Comparative Study of Analysis of Elevated Water Tank Due To Earth Quake from Different Zones of Earth Quake

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Abstract: The main aim of this study is to analyse the elevated water tank and comparing the forces created on elevated water tank in different seismic zones due to earthquake. Any civil engineering structures are conceived keeping in mind its intended use, the materials available, cost and aseptic, considerations. The analysis of elevated water tank is performed on impulsive mode and convective mode using the code IS 1893 (part 2) 2002 and also we considered the forces in both tank full condition and tank empty condition. From this study the forces acting on elevated water tank due to seismic forces are calculated for all the zones and also the Base shear, Base moment values are compared from zone I to zone IV. The Horizontal forces due to seismic and wind effect are also calculated. Then finally the values are represented in the form of tables and graphs.

Keywords: Elevated water tank, Analysis, Comparison of forces

1. INTRODUCTION

Water is human basic needs for daily life. Elevated water tanks consists of a huge water mass at a the top of slender staging which are most critical consideration for the failure of the tank during earthquakes, elevated water tanks are critical and strategic structures and damage of these structures during earthquakes may endanger drinking water supply, cause to fail in preventing large fires and substantial economical loss. The performance of elevated water tanks during earthquakes is of much interest to engineers, not only because of the important of these tanks in controlling fires, but also because the simple structure of an elevated tank is relatively easy to analyse and, hence the study of tanks can de informative as to the behaviour of structures during earthquakes.

2. DEFINITION OF WATER TANK

A water tank is a container for storing water. The need for a water tank is as old as civilisation, providing storage of water for drinking water, irrigation agriculture, fire suppression, agricultural farming, both for plants and livestock, chemical manufacturing, food preparation as well as many other applications.

3. ELEVATED WATER TANK

Water is day by day essential requirement for each human life. A raised Reinforced Concrete roundabout tank is a water storage tank built with the end goal of holding water supply at certain tallness to pressurize the water circulation framework. Numerous new thoughts and developments have been made for the capacity of water and other fluid materials in distinctive structures and molds. There are distinctive routes for the capacity of fluid, for example, underground tanks, ground bolstered tanks, lifted tanks and so on. Indian sub-continent is exceptionally defenceless against characteristic debacles like quakes, drafts, surges, violent winds and so on. Greater parts of states or union domains are inclined to one or numerous calamities. These regular catastrophes are bringing on numerous setbacks and countless property misfortune consistently. Seismic tremors involve ahead of everyone else in powerlessness. As per seismic code IS: 1893(Part I):2002, more than 60% of India is inclined to tremors. After a seismic tremor, property misfortune can be recuperated to some degree nonetheless, the life misfortune can't.

4. SEISMIC ZONES IN INDIA

The problem of designing economical earthquake-resistant structures rests heavily on the determination of reliable quantitative estimates of expected earthquake intensities in particular region. However, it is not possible to predict with any certainty when and where earthquake will occur, how strong they will be, and what characteristics the ground motions will have. Therefore, an Engineer must estimate the ground shaking. A simple method is to use a seismic zone map, where in the area is sub divided into regions, each associated with a known or assigned seismic probability or risk. To serve as a useful basis for the implementation of code provisions on earthquake resistant design. The present earthquake zoning map used in India shows the country divided into four zones of approximately equal seismic probability, depending upon the local hazards.

Seismic zone2	Seismic zone 3	Seismic zone 4	Seismic zone 5
Moderately susceptible to	Most susceptible to	Affected towards	Highly affected to
earthquake	earthquake	zone	earthquake

5. INDIAN CODE PROVISIONS

Two mass models for elevated tank were proposed by Housner [Housner, 1963] which is more appropriate and is being commonly used in most of the international codes. The pressure generated within the fluid due to the dynamic motion of the tank can be separated into impulsive and convective parts.

