ISSN 2229-5518

"Comparison between Static and Dynamic Analysis of Elevated Water Tank"

Gaikwad Madhurar V. , Prof. Mangulkar Madhuri N.

Abstract— In earthquake resigns, the elevated water tanks are one of the most important lifeline structures. In major cities & also in rural area, elevated water tanks forms an integral part of water supply scheme. The elevated water tank must functional even after the earthquakes as water tanks are required to provide water for drinking and firefighting purpose. The main object of this paper is, to compare the Static and Dynamic analysis of elevated water tank, to study the dynamic response of elevated water tank by both the methods, to study the hydrodynamic effect on elevated water tank, to compare the effects of Impulsive and Convective pressure results. From detail study and analysis it was found that, for same capacity, same geometry, same height, with same staging system, with same Importance factor & Response reduction factor, in the same Zone; response by equivalent static method to dynamic method differ considerably. Even if we consider two cases for same capacity of tank, change in geometric features of a container can shows the considerable change in the response of tank. As the capacity increases difference between the response increases. Increase in the capacity shows that difference between static and dynamic response is in increasing order. It is also found that, for small capacity of tank the impulsive pressure is always greater than the convective pressure, but it is vice- versa for tanks with large capacity. Magnitude of both the pressure is different. The effect of water sloshing must be included in the analysis. Free board to be provided in the tank based on maximum value of sloshing wave height. If sufficient free board is not provided, roof structure should be designed to resist the uplift pressure due to sloshing of water.

Index Terms— Convective hydrodynamic pressure, Elevated Water Tank, Equivalent Static analysis, Dynamic analysis, Impulsive hydrodynamic pressure, Sloshing wave height.

1 Introduction

Indian sub- continent is highly vulnerable to natural disasters like earthquake, draughts, floods, cyclones etc. Majority of states or union territories are prone to one or multiple disasters. These natural calamities are causing many casualties and innumerable property loss every year. Earthquakes occupy first place in vulnerability. Hence, it is necessary to learn to live with these events. According to seismic code IS: 1893(Part I): 2000, more than 60% of India is prone to earthquakes. After an earthquake, property loss can be recovered to some extent however, the life loss cannot. The main resign for life loss is collapse of structures. It is said that earthquake itself never kills people, it is badly constructed structures that kill. Hence it is important to analyze the structure properly for earthquake effects.

Water supply is a life line facility that must remain functional following disaster. Most municipalities in India have water supply system which depends on elevated water tanks for storage. Elevated water tank is a large elevated water storage container constructed for the purpose of holding a water supply at a height sufficient to pressurize a water distribution system. These structures have a configuration that is especially vulnerable to horizontal forces like earthquake due to the large total mass concentrated at the top of slender supporting structure. So it is important to check the severity of these forces for particular region.

These structures has large mass concentrated at the top of slender supporting structure hence these structure are especially vulnerable to horizontal forces due to earthquakes. All over the world, the elevated water tanks were collapsed or heavily damaged during the earthquakes because of unsuitable design of supporting system or wrong selection of supporting system and underestimated demand or overestimated strength.

