Parametric Study of R.C Elevated Rectangular Tank for Economical Design Aspect

Sayed Habiburahman Haqbin[1] Chintan.D.Patel[2] Bansal.R.Patel[3]
[1]P.G.Student [2,3]Assistant Professor
[1,2,3]L.D. College of Engineering, Ahmedabad

Abstract— The tank is considered two degrees of freedom system with a large mass is located at the top, supported by columns or frame supporting system. The behavior of tank under earthquake loading is greatly depending on the height of staging and mass of located at the top of staging. This studying work is shown the effect of container height on seismic behavior of R.C elevated rectangular water tank as well as the comparison of the Indian and USA seismic design codes. The elevated water tank with various container heights such as (3.5m, 3.6m, 3.7m and 3.8m) and same supporting system with four capacities such as (200,300,400, & 500 m3) in IV seismic zone were studied in STAAD.pro and Excel sheet developed program. The spring mass model as per IS 1893:2006 (part) 2 draft code the water mass consisting of the convective and impulsive masses was used for analysis. Parameter of studying such as maximum displacement, maximum base shear and maximum overturning moment for different container height and IV seismic zone. Also compared the base shear value of water tank by using the seismic design code of USA and IS with subjected to IV seismic zone.

Key words: Spring Mass Model, Stiffness, Container Height, Excel Sheet and STAAD.pro

I. INTRODUCTION

Water tank is an important and strategic structure and it should remain functional during earthquakes to overcome the water demand due to fire etc. Water tanks are different from the building, because the huge mass of water is located at the top of supporting system. During the earthquake the mass of water is considered two parts such as impulsive and convective liquid mass. The good understanding of the behavior of water tank during seismic activity is necessary in order to evaluate the forces exerted due to earthquake.in the case of elevated water tank resistance against earthquake force is largely dependent of the supporting system and mass of water located at the top of staging system. Staging of the elevated water tank is considered to be the critical element subjected to the lateral force (seismic forces).when the tank partially filled with water, the tank is subjected to horizontal seismic acceleration and sloshing waves generates which exerts hydrodynamic forces on the wall and base of container.to calculate these hydrodynamic forces spring mass model suggested as per IS 1893:2006)part(2 draft code can be used.in the case of elevated water tank behavior of tank under hydrodynamic and hydrostatic forces are considered is greatly dependent on the configuration of staging and container its height and stiffness. For economical design aspect we studied the IS and USA seismic code to understand the difference between both codes. And used STAAD.pro analysis package software, to compare the values of base shear for different capacities such as (200,300,400 &500 m3) and container height such as (3.5,3.6,3.7 &3.8m) in IV seismic zone. The comparisons of base shears result are plotted in the graphs. They are shown the USA seismic code base shear values are more than the IS seismic code values. This comparison of result point out the USA code more safe and uneconomic but IS code is economic and safe.

II. METHODOLOGY

In the present study different container height such as (3.5m, 3.6m, 3.7m, and 3.8m) and capacities such as (200,300,400, & 500 m3) was adopted for the IV seismic zones. Tank is analyzed by using Excel sheet and STAAD.pro analysis package and performance with respect to base shear, overturning moment and displacement are presented. And also comparison of base shears of models with respect to IS and USA design codes. For finding out best configuration with respect to the economic cost.