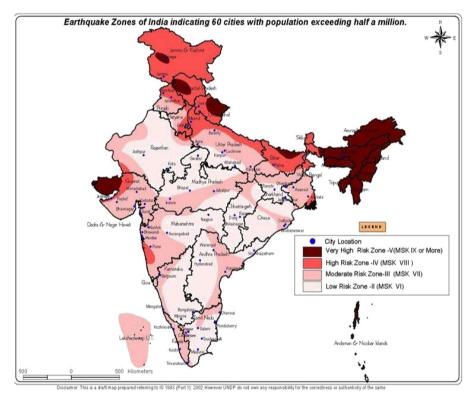


Fig1. Different Earthquake Zones of India

Impulsive liquid mass: When a tank containing liquid with a free surface is subjected to horizontal earthquake ground motion, tank wall and liquid are subjected to horizontal acceleration. The liquid in the lower region of tank behaves like a mass that is rigidly connected to tank wall. This mass is termed as impulsive liquid mass which accelerates along with the wall and induces impulsive hydrodynamic pressure on tank wall and similarly on base.

Convective liquid mass: Liquid mass in the upper region of tank undergoes sloshing motion. This mass is termed as convective liquid mass and it exerts convective hydrodynamic pressure on tank wall and base.

In the spring mass model of tank, hi is the height at which the resultant of impulsive hydrodynamic pressure on wall is located from the bottom of tank wall. On the other hand, hi* is the height at which the resultant of impulsive pressure on wall and base is located from the bottom of tank wall. Thus, if

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effect of base pressure is not considered, impulsive mass of liquid, mi will act at a height of hi and if effect of base pressure is considered, mi will act at hi*.Similarly, hc, is the height at which resultant of convective pressure on wall is located from the bottom of tank wall, while, hc* is the height at which resultant of convective pressure on wall and base is located.

The spring mass model of the tank is shown below.

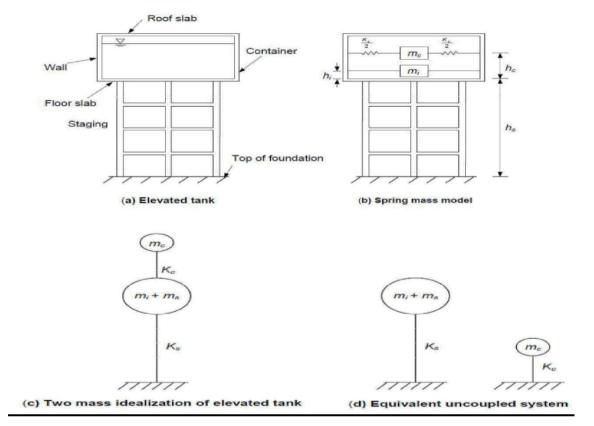
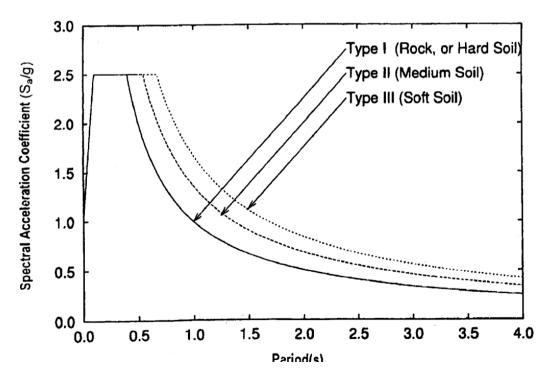


Fig2. Two mass idealization for elevated tank





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6. ANALYSIS OF ELEVATED INTZE TANK SUPORTED ON 6 COLUMN RC STAGING:

I.Preliminary Data:

Details of sizes of various components and geometry are shown below table

S. No	Component	Size (mm)
1	Top Dome	100 Thick
2	Top Ring Beam	150 x 250
3	Cylindrical Wall	200 Thick
4	Bottom Ring Beam	600 x 300
5	Circular Ring Beam	300 x 600
6	Bottom Dome	200 Thick
7	Conical Dome	200 Thick
8	Braces	250 x 350
9	Columns	500diameter