George W. Housner [1] discussed the relation between the motion of water with respect to tank and motion of whole structure with respect to ground. He had considered three basic condition i.e. tank empty, tank partially filled and tank fully filled for the analysis, and finely concluded that the maximum force to which the partially fill tank subjected is less than the half the force to which the full tank is subjected. The actual forces may be little as 1/3 of the forces anticipated on the basis of a completely full tank. Sudhir Jain and U. S. Sameer [2] had given the value of performance factor K =3, which is not included in IS 1893:1984 for the calculation of seismic design force and also given some expressions for calculation of lateral stiffness of supporting system including the beam flexibility. Sudhir Jain & M. S. Medhekar [3] had given some suggestions and modification in IS 1893: 1984. He had replace the single degree of freedom system by two degree of freedom system for idealization of elevated water tank, the bracing beam flexibility is to be included in the calculation of lateral stiffness of supporting system of tank, the effect of convective hydrodynamic pressure is to be included in the analysis. Sudhir Jain & Sajjad Sameer U. [4] added more suggestions other than above i.e. accidental torsion, expression for calculating the sloshing wave height of water, effect of hydrodynamic pressure for tanks with rigid wall and the tanks with flexible wall should be considered separately. M. K. Shrimali & R. S. Jangid [5] discussed the earthquake response of elevated steel water tanks isolated by the bearings which are placed at top and bottom of steel tower structure and concluded that the earthquake response of the isolated tank is significantly reduced and more effective for the tanks with a stiff tower structure in comparison to flexible tower. O. R. Jaiswal & Sudhir Jain [6] had recognized the limitations and shot coming in the IS 1893:1984 and suggestions given by all above authors. He had proposed the different values of response reduction factor for different types of tanks, and also considered the expression for Design Horizontal Seismic Coefficient given in revise IS 1893 (Part-1): 2002, single spring-mass model for both the tanks i.e. tanks with rigid & flexible wall are proposed, correction in expression for convective hydrodynamic pressure, simple expression for sloshing wave height of water is used and added the effect of vertical excitation in the seismic analysis. R. Livaoglu & Dogangun [8] discussed the response of supporting staging system of water tower. He had considered frame supporting as well as cylindrical shell supporting system, and concluded that the frame supporting system is more effective than the shell supporting system. Gareane A. I, S. A. Osman & O.A. Karim [8] discussed the soil and water behavior of elevated concrete water tank under seismic load, and concluded that a significant effects obtained in shear force, overturning moment and axial force at the base of elevated water tank. Lyes Khezzar, Abdennour Seibi & Afshin Gohazadeh [9] discussed the steps involved in a test ring to study the water sloshing phenomenon in a rectangular container subjected to impulsive impact, and concluded that the water level for both simulation and experimental results compared well during the motion and showed the minor discrepancy after impact which may be due to tank bouncing. W. H. Boyce [10] discussed the response of a simple steel water tank measured during the earthquakes and vibration tests, and concluded that the effect of water sloshing must be considered when calculating the period of vibration of water towers. Dr. Suchita Hirde & Dr. Manoj Hedaoo [11] discussed the seismic performance of elevated water tanks for various Zones of India for various heights and capacity of tanks for different soil conditions. The effect of height of water tank, earthquake Zones and soil condition on earthquake forces are discussed and finally concluded that the seismic forces are increases with Zones and decreases with height of supporting system, seismic forces are higher in soft soil than medium soil, higher in medium soil than hard soil. Earthquake forces for soft soil is about 40-41% greater than that of hard soil for all earthquake Zones. IITK-GSDMA [12] discussed the guidelines for seismic design of liquid storage tanks. Is: 3370 (Part-II) [13] discussed the criteria for earthquake resistant design of structure. IS 1893(Part-II): 2002 [14] discussed the criteria for earthquake resistant design of structure. Detail analysis procedure for elevated water tanks are not maintained in this IS code, till today it is under revision.

1. AMIS & OBJECTIVES OF STUDY

This paper is to be presented to serve the following objectives-

[1] To compared the Static and Dynamic analysis of Elevated water tank. This objective clearly states that the behavior of water tank is always different with respect to circumstance. Hence it is an attempt to distinguish both static and dynamic behavior of the tank.

[2] To study the dynamic response of elevated water tank by both the methods. This is nothing but the elaboration of first object. This state that, we are not only going differ statics with dynamics but also we are going to find the response of tank to dynamic loads.

[3] To study the hydrodynamic effect on elevated water tank- When a tank containing liquid with a free surface is subjected to horizontal earthquake ground motion, water stored in the tank gets motion. This motion exerts load on the walls. This effect is called as sloshing effect.

[4] To compare the effects of Impulsive pressure and Convective pressure results. Water in impulsive region and in convective region are may exerts pressure of different magnitude. This objective will help to understand this phenomenon quit easily.