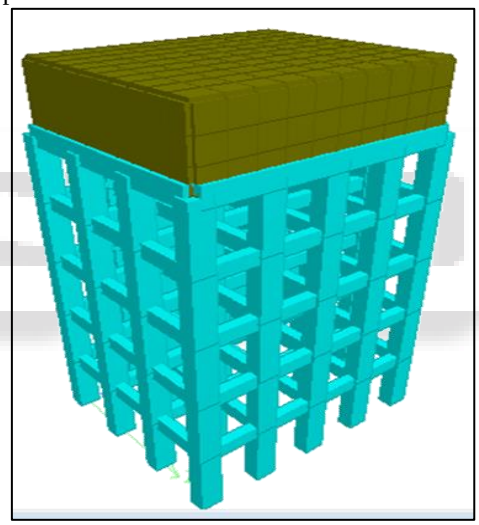


Fig. 1: 3D STAAD.pro Model

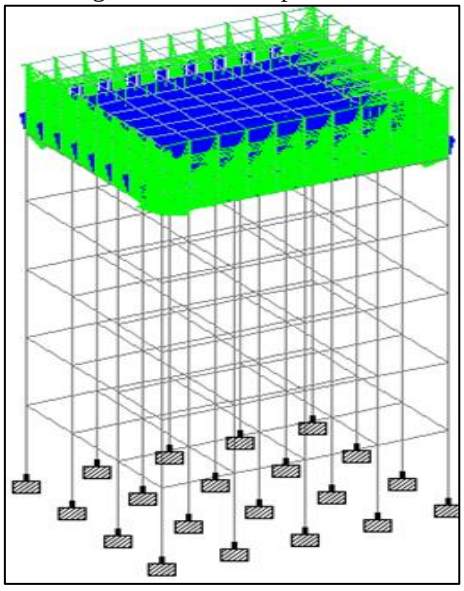


Fig. 2: Hydrostatic Loading

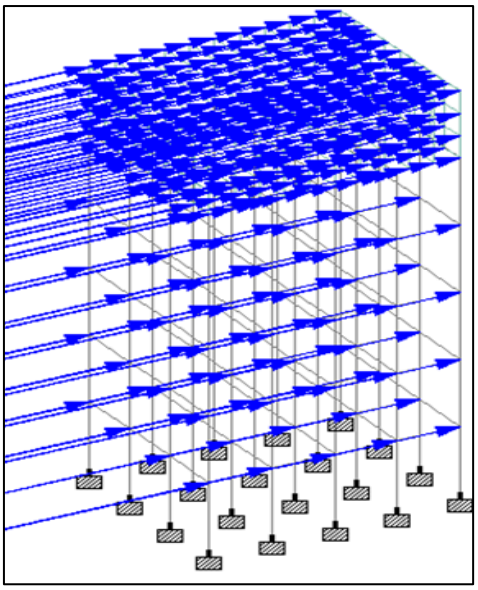


Fig. 3: Seismic Loading

Zone	Capacity (m^3)	Tie Beam (m)	Column (m)	Thickness (m)	Staging Height (m)
ZIV	200	0.5*0.3	0.80*0.5	0.30	17.5
	300	0.75*0.5	0.1*0.7	0.32	
	400	0.75*0.5	0.10*0.75	0.34	
	500	0.8*0.5	0.10*0.8	0.36	

Table 1: analysis data

III. ANALYSIS

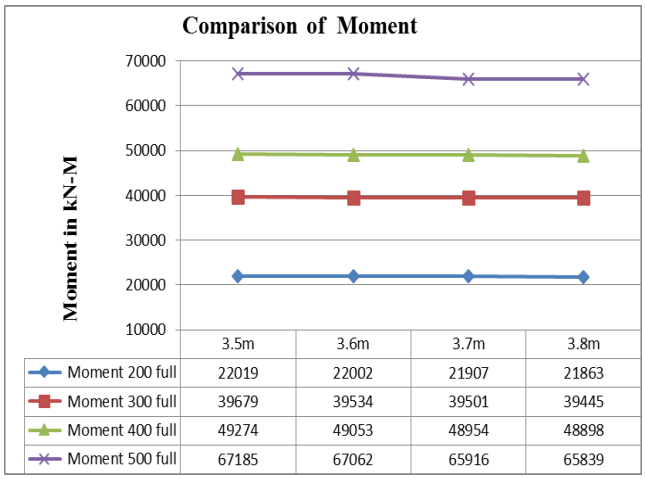
Seismic coefficient analysis or equivalent static analysis was carried out and found out the response of the R.C elevated rectangular tank. The calculation procedure in Excel sheets is considered two spring mass models for every model as per IS 1893:2006 (part) 2 draft code. And found out the response of the elevated water tank (base shear, overturning moment and displacement) and summarized below. Comparison between each of the models are made based on the analysis results and plotted in graphical format. Also we studied the difference of base shear values between the IS and USA seismic codes by using STAAD.pro analysis package software and the results of analysis are plotted in the graphs.Apart from those we are studied the maximum horizontal displacement for determination of the stiffness or flexibility of the tanks. Maximum horizontal displacements show the requirement of columns and sufficient supporting system. For the analysis and designing of models by using STAAD.pro software these steps are followed such as (models, property, support assigning, load definition and applying, analysis, design and viewing result).