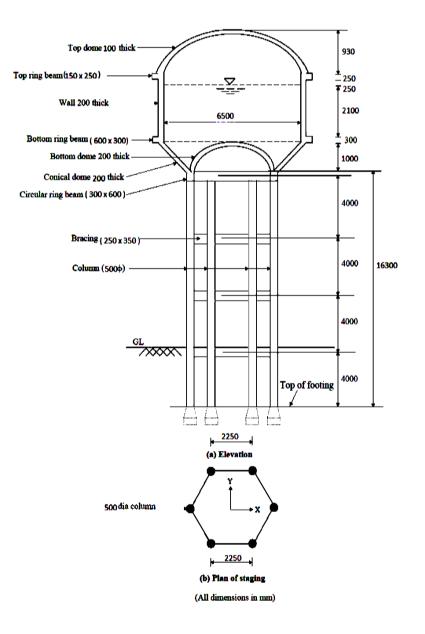
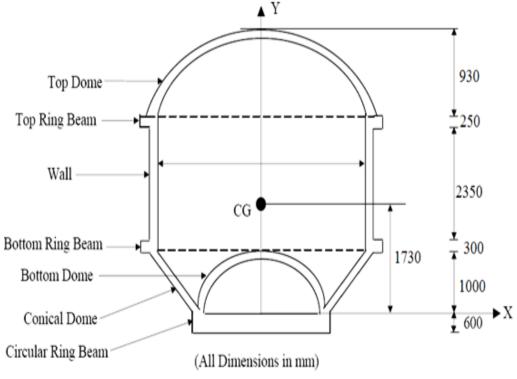
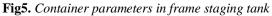


Fig4. Section of elevated intze water tank

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Components	Calculations	Weight (kN)
Top Dome	Radius of dome, $r_1 = [((6.7/2)^2 / 0.88) + 0.88)] / 2 = 6.82$ 2 x π x 6.82 x 0.88 x (0.1 x 25)	94.25
Top Ring Beam	$\pi x (6.5 + 0.15) x 0.15 x 0.15 x 25$	19.58
Cylindrical Wall	π x 6.7 x 0.1 x 2.35 x 25	123.63
Bottom Ring Beam	π x (6.5+ 0.6) x 0.6 x 0.30 x 25	100.35
Circular Ring Beam	π x 4.5 x 0.30 x 0.60 x 25	63.6
Bottom Dome	Radius of dome, $r_2 = [(4.5/2)^2/0.9) + 0.9]/2 = 3.26$ 2 x π x 3.26 x 0.90 x 0.10 x 25	46.07
Conical Dome	Length of Cone, $L_c = (1.15^2 + 1.15^2)^{1/2} = 1.63$ $\pi x ((-6.7 + 4.5) / 2.0) x 1.63 x 0.2 x 25$	143.38
Water	$\left[\left(\pi \ x \ 6.5^2 \ x \ 2.1 \ /4 \right) + \left(\pi \ x 1.0 (\ 6.5^2 + \ 4.0^2 + (\ 6.5 \ x \ 4.0 \)) \ / \ 12 - \left(\pi \ x \ 0.8^2 \ x \ (3 \ x \ 3.26 \ -1.0) \ / \ 3) \ \right] x \ 9.81 \right]$	842.25
Columns	$\pi x (0.50)^2 x 15.7 x 6 x 25 / 4$	462.40
Braces	2.25 x 0.25 x 0.35 x 3 x 6 x 25	88.59





7. COMPARISON

Consideration of different seismic zones, the forces obtained from the analysis is shown in the below table 1 and comparison of base shear and base moment in tank empty and tank full conditions between different seismic zones is shown in table 2.

 Table1. Comparison of Forces between Different Seismic Zones

Zone	II	III	IV	V
Base shear (kN)	55.18	87.39	129.58	195.52
Base moment (kN-m)	1012.69	1604.08	2405.47	3588.28
Hydrodynamic pressure (kN/m ²)	3.57	5.96	8.95	12.71
Sloshing wave height(m)	0.15	0.236	0.34	0.53

Table2. Comparison of Base Shear and Base Moment in Tank Empty and Tank Full Conditions Between
 Different Seismic Zones

Zone	Base shea	ur (kN)	Base moment(kN-m)		
	Tank empty Tank full		Tank empty	Tank full	
II	44.61	55.18	804.36	1012.69	
III	71.25	87.39	1284.75	1604.08	
IV	108.43	129.58	1955.05	2405.47	
V	160.32	195.52	2890.69	3588.28	

8. DISTRIBUTION OF BASE SHEAR:

The Base shear is distributed to the four portions i.e., at cylindrical wall, at conical dome, columns above 10m and columns up to 10m and values are shown in the below tables 3,4,5,6.

