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Seismic Analysis and Design of INTZE Type Water Tank

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Abstract

Due to enormous need by the public, water has to be stored and supplied according to their needs. Water demand is not constant throughout the day. It fluctuates hour to hour. In order to supply constant amount of water, we need to store water. So to meet the public water demand, water tanks need to be constructed. They are grave elements in municipal water supply, firefighting systems and in many industrial amenities for storage of water. Intze type tank is commonly used overhead water tank in India. These tanks are designed as per IS: 3370 i.e. Code of practice for concrete structures for storage of liquids. BIS implemented the revised version of IS 3370 (part 1& 2) after a long time from its 1965 version in year 2009. Presently large number of overhead water tanks is used to distribute the water for public utility. Most of the water tanks were designed as per old IS Code: 3370-1965 without considering earthquake forces. The objective of this dissertation is to shed light on the Intze water tank designed considering the earthquake forces according to Indian standard code: 3370-2009 and draft code 1893-Part 2, (2005) considering two mass modal i.e. impulsive and convective mode method. Intze tank supported on frame staging .Also this report includes analysis by STAAD Pro for wind and seismic forces .Finally the results are validated with the results of manual calculation From the present study, it was observed that, for elevated tanks the two degree of freedom idealization of tank have shown better results when compared to single degree of freedom of idealization.

Keywords: Intze Water Tank, Base Shear, Base Moment, Full Tank Condition, Empty Condition, Displacements

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I. INTRODUCTION

The water is source of every conception. In day to day life, one cannot live without water. The overhead liquid storing tank is the most effective storing competence used for domestic or even industrial rationale. Depending upon the location of the water tank, the tanks can be name as overhead, on ground and underground water tank.The tanks can be made in different shapes like rectangular, circular and intze types. The elevated water tanks are built for direct distribution of water by gravity and are usually of smaller capacity.

Elevated water tanks are prominently in public view and visible from near as well as long distances. Intze type tank is commonly used overhead water tank in India. Presently large number of overhead water tanks is used to distribute the water for public utility. They often become landmarks on the landscape. It is therefore important that the shape and form of the container and the supporting structure must receive due attention from the point of aesthetics.

Water storage tanks should remain functional in the post-earthquake period to ensure potable water supply to earthquake-affected regions and to cater the need for fire-fighting demand. Industrial liquid containing tanks may contain highly toxic and inflammable liquids and these tanks should not lose their contents during the earthquake. During the earthquakes, a number of large elevated water tanks were severely damaged whereas others survived without damage.

An analysis of the dynamic behaviour of such tanks must take into account the motion of the water relative to the tank as well as the motion of the tank relative to the ground. The current design of supporting structures of elevated water tanks are extremely vulnerable under lateral forces due to an earthquake as it is designed for the wind forces and seismic forces.

Water tanks can experience distress in different components due to several reasons such as improper structural configuration design, inferior materials and workmanship, corrosion of reinforcement, wind forces, earthquake forces etc. Because of large mass, especially when the tank is full, earthquake forces are more or less govern the lateral force design criteria in the zone of high seismic activity. In the extreme case, total collapse of tank shall be avoided. However, some damage (repairable) may be acceptable during severe shaking not affecting the functionality of tank. Whatever maybe the cause of distress but water tanks should fulfil the purpose for which it has been designed and constructed with minimum maintenance throughout its intended life. In general, water retaining structure distress has been observed very early even in 9 to 10 years of service life due to some problems related to structural aspects and over emphasis of seismic analysis in earthquake prone zones.

II. METHOD OF ANALYSIS

A. Code-based Procedure for Seismic Analysis

Main features of seismic method of analysis based on Indian standard 1893(Part 1):2002

1) Lumped Mass Model Method

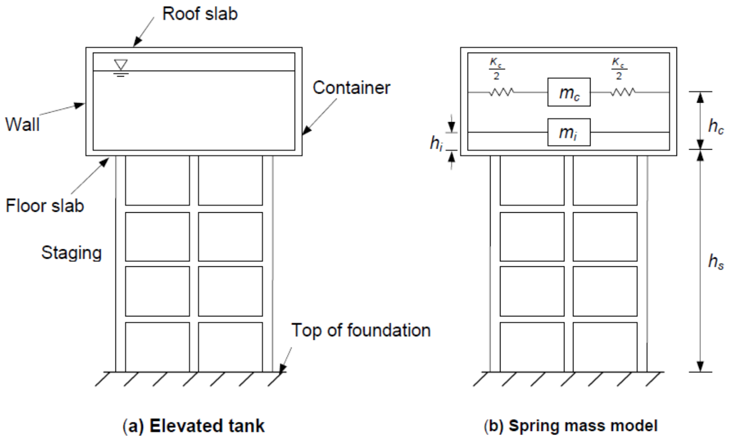

Fig. 1: Lumped Mass Model Method

2) Two Mass Model Method

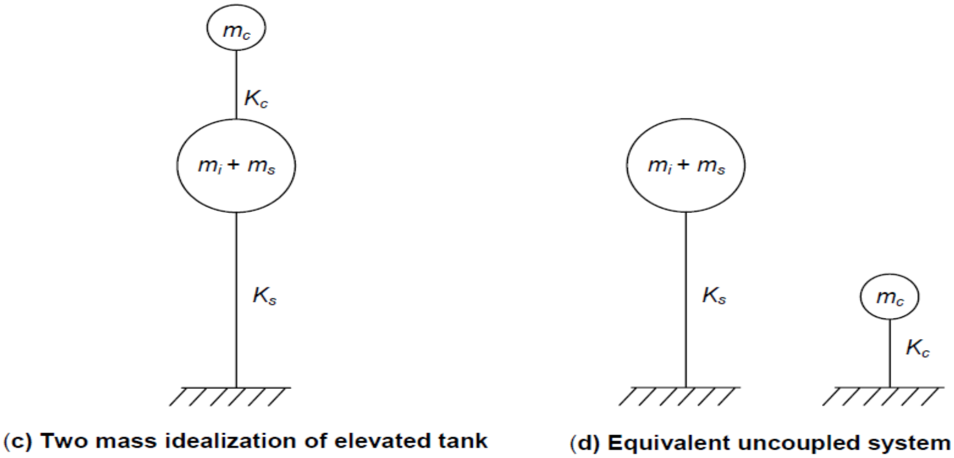

Fig. 2: Two mass model method

III. MODELLING AND ANALYSIS

For the analysis of Elevated Intze water tank following dimensions are considered which are elaborated below.