Zone	Capacity (m3)	Height (m)	Width (m)	Ratio	Length (m)	Base shear (kN)	Moment (kN-m)	Sloshing (m)
ZIV	200	3.5	6.9	1.3	8.3	1039	220199	0.195
		3.6	6.8	1.3	8.2	1035	220002	0.199
		3.7	6.7	1.3	8.1	1030	219907	0.197
		3.8	6.6	1.3	8	1026	218663	0.197
	300	3.5	8.4	1.3	10.2	1872	396799	0.216
		3.6	8.3	1.3	10	1862	395534	0.214
		3.7	8.2	1.3	9.9	1856	395001	0.12
		3.8	8.1	1.3	9.7	1851	394445	0.211
	400	3.5	9.8	1.3	11.7	2303	492774	0.22
		3.6	9.6	1.3	11.6	2292	490503	0.224
		3.7	9.5	1.3	11.4	2288	489554	0.223
		3.8	9.4	1.3	11.2	2284	488898	0.2245
	500	3.5	10.9	1.3	13.1	3139	671885	0.233
		3.6	10.8	1.3	12.9	3123	670662	0.232
		3.7	10.6	1.3	12.7	3074	659116	0.235
		3.8	10.4	1.3	12.7	3059	658339	0.233

Table 2: Base shear, Overturning Moment and Displacement

IV. RESULTS AND DISCUSSION

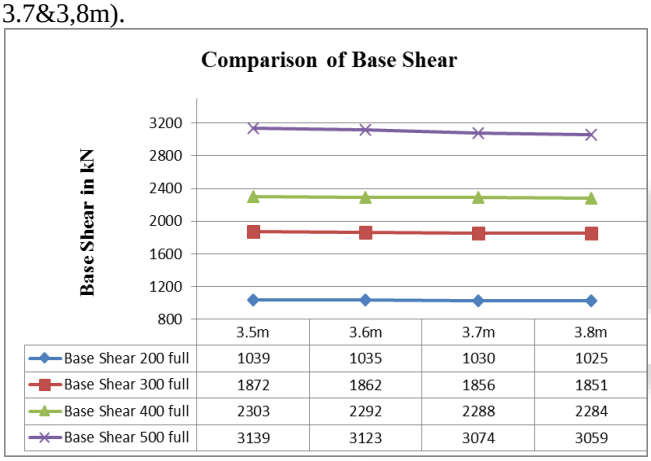
Base shear overturning moment and displacements: Base shear, overturning moment and displacement for earthquake analysis are presented in the graphs they are observed that base shear and overturning moment decrease as increase container height. And the displacement values are remained costant. Because the supporting systems are not changed.



	3.5m	3.6m	3.7m	3.8m
Moment 200 full	22019	22002	21907	21863
Moment 300 full	39679	39534	39501	39445
Moment 400 full	49274	49053	48954	48898
Moment 500 full	67185	67062	65916	65839

Graph 1: Variation of Moment in ZIV for Different Container Height

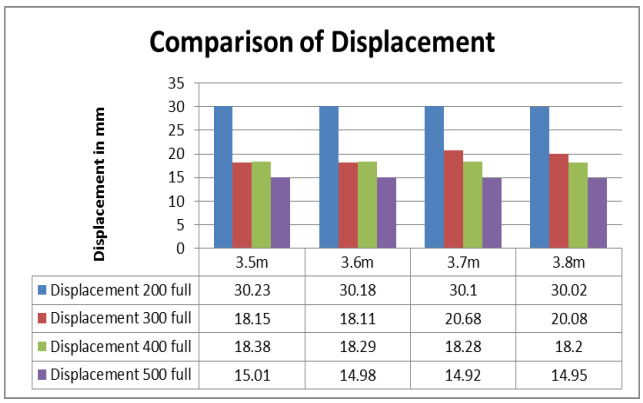
As the above graph is plotted shows there is a gradual decreased in the moment as increase in the height of container in IV seismic zone. Also we can say 3.8m container height is the best configuration for the same capacity of water tank with different container height such as (3.5, 3.6, 3.7&3,8m).