Element	Force per unit height (kN)		Height of	Total horizontal force		Centre of
Element	Tank full	Tank empty	element	Tank full	Tank empty	gravity
Cylindrical portion	1180.8	337.83	3.83	20.30	6.379	1.72
Conical dome	189.452	189.452	4.83	4.135	4.46	0.66
Shaft above 10m	132.47	132.47	7.12	4.19	4.63	1.58
Shaft upto 10m	344.3	344.36	17.12	26.486	28.99	5.11

Table3. Comparison of Distribution of Base Shear in Zone – Ii

 Table4. Comparison of Distribution of Base Shear in Zone – Iii

Element	Force per unit height (kN)		Height of	Total hori	Centre of	
	Tank full	Tank empy	element	Tank full	Tank empty	gravity
Cylindrical portion	1180.8	337.83	3.83	32.15	10.18	1.72
Conical dome	189.452	189.452	4.83	6.46	7.12	0.66
Shaft above 10m	132.47	132.47	7.12	6.64	7.41	1.58
Shaft upto 10m	344.3	344.36	17.12	41.94	46.3	5.11

Table5. Comparison of Distribution of Base Shear in Zone –iv

Element	Force per unit height (kN)		Height of	Total hori	Centre of	
	Tank full	Tank empy	element	Tank full	Tank empty	gravity
Cylindrical portion	1180.8	337.83	3.83	47.68	15.50	1.72
Conical dome	189.452	189.452	4.83	9.58	10.84	0.66
Shaft above 10m	132.47	132.47	7.12	9.84	11.26	1.58
Shaft upto 10m	344.3	344.36	17.12	62.19	70.47	5.11

Table6. Comparison of Distribution of Base Shear in Zone – V

Element	Force per unit height (kN)		Height of	Total hori	Centre of	
	Tank full	Tank empy element		Tank full	Tank empty	gravity
Cylindrical portion	1180.8	337.83	3.83	71.95	22.9	1.72
Conical dome	189.452	189.452	4.83	14.46	16.03	0.66
Shaft above 10m	132.47	132.47	7.12	14.85	16.67	1.58
Shaft upto 10m	344.3	344.36	17.12	93.84	104.21	5.11

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Element	-	per unit ight	Height of element		Total horiz	contal force	C.G of force from the ground	
	Wind force	Seismic force	Wind force	Seismic force	Wind force	Seismic force	Wind force	Seismi c force
Cylindrical portion	15.78	337.38	2.6	3.83	41.028	10.18	14.6	1.72
Conical dome	13.69	189.45	1.3	4.83	17.79	7.12	13.04	0.60
Shaft above 10m	1.896	132.47	2.0	7.12	3.792	7.41	11	1.58
Shaft upto 10m	1.8	344.36	10.0	17.12	18.0	46.3	5	5.11

Table7. Summary of forces and Total Loads on the Tank

9. CONCLUSIONS

- The forces acting on the elevated water tank due to seismic forces are calculated for all the zones.
- The Base shear, Base moment and Hydrodynamic pressures are increases from Zone II to Zone IV.
- Base shear is increases 3 to 6% and Hydrodynamic pressure is increases from 17 to 28% from Zone II to Zone III.
- Base shear is increases 6 to 9% and Hydrodynamic pressure is increases from 28 to 43% from Zone III to Zone IV.
- Base shear is increases 9 to 10% and Hydrodynamic pressure is increases from 43 to 61.7% from Zone IV to Zone V.
- Base shear and Base moment values obtained in the tank full condition are greater than the values obtained in the tank empty condition, so the design will be governed by tank full condition.
- By comparing the seismic forces and wind forces the weight per unit height is more due to seismic for than wind forces.
- Horizontal forces higher at bottom level due to seismic effect and it is decreases from bottom to top.
- Horizontal forces higher at top level due to wind effect and it is decreases from bottom and the elevated water tank should be designed by considering the both the conditions.

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