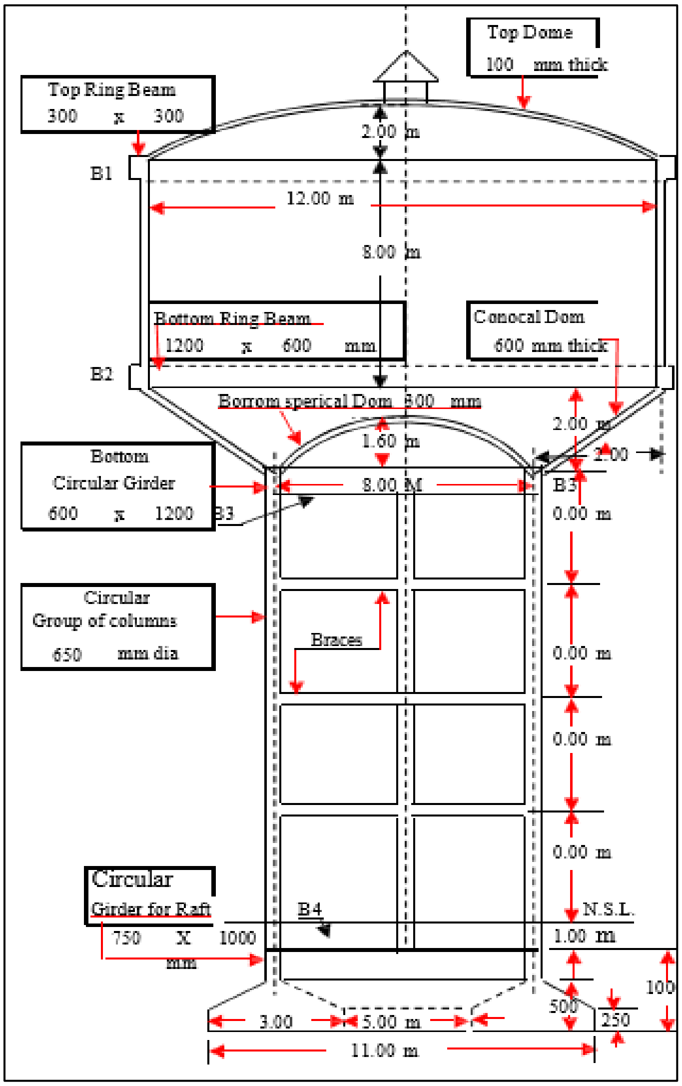

Fig. 1: Dimensions of the elevated intze water tank

Table – 1
Design data of Elevated Intze Water tank

Components	*Calculations*	*Weight (kN)*
Top Dome	*Radius of the dome=6.0m* $2\times\pi\times6\times2\times(0.1\times25)$	*188.5kN*
Top Ring Beam	$\pi(12+0.30)\times0.30\times0.30\times25$	*86.94kN*
Cylindrical Wall	$\pi\times12\times0.15\times8\times25$	*1131kN*
Bottom Ring Beam	$\pi\times12\times1.2\times0.6\times25$	*678.5kN*
Circular Ring Beam	$\pi\times0.6\times1.2\times8\times25$	*452.38kN*
Bottom Dome	$2\pi\times6\times4\times1.6\times03\times25$	*1809.55kN*
Conical Dome	$\pi\times12\times2\times25\times0.60$	*1130.97kN*
Water	$5655000+9810\times(\pi/4)\times8\times8\times10$	*10586kN*
Columns	$\pi\times0.65\times0.65\times8\times16\times(25/4)$	*1081.85kN*
Braces	$\pi\times3\times8\times25\times0.65\times0.65$	*796.38kN*

B. *Comparative Study: Lumped Mass Vs Two Mass Model*

Comparison of different seismic analysis parameters of intze tank supported on frame staging is shown in Table. In this table all parameters for single mass modal as well two mass modal with frame staging are summarized

Table - 4.2
Comparison of various parameters by two methods

Sl. No	*Idealization of tank*	*Lumped-mass model*	*Two-mass model*
1	*Brace beam flexibility*	*Neglected*	*Considered*
2	*Lateral stiffness of staging*	*17800 kN/m*	*17800 kN/m*
3.	*Time period*		

	Impulsive mode *a) Tank Empty (T_i)* *b) Tank Full (T_i)* *Convective mode* *a) Tank Full (T_c)*	*0.763 s* *1.23 s* *------*	*1.18 s* *1.80 s* *3.705s*
4.	*Design horizontal seismic coefficient:* *Impulsive mode* *a) Tank Empty $(A_h)_i$* *b) Tank Full $(A_h)_i$* *Convective mode* *a) Tank Full $(A_h)_c$*	*0.019* *0.010* *-------*	*0.025* *0.165* *0.033*
5	*Base shear (V)* *a) Tank Empty* *b) Tank Full*	*117.818 kN* *161.910 kN*	*154 kN* *241 kN*
6	*Overturning Moment (M)* *a) Tank Empty* *b) Tank Full*	*2321.05 kN-m* *3189.43 kN-m*	*3084 kN-m* *5311 kN-m*

