Analysis of Circular Water Tanks under Different SeismicConditions For Two Different Conditions

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ABSTRACT

Water tanks are very important components of lifeline. They are grave elements in municipal water supply, fire fighting systems and in many industrial amenities for storage of water. In the seismic analysis of ground supported water tanks ,the total mass subjected to the seismic forces is divided into two parts that is impulsive and convective. Impulsive mass is subjected to the impulsive pressure whereas convective mass is subjected to the convective pressure. The impulsive pressures are associated with the inertial forces produced by the accelerations of the walls of the container and are directly proportional to these accelerations. The convective pressures are those produced by the oscillations of the fluid and are therefore the consequencesof the impulsive pressures. Corresponding to the impulsive and convective pressure variousdesign parameters like time period, sloshing height, design horizontal seismic coefficient in both impulsive and convective modes is calculated.

Keywords:-Convective mass, Impulsive mass, Sloshing height, Spring mass model

INTRODUCTION

Water tank is a structure which is used for the storage of liquids. Water tanks are classified based on their shapes and resting condition. If we talk about the shapes then the shapes which are most common are rectangular, square and circular. on the basis of resting condition the tanks are classified as underground, resting on ground and overhead tanks. For storage purpose resting on ground tanks are generally preferred whereas for direct distribution by gravity overhead tanks are generally preferred. Rectangular tanks are generally used when the amount of liquid to be kept is limited. For small capacity circular tanks cost is high because the cost involved with the shuttering increases drastically, whereas for large capacities circular tanks are preferred because they require least perimeter for given area. In the present research work the circular water tanks of different capacities under different seismic conditions are analysed using staad software. hydrostatic loading due to water is considered.

OBJECTIVES & PARAMETERS OF STUDY

The objectives of the present study is to observe the effect of various parameters like volume oftank, aspect ratio,seismic zones and the height of the tank above and below the ground on time period , design horizontal seismic coefficient (Ahc) and sloshing height which are required for the design of water tanks.The following are the parameters of study

1. Volume of tank-(500kl,1000kl,1500kl)
2. Aspect ratio-three different aspect ratios of 0.40,0.55 and 0.70 have been considered
3. Seismic zone-The location of water tanks in different seismic zones have been considered .Theseismic zone II,III,IV&V as defined by IS 1893:2016 have been considered in the design.
4. The total height of tank(h) has been divided into two parts i.e height of tank above and belowthe ground have been considered
5. The two different case have been considered

- Tank is 50% above and 50% below ground(called as Case A)
- Tank is 75% above and 25% below the ground(called as Case B)

Table 1 Seismic load parameters

Zone Factor	Zone I	0.10
	Zone II	0.16
	Zone III	0.24
	Zone IV	0.36
Response Reduction Factor		2.5
Importance Factor		1
Rock/Soil type		Medium Soil
Damping Ratio		5%

DESCRIPTION OF TANK MODELS

The different capacity of tank has been considered .To study the effect of aspect ratio (h/D) has beenvaried as 0.40,0.55 and 0.70.The numerical values of height and diameter for different capacities aretabulated in Table 2.

Table 2 Description of Tank models

VOLUME	MODEL	ASPECT RATIO(h/D)	HEIGHT(h)	DIAMETER(D)
500 KL	**1**	0.40	4.67	11.675
	2	0.55	5.775	10.5
	3	0.70	6.782	9.689
1000 KL	**1**	0.4	5.884	14.71
	2	0.55	7.275	13.229
	3	0.70	8.545	12.2
1500 KL	**1**	0.40	6.735	16.839
	2	0.55	8.329	15.143
	3	0.70	9.781	13.973

METHODOLOGY ADOPTED

Modelling of the structure has been done by using STAAD.Pro V8iSS6.

Excel Spreadsheets has been generated to determine lateral load distribution according to IS1893:2014(part2).