	3.5m	3.6m	3.7m	3.8m
Base Shear 200 full	1039	1035	1030	1025
Base Shear 300 full	1872	1862	1856	1851
Base Shear 400 full	2303	2292	2288	2284
Base Shear 500 full	3139	3123	3074	3059

Graph 2: Variation of Base Shear in ZIV for Different Container Height

As the above graph is plotted shows, there is a gradual decreased in the base shear values as increase the height of container in IV seismic zone. Also we can say 3.8m container height is the best configuration for the same capacity of water tank with different container height such as (3.5, 3.6, 3.7&3,8m).



	3.5m	3.6m	3.7m	3.8m
Displacement 200 full	30.23	30.18	30.1	30.02
Displacement 300 full	18.15	18.11	20.68	20.08
Displacement 400 full	18.38	18.29	18.28	18.2
Displacement 500 full	15.01	14.98	14.92	14.95

Chart 1: Variation of Dispacement in ZIV for Different Container Height

As the above chart is plotted shows there is no changing the displacements values when the container height is changed. Because the stiffness of the supporting systems are remained constant and the displacements values show the requirement of columns and sufficient supporting system.

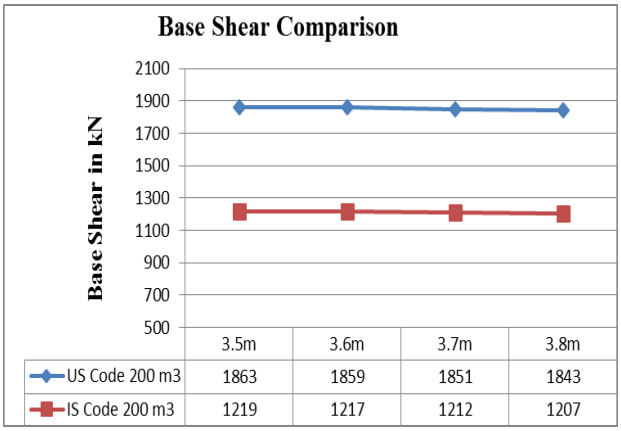
V. COMPARISON OF SEISMIC CODE

Comparison of IS and US codes: Some parameters in IS and USA seismic codes are different that affect the result of analysis while using the mentioned codes:

1) Soil classification according the Indian seismic code is divided into three categories(soft, medium and hard).But those soil classification according the USA seismic code is divided into six classes such as (A,B,C,D,E & F).
2) In seismic analysis of structure in Indian code seismic coefficient is taken according the zone factor. But in the USA seismic code is taken from the mapped horizontal spectral response acceleration in short times 0.2 second and 1 second.
3) The site seismicity according the IS code is divided into V seismic zones (II, III, IV & V) the values of zone factor is taken from the table of zone factor is prepared in the IS code. But according the USA seismic code the site is divided according the zip-code (latitude and longitude) the values of mapped spectral response of horizontal accelerations are taken from mapped with respect to short period such as (0.2 second) and 1 second time periods.

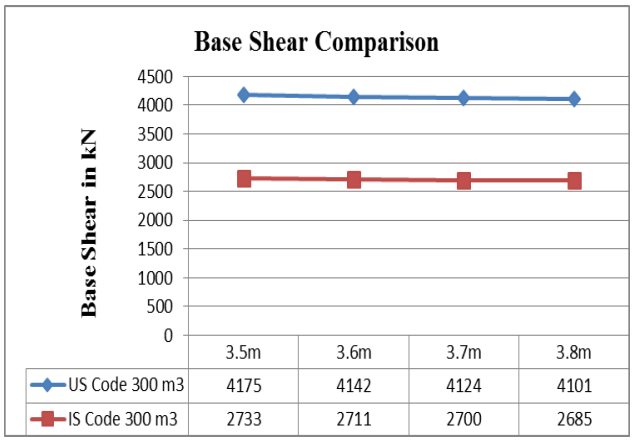
Resultant: In this analysis we are considered the maximum base shear of the different container height such as (3.5m, 3.6m.3.7m and 3.8m).and different capacities such as (200,300.400 and500 m3) in the IV seismic zone. The results of analysis which analyzed with IS and USA seismic codes by using STAAD.pro analysis package are plotted in the bellow graphs.