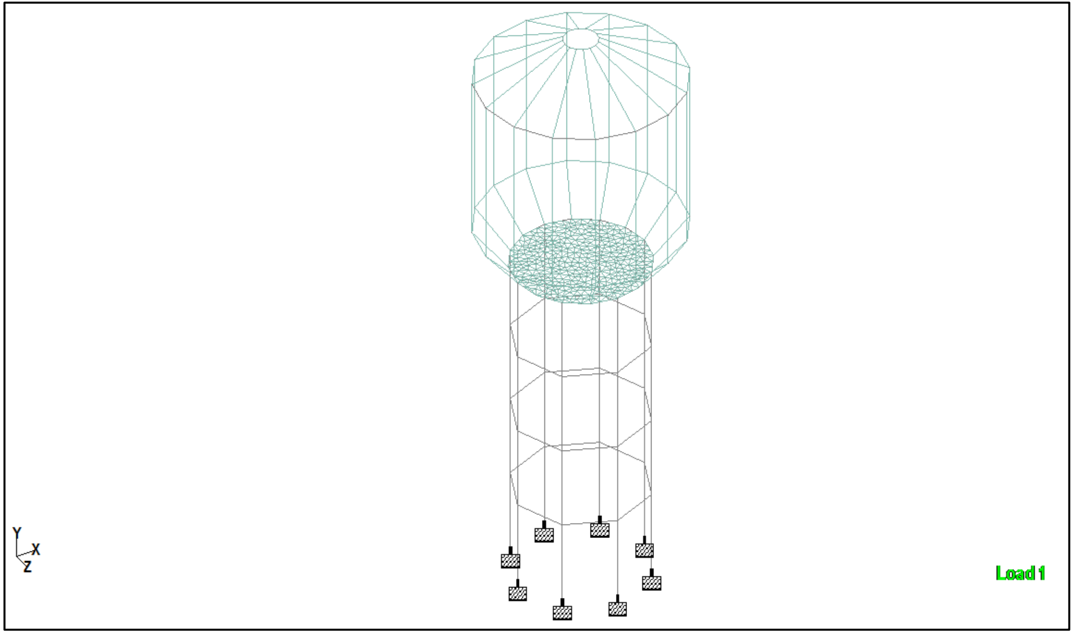

Fig. 2.1: Plan of Intze water tank

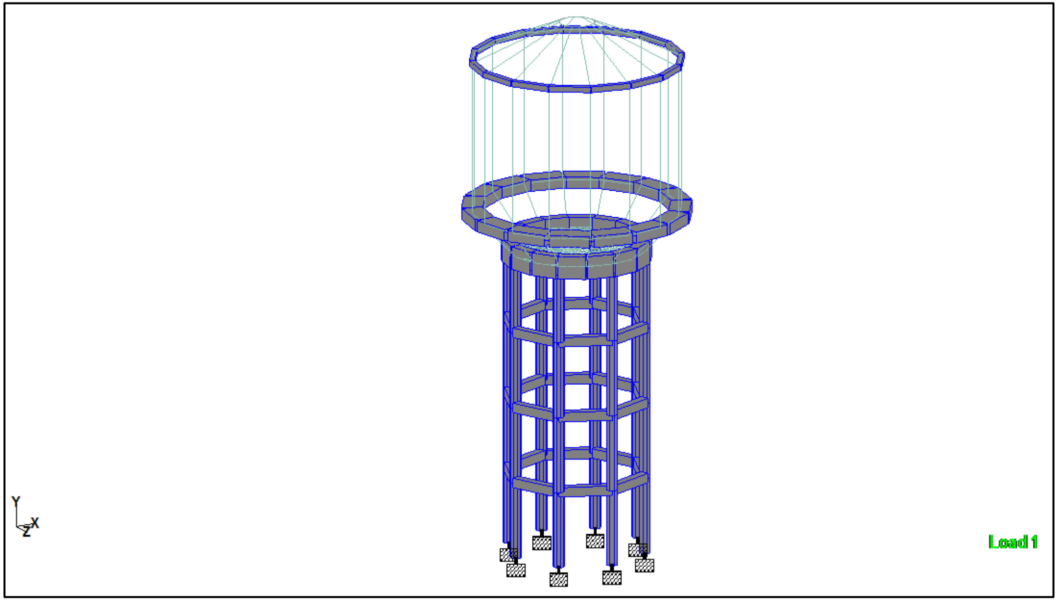

Fig. 2.1.1: Model of Intze tank with sections

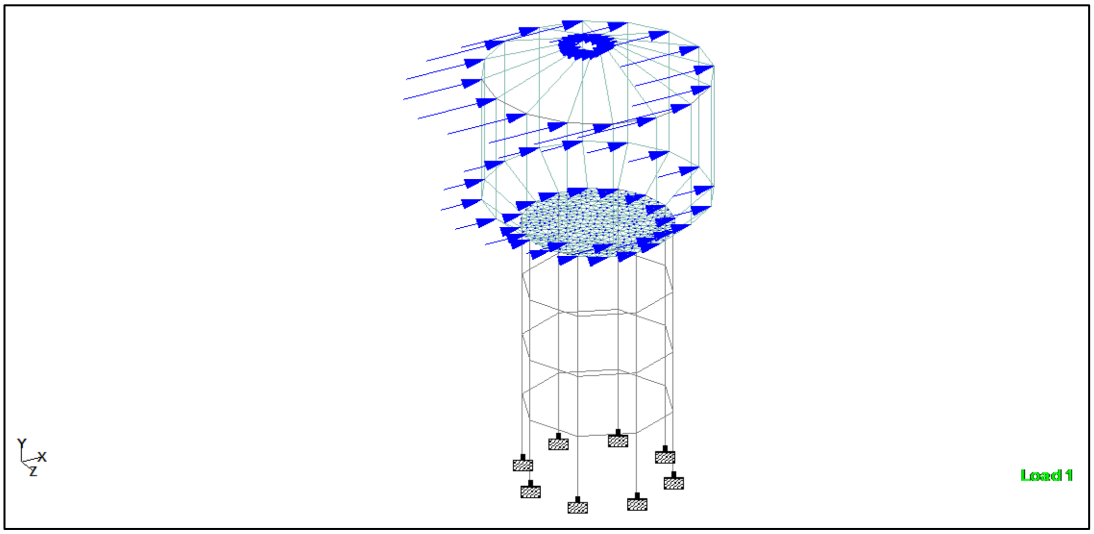

Fig. 2.1.2: Earthquake loading in X(+)direction

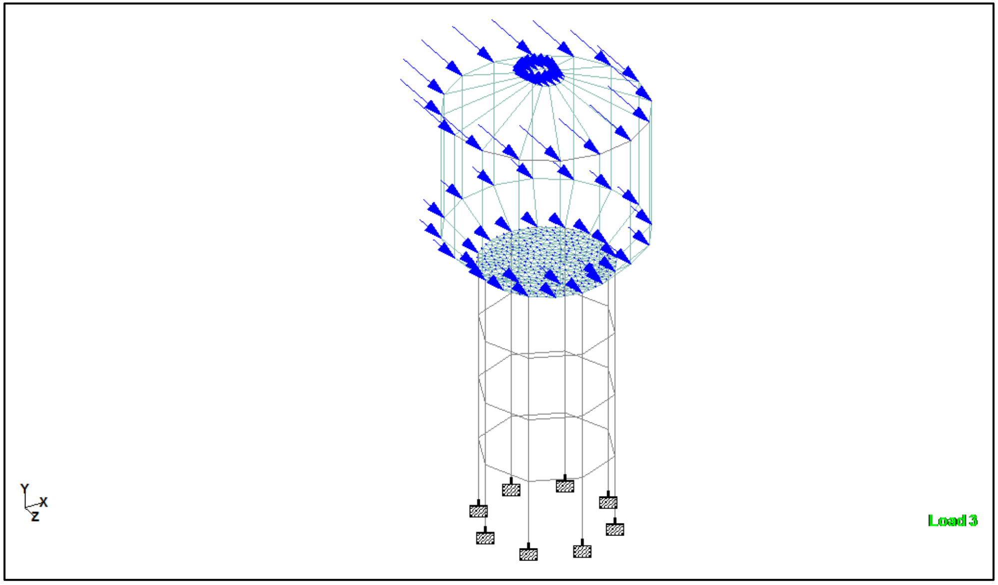

Fig. 2.1.3: Earthquake loading in z(+) direction

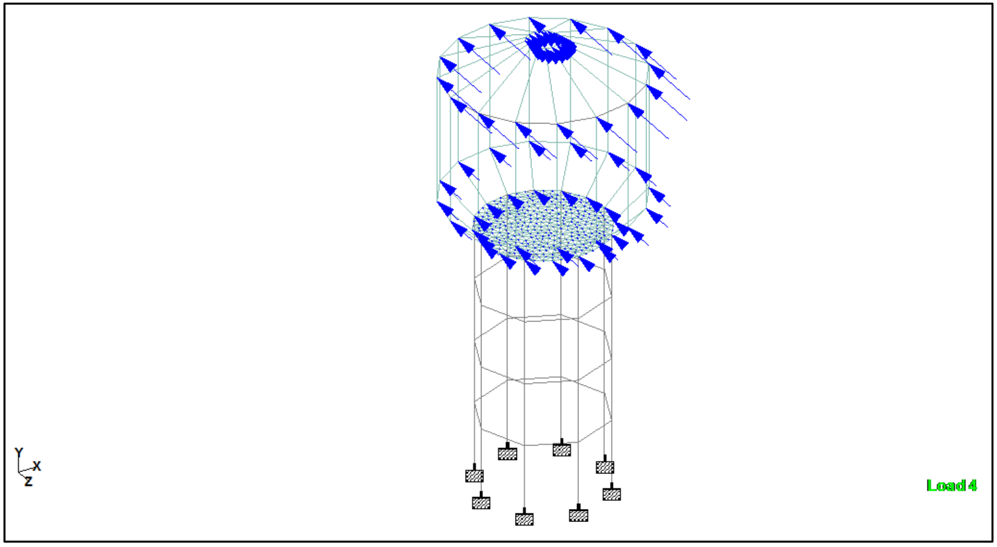

Fig. 2.1.4: Earthquake loading in z(-)direction

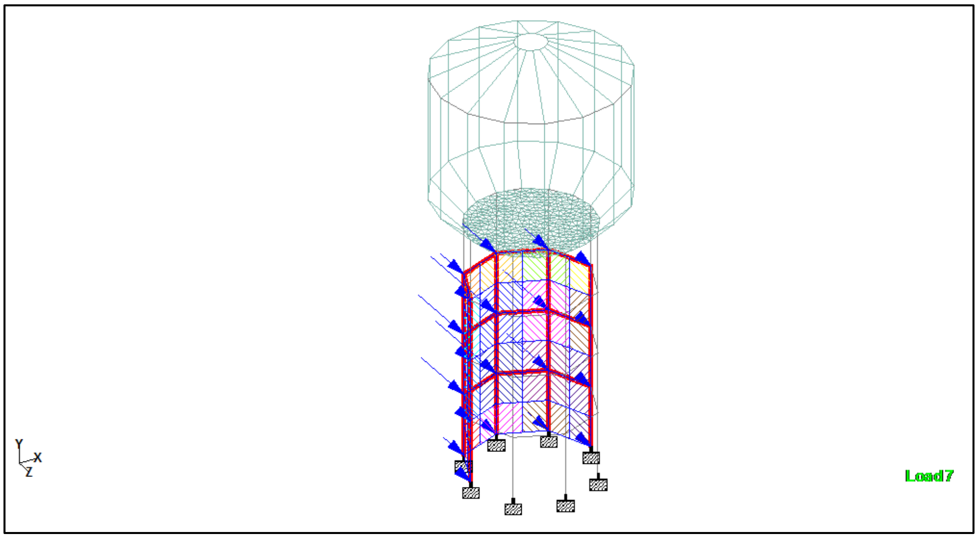

Fig. 2.1.5: Wind loading in x(-)direction