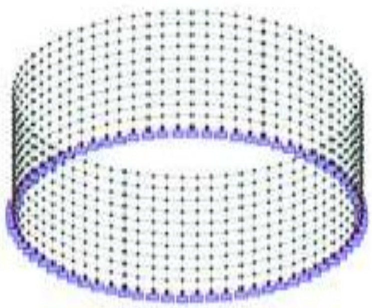
The size of the plate used is 0.5m*0.5m with base condition as fixed.the tank is designed in twodifferent exposure conditions:

- Tank is 50% above and 50% below ground
- Tank is 75% above and 25% below the ground

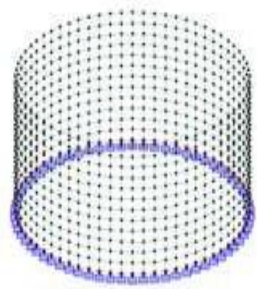
The part of the tank which is below the ground is subjected to earth pressure with maximum intensity at the base(varying linearly with zero intensity at the ground to maximum at the base).The liquid inside the tank is subjected to both hydrostatic and hydrodynamic forces which has been seprated into impulsive and convective parts.the impulsive part is attributed to the part of the liquid moves with the tank and convective component is formed by the liquid near the free surface and is characterized by long period oscillations.the tank is designed in each of the four seismic zones for medium soil condition.

The concrete of M30grade for all components of tank i.e bottom slab and wall has been considered while the grade of the steel is assumed to be Fe500.the density of liquid to be stored in the tank has been assumed as 10 Kn/m^3.the density of underlying soil has been assumed as 18 kn/m^3.

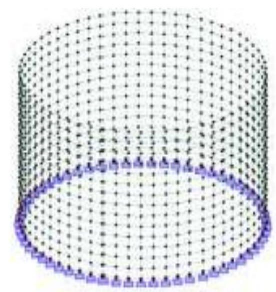
Stresses generated from STAAD.Pro output have been used to design tank satisfying the minimum thickness , minimum reinforcement and other detailing criteria according to IS3370:2009.



Model 1.1



Model 1.2



Model 1.3

Model 1.1 shows the 500kl tank with (h/D) Ratio 0.40.Model 1.2 shows the 500kl tank with (h/D) ratio 0.55. Model 1.3 shows the 500kl tank with aspect ratio 0.70.

OBSERVATIONS & DISCUSSIONS

After the analysis of different models, various outputs required for the design purpose have been determined.These includes time period (for impulsive and convective mode),Design horizontal seismic coefficient and sloshing wave height have been determined. The effect of different parameters on these output has been determined as follows

TIME PERIOD

- Time period of any structure depends on its geometry thus for both mode of vibrations , itis independent of seismic zone but hydrodynamic forces are associated with liquid sloshing thus depends on density of liquid too.
- Impulsive mode of vibration is associated with tank wall and liquid filled in tank thus itstime is dependent on materials properties of both tank wall & liquid stored.

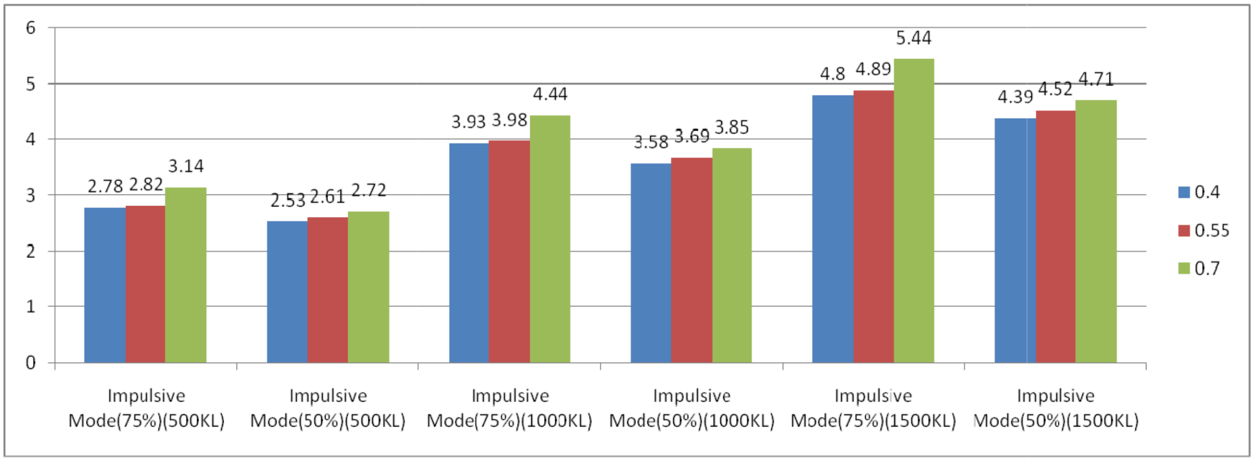


Fig 1 Time period in sec for impulsive mode for 500kl,1000kl,1500kl in two different

