions		No. of elements
				Along circumference	Along height	
1.	50	2.0	5.0	36	4	144
2.	100	3.5	5.5	36	7	252
3.	150	4.5	6.0	36	9	324
4.	200	5.3	6.5	36	11	396
5.	250	5.8	7.0	36	12	432

On the basis of above specified geometry, sectional properties and model data, the modeling has been done using STAAD. Pro. (Fig. 1 & 2) and the analysis of the tanks for filled and empty conditions have been carried out to evaluate the maximum stresses in different elements of tanks.

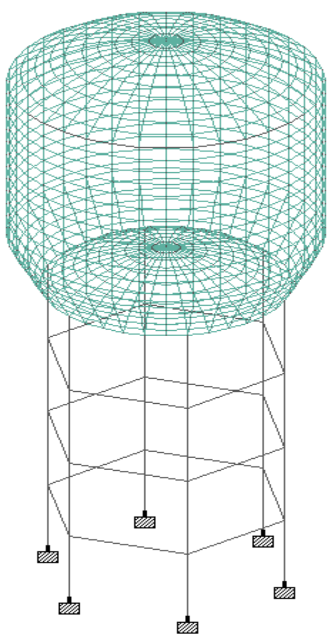


Figure 1: Model of intze tank

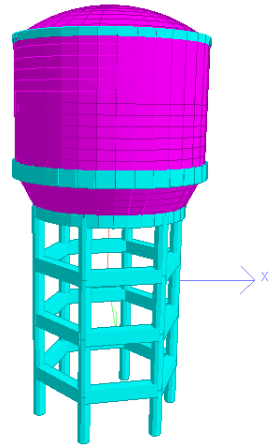


Figure 2: Rendered view of intze tank

5. RESULT AND DISCUSSION

We have analyzed 40 cases of intze tank for filled and empty condition and the observed results are tabulated below in Table 5 to 12.

Table 5: Max. stress in filled condition in zone - II

CAPACITY	50kL	100kL	150kL	200kL	250kL
RESULTS					
Max. stress in bottom ring beam (MPa)	0.035	0.049	0.060	0.065	0.071
Max. stress in bottom dome (MPa)	0.188	0.312	0.334	0.409	0.421
Max. stress in conical bottom (MPa)	0.304	0.498	0.554	0.687	0.705
Max. stress in cylindrical wall (MPa)	0.385	0.649	0.785	0.930	1.028

Table 6: Max. stress in empty condition in zone - II

CAPACITY	50kL	100kL	150kL	200kL	250kL
RESULTS					
Max. stress in bottom ring beam (MPa)	0.035	0.049	0.060	0.065	0.071
Max. stress in bottom dome (MPa)	0.167	0.243	0.259	0.300	0.313
Max. stress in conical bottom (MPa)	0.215	0.291	0.323	0.368	0.382

Max. stress in cylindrical wall (MPa)	0.112	0.168	0.197	0.254	0.267

Table 7: Max. stress in filled condition in zone - III

CAPACITY →	50kL	100kL	150kL	200kL	250kL
RESULTS ↓					
Max. stress in bottom ring beam (MPa)	0.057	0.078	0.097	0.105	0.109
Max. stress in bottom dome (MPa)	0.223	0.356	0.385	0.464	0.468
Max. stress in conical bottom (MPa)	0.309	0.505	0.560	0.696	0.712
Max. stress in cylindrical wall (MPa)	0.385	0.649	0.785	0.930	1.028

Table 8: Max. stress in empty condition in zone - III

CAPACITY →	50kL	100kL	150kL	200kL	250kL
RESULTS ↓					
Max. stress in bottom ring beam (MPa)	0.057	0.078	0.097	0.105	0.109
Max. stress in bottom dome (MPa)	0.211	0.297	0.322	0.368	0.385
Max. stress in conical bottom (MPa)	0.225	0.392	0.429	0.473	0.489
Max. stress in cylindrical wall (MPa)	0.126	0.188	0.225	0.288	0.304

Table 9: Max. stress in filled condition in zone - IV

CAPACITY →	50kL	100kL	150kL	200kL	250kL
RESULTS ↓					
Max. stress in bottom ring beam (MPa)	0.085	0.117	0.145	0.157	0.162
Max. stress in bottom dome (MPa)	0.270	0.414	0.452	0.537	0.542
Max. stress in conical bottom (MPa)	0.437	0.533	0.594	0.748	0.768
Max. stress in cylindrical wall (MPa)	0.385	0.649	0.785	0.930	1.028

Table 10: Max. stress in empty condition in zone - IV

CAPACITY →	50kL	100kL	150kL	200kL	250kL
RESULTS ↓					
Max. stress in bottom ring beam (MPa)	0.085	0.117	0.145	0.157	0.162
Max. stress in bottom dome (MPa)	0.264	0.374	0.407	0.460	0.479
Max. stress in conical bottom (MPa)	0.338	0.426	0.518	0.630	0.651
Max. stress in cylindrical wall (MPa)	0.146	0.216	0.261	0.332	0.353

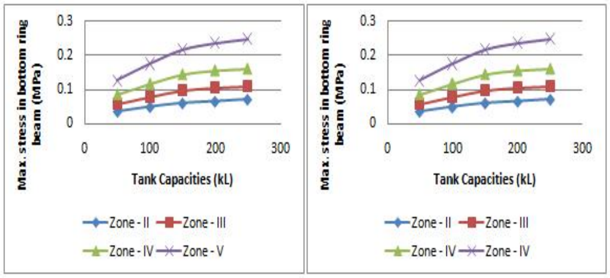
Table 11: Max. stress in filled condition in zone - V