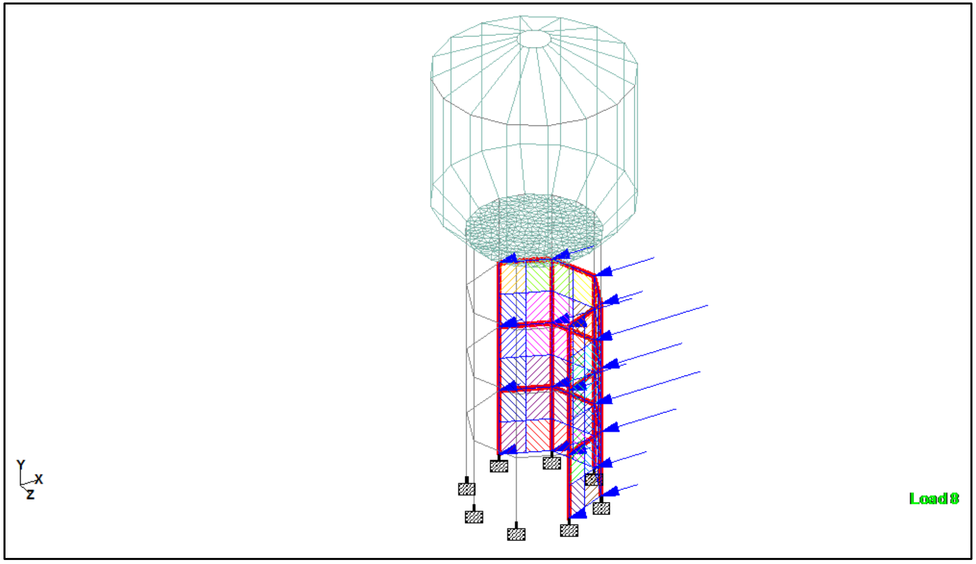

Fig. 2.1.6: Wind loading in z(-)direction

C. Live Loads

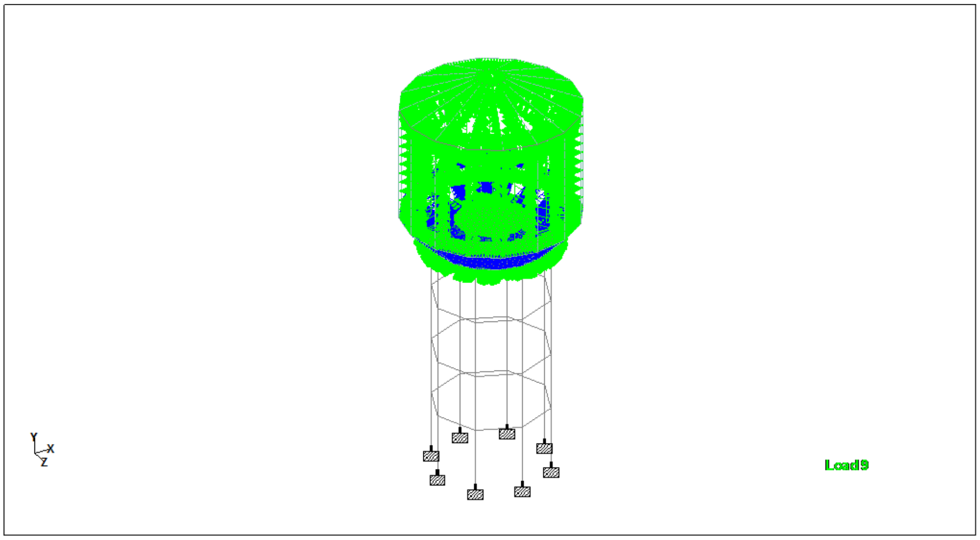

Fig 2.1.7: Trapezoidal load on bottom ring beam

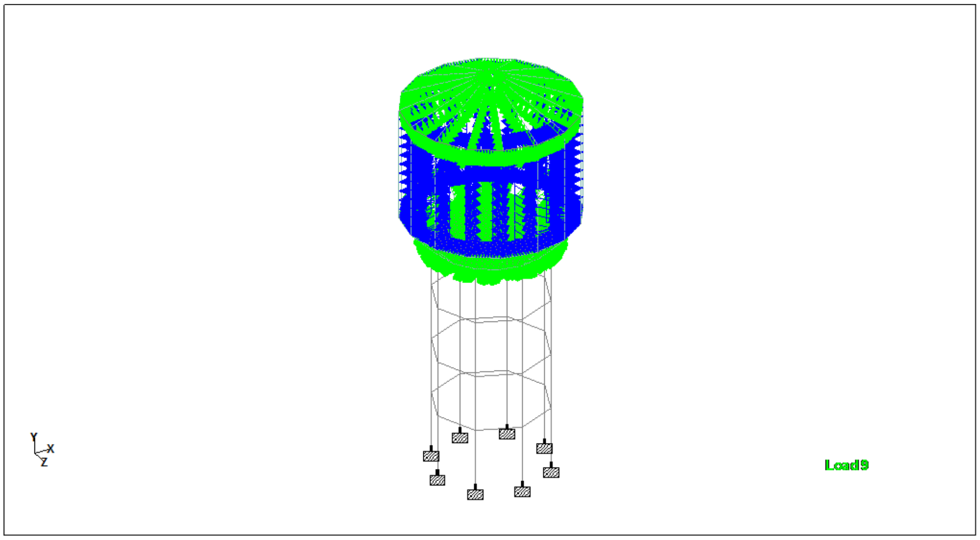

Fig 2.1.8.Trapezoidal load on cylindrical wall

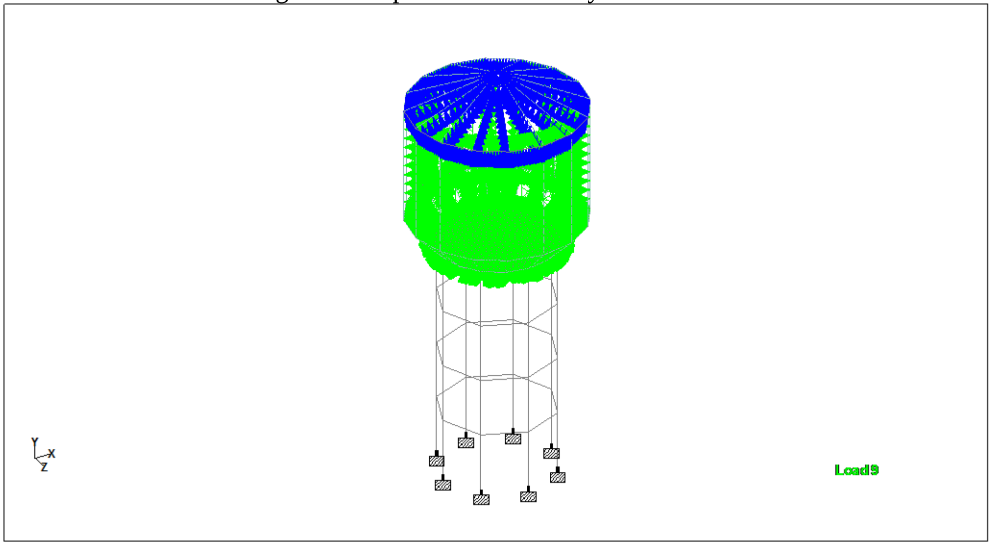

Fig. 2.1.9.Trapezoidal load on top ring beam

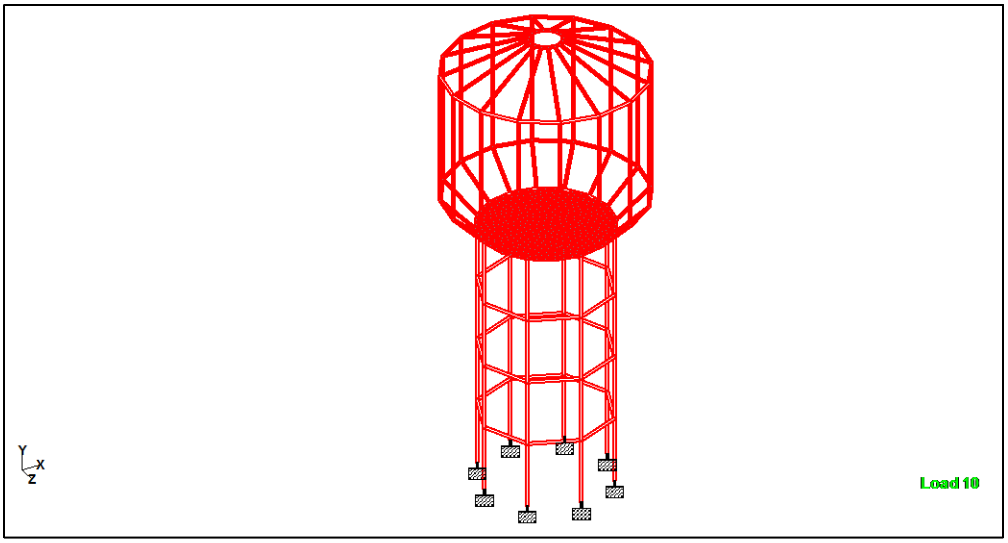

Fig 2.1.10 Self weight of the structure

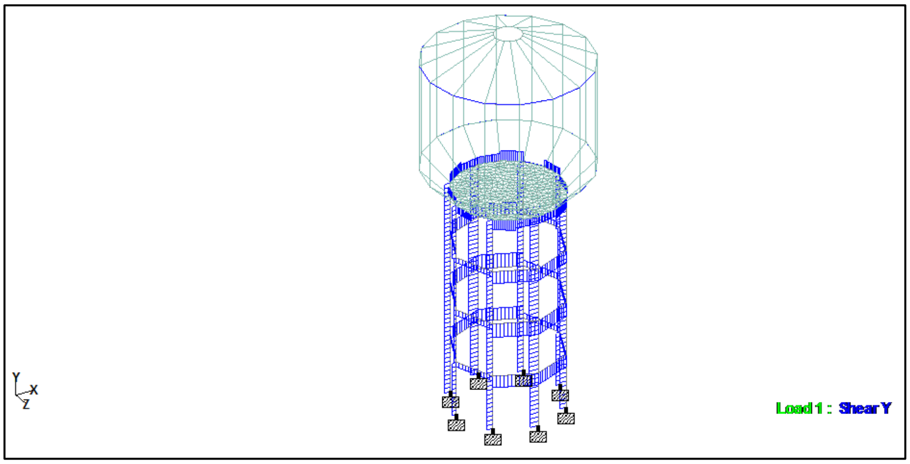

Fig 2.1.11.Shear force diagram