Resting condition

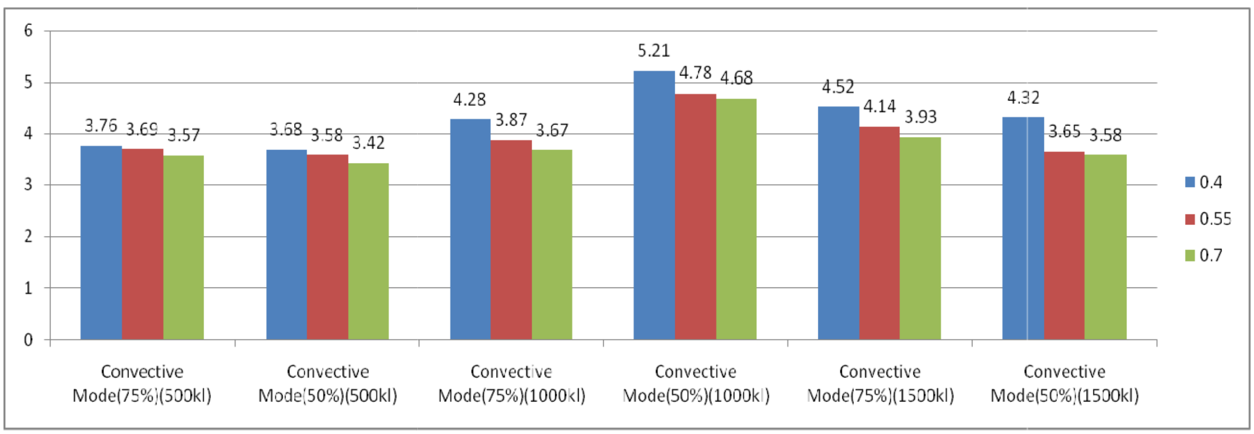


Fig 2 Time period in sec for Convective mode for 500kl,1000kl,1500kl in two differentResting condition

Fig 1 and Fig 2 are observations of time period in impulsive and convective mode in the form ofbar charts.It is observed that

1) For a given volume of tank of capacity 500kl above and below the ground time period for impulsive mode increases with increase in the aspect ratio while for convective mode it decreaseswith increase in the aspect ratio.

2) For a given volume of tank of capacity 1000kl above and below the ground time period for impulsive mode increases with increase in the aspect ratio while for convective mode it decreaseswith increase in the aspect ratio.

3) For a given volume of tank of capacity 1500kl above and below the ground time period for impulsive mode increases with increase in the aspect ratio while for convective mode it decreaseswith increase in the aspect ratio.

TABLE 3 Observations for time period in impulsive and convective mode

Volume(kl)	Resting Condition	Aspect Ratio	Ti(Sec)	Tc(sec)
500	A	0.40	2.53	3.68
		0.55	2.61	3.58
		0.70	2.72	3.42
	B	0.40	2.78	3.76
		0.55	2.82	3.69
		0.70	3.14	3.57
1000	A	0.40	3.58	5.21
		0.55	3.69	4.78
		0.70	3.85	4.68
	B	0.40	3.93	4.28
		0.55	3.98	3.87
		0.70	4.44	3.67
1500	A	0.40	4.39	4.32
		0.55	4.52	3.65
		0.70	4.71	3.58
	B	0.40	4.8	4.52
		0.55	4.89	4.14
		0.70	5.44	3.93

A-50% above ground

B-75%above groundDESIGN HORIZONTAL SEISMIC COEFFICIENT

Design horizontal seismic coefficient is calculated in both impulsive and convective modes of vibration. The value of design horizontal seismic coefficient in impulsive mode is not taken into consideration because the value of time period in impulsive mode is very less as compared to that of convective mode hence the value of (Sa/g) is very less for medium soil condition & hence ignored in the analysis.