CAPACITY →	50kL	100kL	150kL	200kL	250kL
RESULTS ↓					
Max. stress in bottom ring beam (MPa)	0.128	0.176	0.217	0.236	0.248
Max. stress in bottom dome (MPa)	0.357	0.502	0.553	0.647	0.669
Max. stress in conical bottom (MPa)	0.631	0.746	0.841	0.882	0.902
Max. stress in cylindrical wall (MPa)	0.385	0.649	0.785	0.930	1.028

Table 12: Max. stress in empty condition in zone - V

CAPACITY →	50kL	100kL	150kL	200kL	250kL
RESULTS ↓					
Max. stress in bottom ring beam (MPa)	0.128	0.176	0.217	0.236	0.248
Max. stress in bottom dome (MPa)	0.332	0.479	0.533	0.598	0.619
Max. stress in conical bottom (MPa)	0.507	0.686	0.777	0.830	0.847
Max. stress in cylindrical wall (MPa)	0.203	0.258	0.316	0.399	0.416

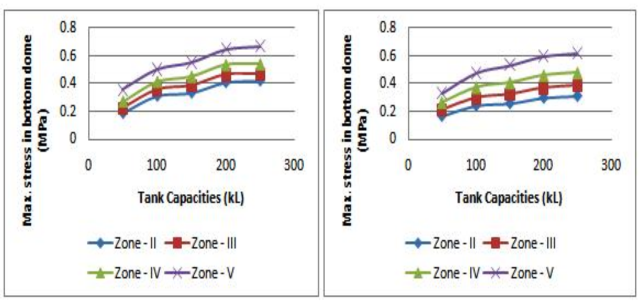
Graphical comparison of above tabulated results are given below –



Filled Condition Empty Condition

Figure 3: Max. stress in bottom ring beam for filled and empty condition for all seismic zones

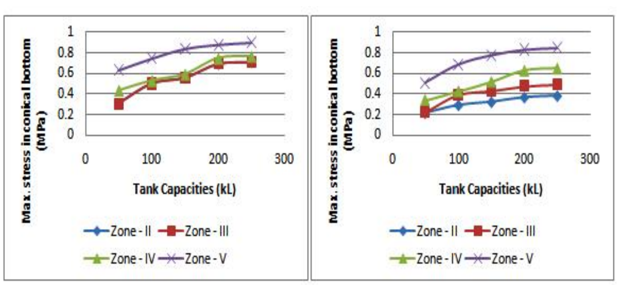
Figure 3 shows the graphical representation of maximum stress in bottom ring beam with respect to the tank capacities for all seismic zones for filled and empty conditions. From the graph it can be observed that the stress in filled and empty condition is same because governing stress is due to dead and seismic loads.



Filled Condition Empty Condition

Figure 4: Max. stress in bottom dome for filled and empty condition for all seismic zones

Figure 4 shows the graphical representation of maximum stress in bottom dome with respect to the tank capacities for all seismic zones for filled and empty conditions. From the graph it can be observed that the stress in filled and empty condition increases non-linearly with the capacity.

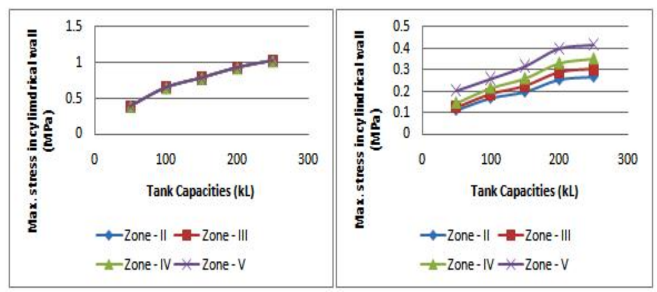


Filled Condition Empty Condition

Figure 5: Max. stress in conical bottom for filled and empty condition for all seismic zones

Figure 5 shows the graphical representation of maximum stress in conical bottom with respect to the tank capacities for all seismic zones for filled and empty conditions. From the graph it can be observed that the stress in filled and empty condition increases non-linearly with the capacity.

Figure 6 shows the graphical representation of maximum stress in cylindrical wall with respect to the tank capacities for all seismic zones for filled and empty conditions. From the graph it can be observed that the stress in filled and empty condition increases non-linearly with the capacity and stress in filled condition is same in all seismic zones because governing stress is due to water pressure.



Filled Condition Empty Condition

Figure 6: Max. stress in cylindrical wall for filled and empty condition for all seismic zones

6. CONCLUSION

1. The stresses in different elements of intze tank increases non-linearly with respect to the capacity of tank.
2. The stresses in filled condition are more than the stresses in empty condition.
3. Maximum stress in cylindrical wall is same for all seismic zones for a single capacity because it is governed by dead and seismic loads.
4. Stresses are highest in seismic zone – V.
5. Rate of increment of stresses decreases with increase in tank capacity but increases with increase in zone number.
6. Maximum variation of stresses between empty and filled conditions is observed in cylindrical wall for all capacities and zones.

7. FUTURE SCOPES

1. In this study, linear elastic material property has been considered. Same analysis may be carried out by considering non-linear material property.
2. In this study, effect of staging height has not been considered. In future study, effect of height of staging may also be considered.
3. This study has been carried out using STAAD. Pro. software considering 4-noded plate for cylindrical wall and conical bottom and 3-noded plate for top and bottom dome. The same may be carried out by using other analysis software such as ANSYS, ABAQUS, etc. using different types of plate elements.

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