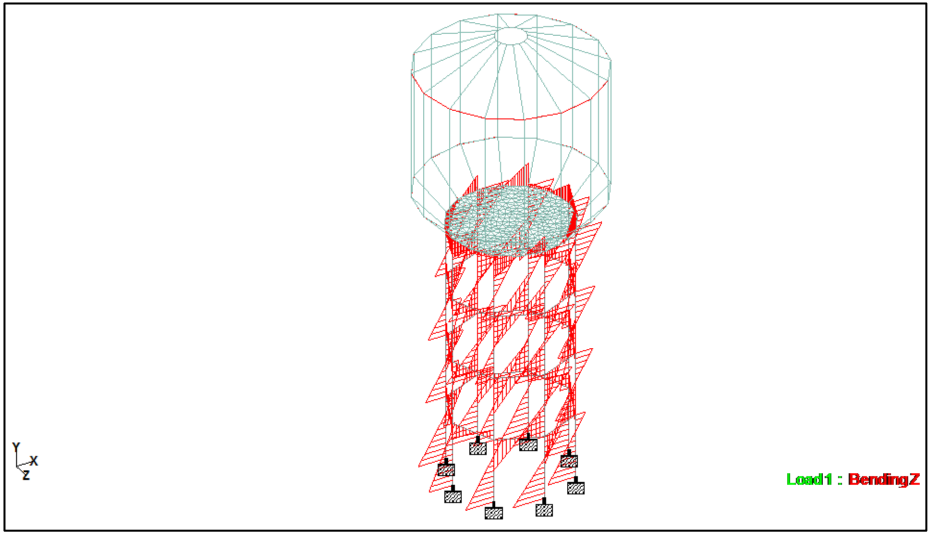

Fig 2.1.12.Bending moment diagram

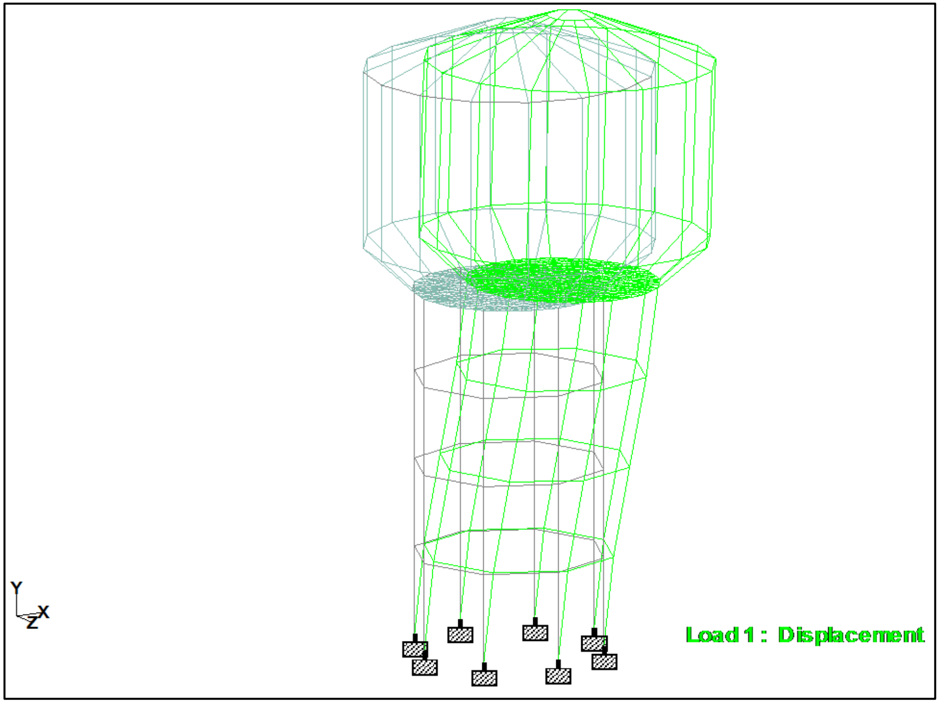

Fig. 2.1.13 Displacement diagram of Intze tank

IV. RESULTS AND DISCUSSIONS

A. *Lumped Mass Model Graphical Representation*

Table - 4.1.1
Hydrodynamic pressure on the wall

y (m) (from top)	*P_w (N/m^2)*
0	*0*
1	*727.784*
2	*1262.066*
3	*1384.963*
4	*1996.134*
5	*2202.998*

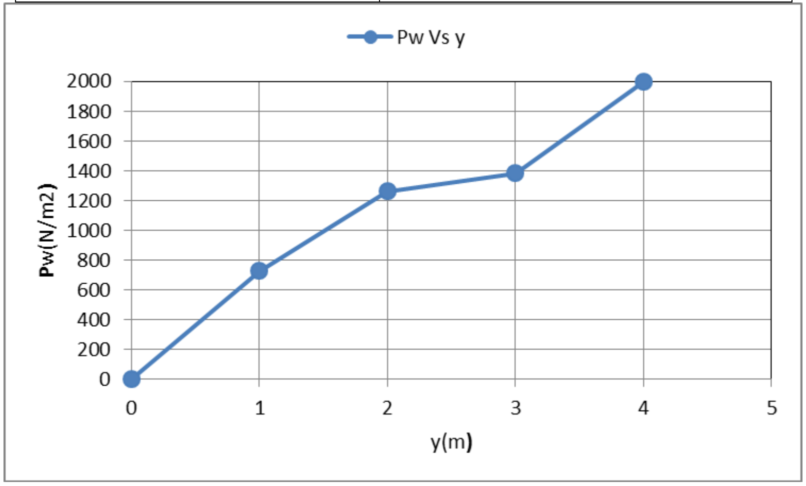

Fig. 4.1.1.Variation of hydrodynamic pressure with the depth of the cylindrical wall for lumped mass condition