The observations of design horizontal seismic coefficient are tabulated in Table 4

For a given volume of tank design horizontal seismic coefficient increases with increasein aspect ratio for all seismic zones. It has been observed that Ahc increases to 8.33% and 15.27% respectively when the aspect ratio is increased from 0.40 to 0.55 & 0.40 to 0.70 respectively for Zone II for the tank having height 50% above and 50% below ground.

The increase is more for change in aspect ratio from 0.55 to 0.70 as compared to change in aspect ratio from 0.4 to 0.55 for all cases.

Similarly for a constant aspect ratio and given seismic zone the value of Ahc increases with increase in the volume of the tank, its value is more for the case B(i.e for tank having height 75% above ground & 25% below ground) for a given volume,aspect ratioand all seismic zones.

Similarly for all aspect ratios & volume of the tanks,Ahc increases with the severity ofthe zone(i.e for zone II to zone V) for both exposure conditions(i.e case A and case B)

Table 4 Observations of Ahc for different seismic zones & capacity of tanks

Volume(Kl)	eismic Zone	Resting condition	Ahc			Percentage variation (h/D) Changes from	
			0.40	0.55	0.70	0.40 to 0.55	0.40 to0.70
500	Zone II	A	0.0072	0.0078	0.0083	8.33	15.27
		B	0.008	0.0081	0.0091	1.25	13.75
	Zone III	A	0.0081	0.0092	0.0097	13.58	19.75
		B	0.0085	0.0095	0.0102	11.76	20.11
	Zone IV	A	0.016	0.017	0.02	6.25	25
		B	0.019	0.0234	0.027	23.15	42.1
	Zone V	A	0.024	0.025	0.026	4.17	8.33
		B	0.029	0.031	0.035	6.90	20.69
1000	Zone II	A	0.0092	0.0098	0.01	6.52	11.09
		B	0.0098	0.0104	0.012	6.12	22.44
	Zone III	A	0.011	0.0126	0.0133	14.50	20.91
		B	0.0135	0.0158	0.0166	17	22.96
	Zone IV	A	0.017	0.019	0.02	11.7	17.65
		B	0.021	0.026	0.029	23.80	38.10
	Zone V	A	0.026	0.028	0.03	7.7	15.38
		B	0.034	0.037	0.04	8.82	17.65
1500	Zone II	A	0.02	0.026	0.033	30	65
		B	0.029	0.0328	0.041	13.1	41.38
	Zone III	A	0.03	0.04	0.046	33.33	53.33
		B	0.035	0.043	0.052	22.85	48.57
	Zone IV	A	0.038	0.043	0.052	13.15	36.84
		B	0.049	0.05	0.059	2.04	20.41
	Zone V	A	0.044	0.053	0.064	20.45	45.45
		B	0.058	0.061	0.072	5.17	24.13

A-50% above ground

B-75%above ground

SLOSHING HEIGHT

Sloshing height is the height of the waves formed on the surface when the liquid tank is subjected to seismic disturbance. The effect of sloshing is more when the aspect ratio i.e ratio of (h/D) is less because the tank with more surface area has more waves formed when subjected to the seismic disturbance.

The observations of sloshing height are tabulated in Table 5 and from Fig 3 to Fig 5 in terms of bar charts.

It has been observed that for a given volume and exposure condition(i.e Case A or Case B)the sloshing height decreases with increase in the aspect ratio for all seismic zones.

It increases with increase in the volume of the tank for all aspect ratios, exposure seismic zones and condition.

The sloshing height is more for case B as compared to case A for all volumes aspect ratio and seismic zones.

The value of sloshing height increases with severity of seismic zone for a given volume , aspect ratio and exposure condition.

It increases with increase in volume of the tank for all aspect ratios and seismic zones .The sloshing height is more for case B as compared to case A for all volumes , aspect ratio& seismic zones.