3. SEISMIC ANALYSIS OF ELEVATED WATER TANK

Seismic analysis of elevated water tank involved two types of analysis,

3.1 Equivalent Static analysis of elevated water tank.

3.2 Dynamic analysis of elevated water tank.

3.1 Equivalent Static analysis of elevated water tanks.

Equivalent static analysis of elevated water tanks is the conventional analysis based on the conversion of seismic load in equivalent static load. IS: 1893- 2002 has provided the method of analysis of elevated water tank for seismic loading. Historically, seismic loads were taken as equivalent static accelerations which were modified by various factors, depending on the location's seismicity, its soil properties, the natural frequency of the structure, and its intended use. Elevated water tank can be analyzed for both the condition i.e. tank full condition and tank empty condition. For both the condition, the tank can be idealized by one- mass structure. For equivalent static analysis, water- structure interaction shows, both water and structure achieve a pick at the same time due to the assumption that water is stuck to the container and acts as a structure itself and both water and structure has same stiffness. The response of elevated water tanks obtained from static analysis shows the high scale value. That's why for large capacities of tanks, static response are not precise. If we analyzed the elevated water tank by static method and design by the same, we get over stabilized or say over reinforced section but it will be uneconomical. That's why static systems of designing of elevated water tanks is not useful in seismic zones. And hence, IS code provision for static analysis is restricted for small capacities of tanks only.

3.2 Dynamic response of elevated water tank

Dynamic response of elevated water tanks is hard to define, as a behavior of tank is unpredictable. Dynamic analy-

ISSN 2229-5518

sis of liquid storage tank is a complex problem involving water- structure interaction. Based on numerous analytical, numerical and experimental studies, simple spring- mass models of tank- liquid system have been developed to calculate the hydrodynamic forces. During the earthquake, water contained in the tank exerts forces on tank wall as well as bottom of the tank. These hydrodynamic forces should consider in the analysis in addition to hydrostatic forces.

3.3 Two- Mass model theory for Elevated water tank

Elevated water tank containing the liquid with free surface is subjected to horizontal earthquake ground motion. Due to the ground motion, the tank wall and liquid get accelerate. The liquid in the lower resign of the tank behaves like a mass that is rigidly attached to the tank wall. This mass is termed as impulsive liquid mass (mi) which accelerates along with the wall and exerts impulsive hydrodynamic pressure on tank wall as well as on base of the tank. Liquid mass in the upper region of tank undergoes sloshing motion. This mass is termed as convective liquid mass (mc) and it exerts convective hydrodynamic pressure on tank wall and base. Thus total liquid mass gets divide into two parts, i.e. impulsive mass and convective mass.

In spring- mass model for tank - liquid system, these two liquid masses are to be suitably represented. A qualitative description of hydrodynamic pressure distribution on tank wall and base are shown in “figure 1”

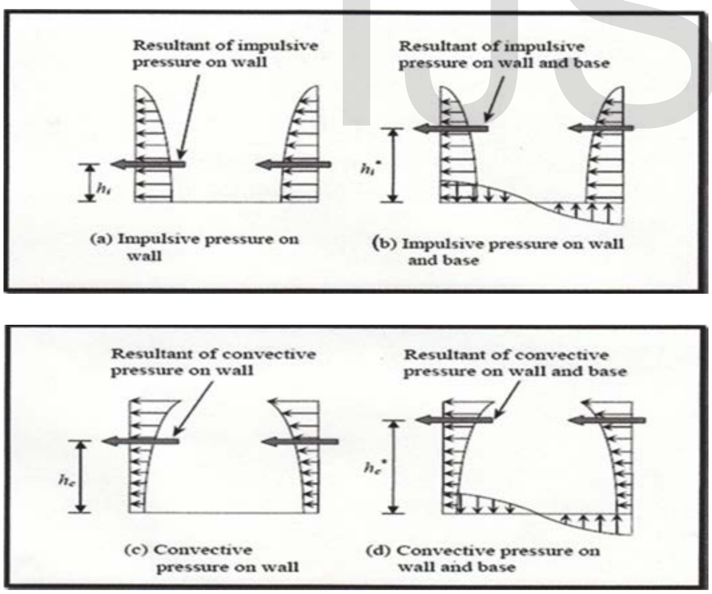


Figure 1. Qualitative description of hydrodynamic pressure distribution on tank wall & base.