Table - 4.1.2
Hydrodynamic pressure on the bottom of the tank

y (m)	*y/h*	*P_b (N/m^2)*
0	*0*	*0*
1	*0.2*	*361.26*
2	*0.4*	*750.08*
3	*0.6*	*1187.63*
4	*0.8*	*1412.23*
5	*1.0*	*1789.62*

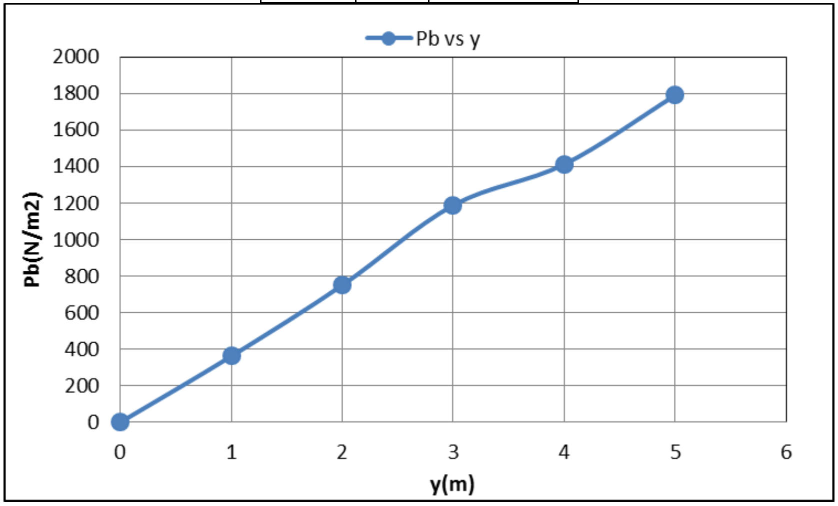

Table 4.1.2: Hydrodynamic pressure on the bottom of the tank

B. Two Mass Model Graphical Representation

Table - 4.2.1
Impulsive hydrodynamic pressure on wall

y (m)	y/h	P_{iw} (N/m^2)
0	0	0
1	0.2	7842.18
2	0.4	10967.22
3	0.6	14421.68
4	0.8	16623.42
5	1	17792.14