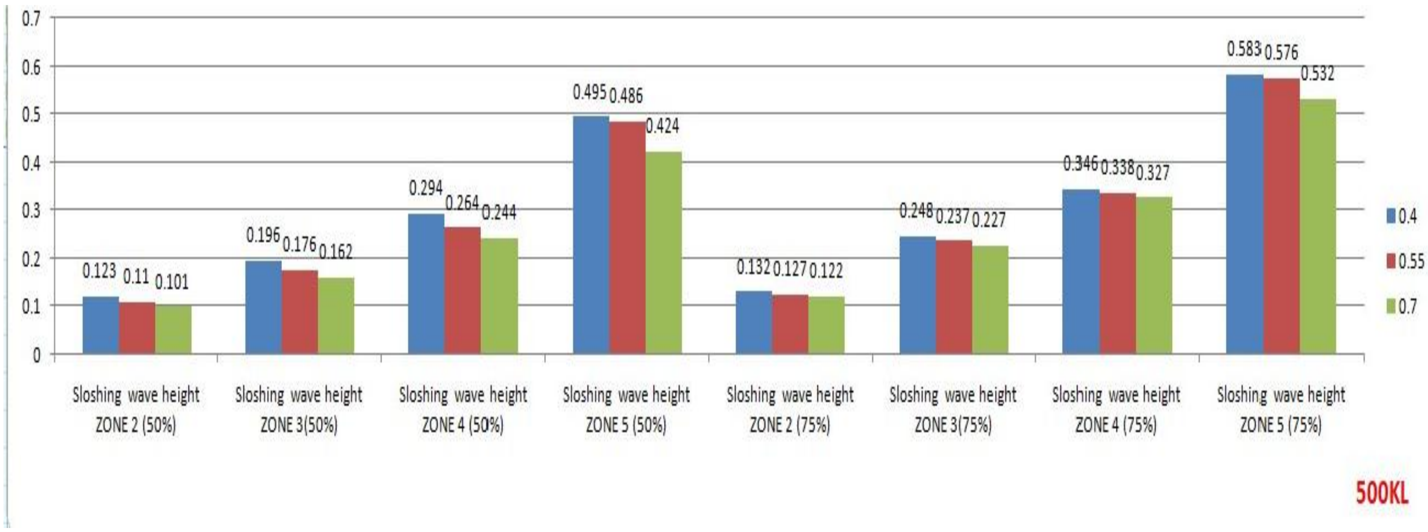


Fig 3 Sloshing wave height for 500kl in four seismic zones with two different resting conditions

Fig 4 Sloshing wave height for 1000kl in four seismic zones with two different resting conditions

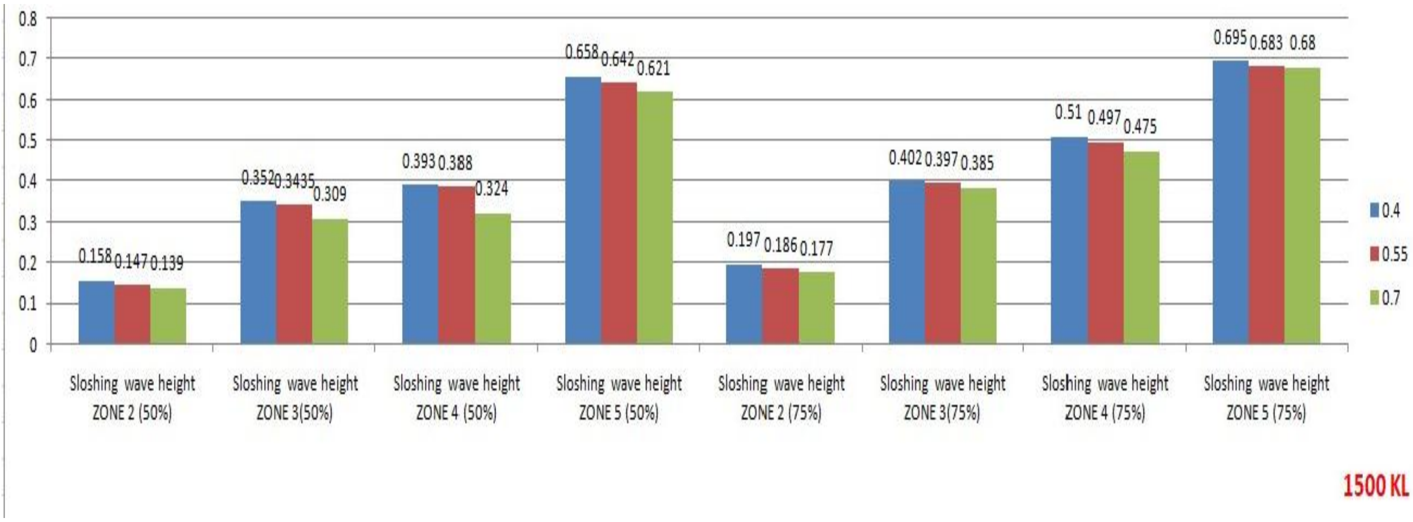


Fig 4 Sloshing wave height for 1500kl in four seismic zones with two different resting conditions