3.4 Spring- Mass model for Seismic Analysis of Elevated water Tank

Most elevated water tanks are never completely filled with liquid. Hence a two – mass idealization of the tank is more appropriate as compared to a one-mass idealization, which was used in IS 1893 : 1984. Two mass model for elevated water tank was proposed by Housner (1963b) and is being commonly used in most of the international code.

The response of two-degree of freedom system can be obtained by elementary structural dynamics. However, for most elevated water tank it is observed that two period are well separated. Hence, the system may be considered as two uncoupled single degree of freedom system. This method will be satisfactory for design purpose, if the ratio of the period of the two uncoupled system exceed 2.5. If impulsive and convective time periods are not well separated, then coupled two degree of freedom system will have to be solved using elementary structural dynamics.

For elevated water tank, the two degree of freedom system of figure 2a can be treated as two uncoupled single degree of freedom systems (figure 2b), one representing the impulsive plus structural mass behaving as an inverted pendulum with lateral stiffness equal to the stiffness of staging, k_s and the other representing the convective mass with a spring of stiffness, k_c.

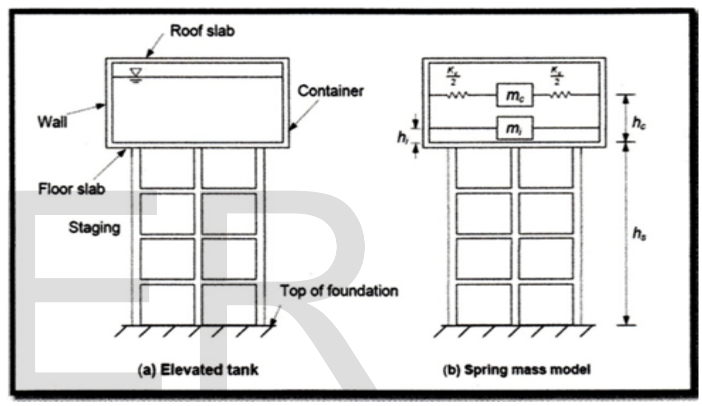


Figure 2a. Two mass model idealization of Elevated water tank.

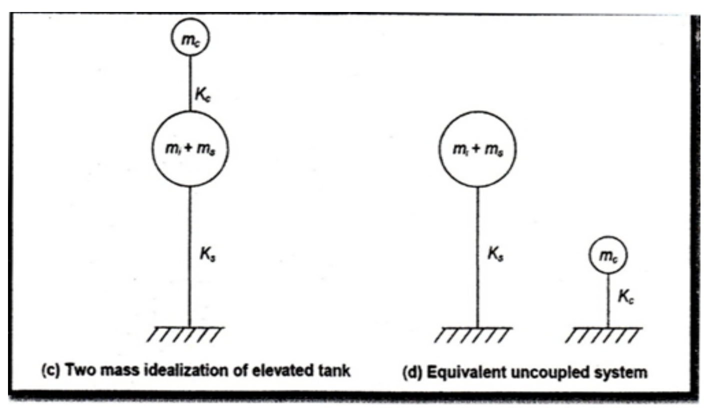


Figure 2b. Two uncoupled single degree of freedom system

4. Numerical Problem Statement for case 1, 2, 3.

A RC circular water container of 50 m^3 capacity has internal diameter of 4.65 m and height of 3.3 m (including freeboard of 0.3 m). It is supported on RC staging consisting of 4

ISSN 2229-5518

columns of 450 mm dia. with horizontal bracings of 300 x 450 mm at four levels. The lowest supply level is 12 m above ground level. Staging conforms to ductile detailing as per IS 13920. Staging columns have isolated rectangular footings at a depth of 2m from ground level. Tank is located on soft soil in seismic zone III. Grade of staging concrete and steel are M20 and Fe415, respectively. Density of concrete is 25 kN/m^3. Analyze the tank for seismic loads.
Elevated water tank can be analyzed by both the condition i.e. for tank full condition and tank partially full condition.