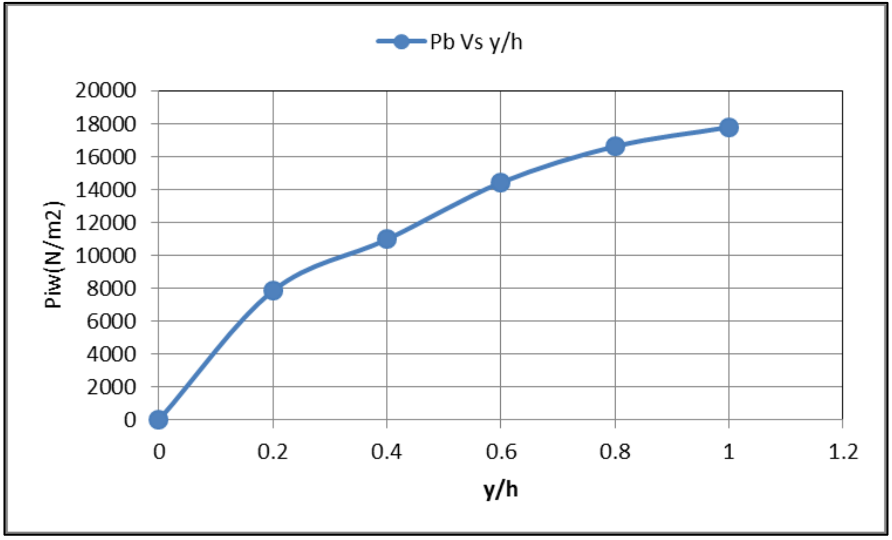

Fig. 4.2.1.Impulsive hydrodynamic pressure on wall

Table - 4.2.2
Impulsive hydrodynamic pressure on the bottom of tank

y (m)	P_{ib} (N/m^2)
0	0
1	2704.36
2	5682.29
3	10845.36
4	16978.01
5	22842.69
6	30505.12
7	42796.33

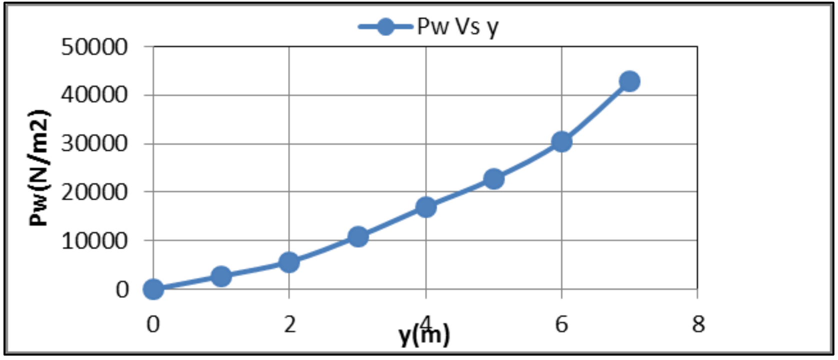

Fig. 4.2.2: Impulsive hydrodynamic pressure on the bottom of tank

C. *Convective Hydrodynamic Pressure*

Table - 4.3.1
Convective hydrodynamic pressure on the wall

y (m)	*y/h*	*P_{cw} (N/m^2)*
0	*0*	*0*
1	*0.083*	*1986.43*
2	*0.166*	*2102.69*
3	*0.250*	*2523.40*
4	*0.333*	*2598.62*
5	*0.416*	*3691.69*
6	*0.500*	*4498.92*

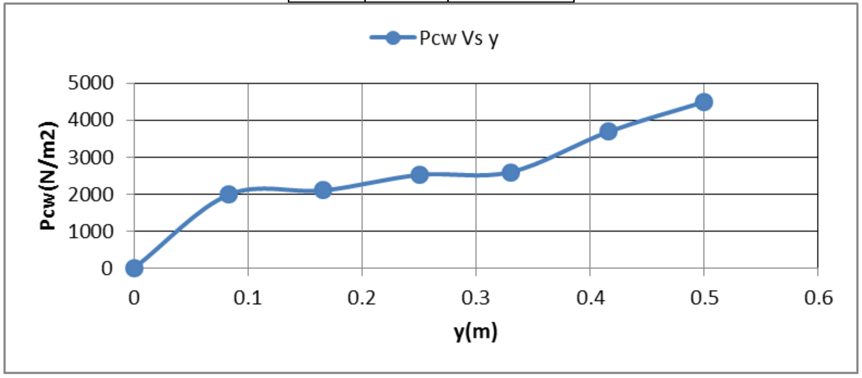

Fig. 4.3.1: Convective hydrodynamic pressure on the wall

y(m)	***P_{cb} (N/m^2)***
0	*0*
1	*361.26*
2	*750.08*
3	*1187.63*
4	*1412.23*
5	*1614.45*
6	*1789.76*
7	*1948.62*

Table - 4.3.2
Convective hydrodynamic pressure on the base slab

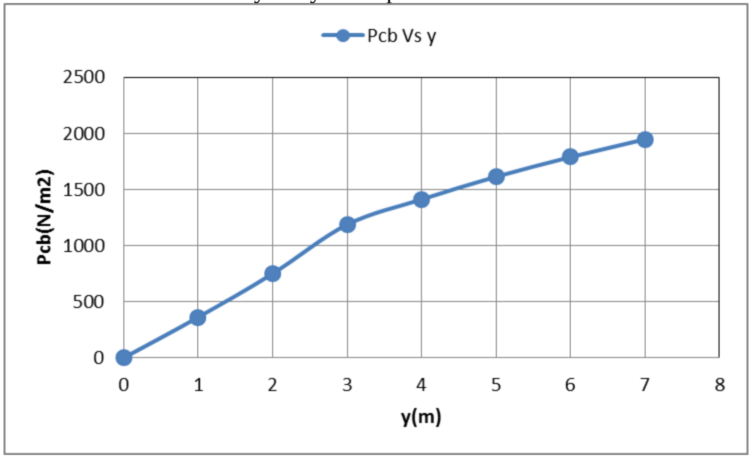

Fig. 4.3.2: Variation of Convective hydrodynamic pressure on base slab

D. Comparison of Total Base Shear and Moment for Both Conditions

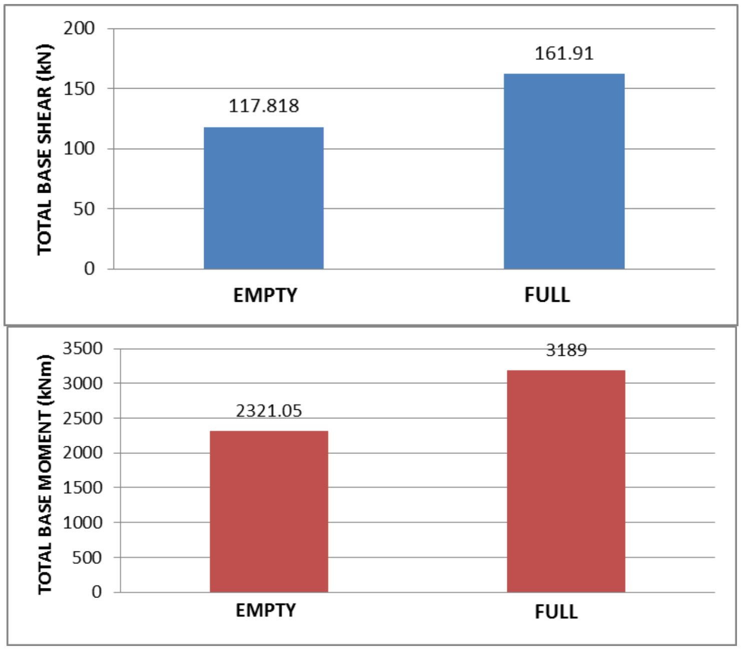

Fig. 4.4.1: Values of Total base shear and total base moment for tank full and tank empty conditions