Table 5 Sloshing wave height for capacity 500,1000 & 1500kl in all seismic zones

lume(Kl)	**Resting Condition**	**Sloshing Height(in m)**											
		Zone II			**Zone III**			**Zone IV**			**Zone V**		
		0.4	**0.55**	**0.70**	**0.4**	**0.55**	**0.70**	**0.4**	**0.55**	**0.7**	**0.4**	**0.55**	**0.7**
500	A	.123	.110	.101	.196	.176	.162	.294	.264	.244	.495	.486	.424
	B	.132	.127	.122	.248	.237	.227	.346	.338	.327	.583	.576	.532
1000	A	.145	.139	.128	.251	.222	.201	.333	.307	.285	.582	.569	.557
	B	.168	.151	.143	.295	.286	.278	.396	.372	.354	.623	.617	.605
1500	A	.158	.147	.139	.352	.343	.309	.398	.388	.324	.658	.642	.621
	B	.197	.186	.177	.402	.397	.385	.51	.497	.475	.695	.683	.680

A-50% above ground

B-75%above ground

CONCLUSIONS

1. Time period in impulsive mode increases with increase in the aspect ratio and that inconvective mode decreases with increase in the aspect ratio.

2. Time period in both impulsive and convective mode increases with increase in the exposurecondition.

3. The value of design horizontal seismic coefficient(Ahc) increases with

    I. Severity of the earthquake
    II. Increase in the aspect ratio
    III. Increase in the volume of the tank
    IV. Decrease in the portion below the ground level because with more portion below the ground level, soil surrounding the structure from all sides provides stability to the structure.

2) The sloshing wave height increases with

I. Decrease in the aspect ratio

II. Increase in the seismic zone

III. Increase in the volume of the tank because large capacity tanks have thin walls andare subjected to large vibrations

IV. Increase in the portion above the ground level

References

1. Bhandari, M.(2014) "Economic design of water tank of different shapes with reference to IS:3370:2009", "International journal of modern engineering research".

2. Chaduvulaa U., et.al.(2013) "Fluid-structure-soil interaction effects on seismic behavior of elevated water tanks", proc 3rd Nirma University International Conference on Engineering PP:84- 91.

3. Ghaemmaghami A.R. and Kianoush M.R. (2010) "Effect of Wall Flexibility on Dynamic Response of Concrete Rectangular Liquid Storage Tanks under Horizontal and Vertical Ground Motions" J. of structural engineering, ASCE 136 (4),441-451.

4. Jaiswal O.R and Jain S.K.(2005) "Modified Proposed Provisions for A seismic Design of Liquid Storage Tanks: Part II – Commentary and Examples", Journal of Structural Engineering Vol. 32, No.

5. Joseph, A. et.al(2018) "Dynamic behavior and seismic response of ground supported cylindrical water tanks", "The institute of engineers (India)".

6. Kazem H.(2012) "Estimation of sloshing wave height in broad cylindrical oil storage tanks using numerical methods", "Journal of structural engineering and geotechnical".

7. Hakan A.(2005) "Experimental investigation of pressuredistribution on a rectangular tankdue to the liquid sloshing", "Department of ocean engineering"2005.

8. Housner G.W(1963), "The Dynamic Behavior Of Water Tank" Bulletin of The Seismological Society of America, Vol. 53, No. 2, pp. 381-387

9. Mohammed H.J.(2011) "Economical design of water concrete tank","European journal ofscientific research" Vol.49, No.4.

10. Moslemi M.(2012) "parametric study on dynamic behavior of cylindrical ground supported tanks", "Sciverse direct science engineering structures".