We have seen the difference values of maximum base shear, between the IS and USA seismic codes, and the values of base shear in the USA seismic code is more than the IS seismic codes. We can say the USA seismic code is more safe and uneconomic and the IS code is economical and safe.
Where
US= United states American seismic code.
IS= Indian Standard or Indian seismic code.

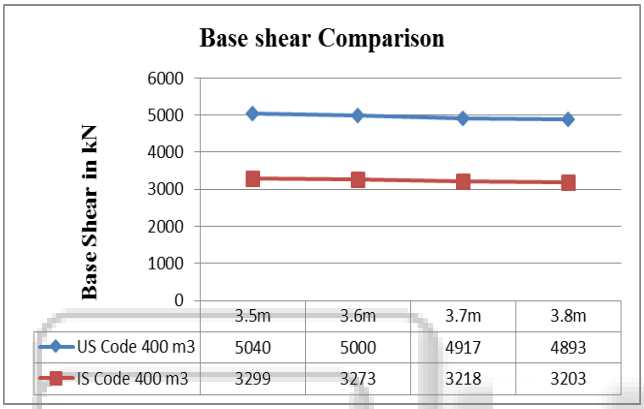


	3.5m	3.6m	3.7m	3.8m
US Code 200 m3	1863	1859	1851	1843
IS Code 200 m3	1219	1217	1212	1207

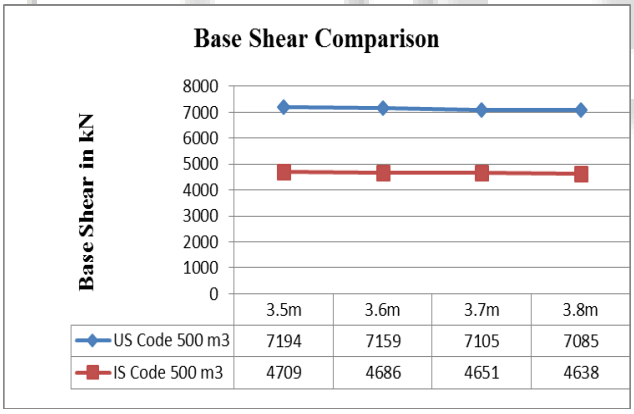
Graph 3: Difference of Base Shear between IS &US Seismic Code in ZIV for 200 m3



Graph 4: Difference of Base Shear between IS and USA Seismic Code in ZIV for 300 m3



Graph 5: Difference of Base Shear between IS and USA Seismic Code in ZIV for 400 m3



Graph 6: Difference of Base Shear between IS and USA Seismic Code in ZIV for 500 m3

VI. Conclusion

The elevated water tank with various container heights such as (3.5m, 3.6m, 3.7m, and 3.8m) and same supporting system with four capacities such as (200,300,400, & 500 m3) were studied in STAAD.pro and Excel sheet developed program. The spring mass model is considered as per IS 1893:2006 (part) 2 draft code and it is consisting of the convective and impulsive masses were used for analysis. Parameter studying of (maximum displacement, maximum base shear and maximum overturning moment) for different container height in IV seismic zone is carried out. The result of the studying are summarized as follows:

1) Base shear and overturning moment with increasing container height are decreased for the same seismic zone. These decreased values of base shear and overturning moment show 3.8m of container is the best economic configuration of container for different height of container such as(3.5, 3.6, 3.7&3.8m) and the same capacity.
2) Displacements of elevated water tanks show the requirement of columns and supporting system. And also the value of displacement shows the stiffness or flexibility of the supporting system. We have seen while container height is increasing the displacement values are remained constant .Because the supporting system is not changed.
3) The values of base shear for USA seismic code is more than 10% from the values of base shear for IS seismic code. These values of base shears are shown, the USA seismic code is more safe and uneconomic .But the values of base shear for same capacity in IS seismic code is more economic and safe.

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