E. Comparison of Time Period, Base Shear and Base Moment for Impulsive and Convective Mode of Vibration for Tank with Full Condition

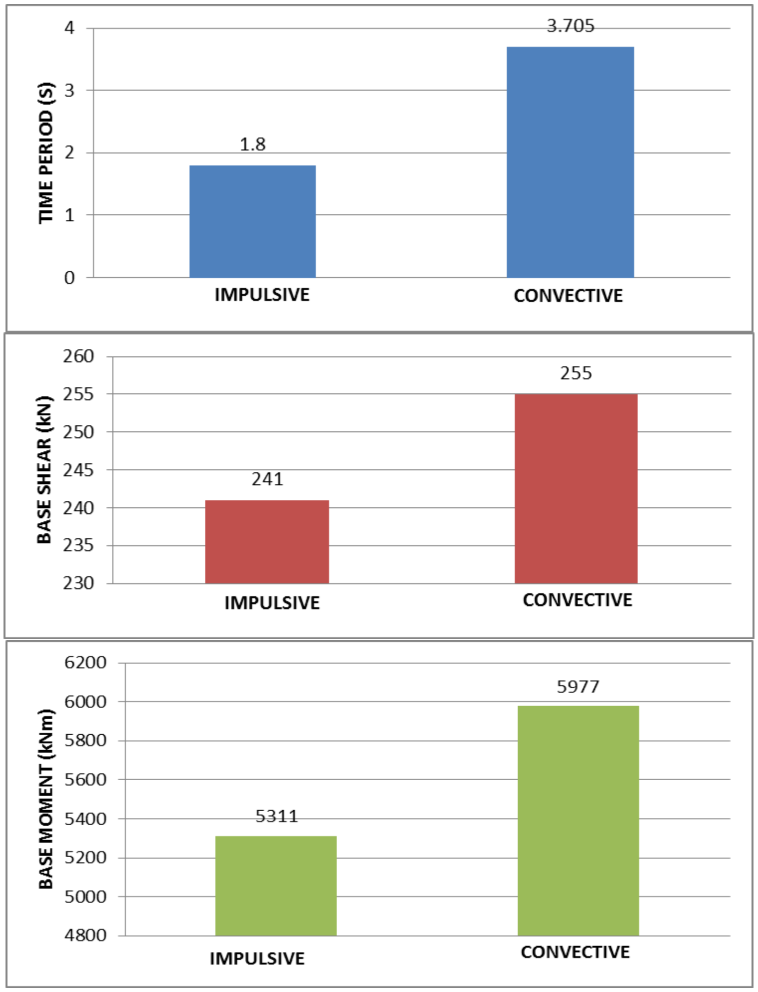

Fig. 5.5.1: Values of base shear and base moment for Impulsive and Convective mode of vibration for tank full condition

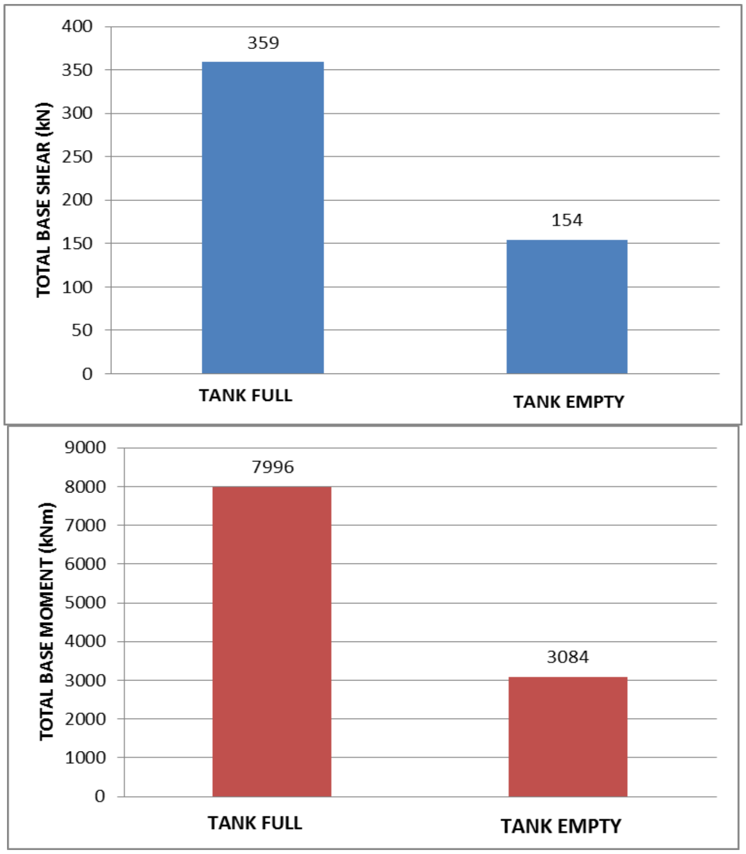

Fig. 5.5.2: Values of Total base shear and total base moment for tank full and tank empty conditions

V. CONCLUSIONS

Generally, when earthquake occur major failures of elevated water tank take place due to failure of supporting systems, as they are to take care for seismic forces. Therefore supporting structures of elevated water tanks are extremely vulnerable under lateral forces due to an earthquake. Seismic analysis and performance of elevated RC intze water tanks have been presented in this study for frame type of staging pattern

Modelling is performed using STAAD PRO software. Further, the behaviour of elevated water tank with staging pattern is analyzed using lumped mass model and two mass model methods. It can be observed from the analyses that elevated water tank with frame type of staging perform better by following draft code IS: 1893 (Part-2) guidelines than earlier guidelines due to the following characteristics.

– From the comparison of impulsive and convective mode of vibration it was observed that Time Period, Base shear, Base moment obtained by convective mode of vibration is greater than impulsive mode of vibration.
– Total base shear and base moment obtained for tank full condition are more than tank empty condition by 47% and 51% respectively. Hence design will be governed by tank full condition.
– Lateral force is more in tank full condition when compared to tank empty condition and hence tank full case is considered for seismic analysis.
– Base shear obtained by two mass model is found to be increased by 36% when compared to lumped mass model method.
– Overturning moment obtained by two mass model method is found to be greater than the moment obtained in lumped mass model method by 41%.
– Results from the study suggest to consider convective and impulsive components in seismic analysis of tanks.
– The convective pressures during earthquakes are considerably more in magnitude as compared to impulsive pressures and its effect is a sloshing of the water
– The hydrodynamic pressure obtained by two mass model is more than that obtained by lumped mass model.
– For elevated tanks, the two degree of freedom idealization of tank should be used for analysis instead of using single degree of freedom of idealization of tank as the effect of convective hydrodynamic pressure has been included in the analysis of the tanks.
– The maximum value of forces and moments obtained from STAAD Pro tells the maximum load to which the tank is subjected and thus critical. The check for critical members from STAAD Pro also reveals that the tank is stable for maximum forces and moments.

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