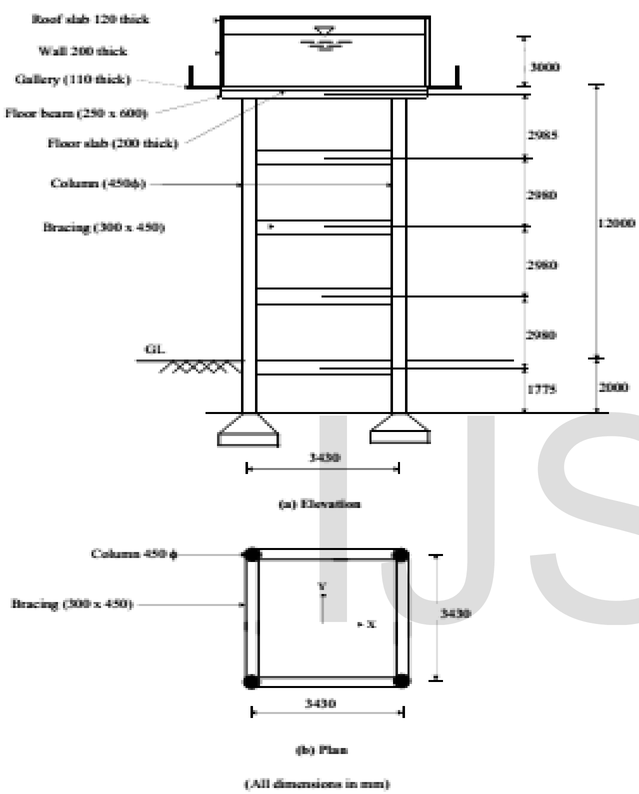


Figure 3: Details of Tank geometry-

4.1 Formulation of Problem

Table 1. Constants which are considered for calculation-

Sr. No	Constants	values	Remarks
01	Z	0.16	Structure is assumed in Zone III
02	I	1.5	
03	R	3.0	OMRF Frame
04	M-20		
05	Fe-415		

Table 2. Table showing change in iterations with respect to volume-

Sr. No	Itera-tion	Volume (lit.)	Diame-ter. of tank (meter)	Height. of tank (meter)	Free Board Tank (meter)
	CASE NO 01 -				
01	1	50000.00	4.65	3.30	0.30
02	2		4.25	3.83	0.30
03	3		3.75	4.83	0.30
04	4		3.50	5.50	0.30
05	5		3.25	6.40	0.30
	CASE NO 02				
06	1	100000.0	6.50	3.30	0.30
07	2		6.00	3.83	0.30
08	3		5.75	4.15	0.30
09	4		5.50	4.50	0.30
10	5		5.00	5.45	0.30
	CASE NO 03-				
11	1	200000.0	8.50	3.82	0.30
12	2		8.00	4.28	0.30
13	3		7.50	4.9	0.30
14	4		7.00	5.50	0.30
15	5		6.50	6.40	0.30

Table 3. Geometry details for Case. 1

Vol. Of tank	Dia. Of Col mm	No of Col.	Bracing beam Size mm	Roof Slab Thic mm	wall Thickness mm	Floor Slab thickness mm	Gallery Slab thick-ness mm	Floor Beam mm
50 m^3	450	04	300 * 450	120	200	200	110	250 * 600

Table 4. Geometry details for Case. 2

Vol. Of tank	Dia. Of Col mm	No of Col.	Brac-ing beam Size mm	Roo-f Slab Thic mm	wall Thickness mm	Floor Slab thickness mm	Gallery Slab thick-ness mm	Floor Beam mm
100 m^3	500	06	300 * 500	150	200	200	110	250 * 600

Table 5. Geometry details for Case. 3

Vol. Of tank	Dia. Of Col mm	No of Col.	Brac-ing beam Size mm	Roo-f Slab Thic mm	wall Thickness mm	Floor Slab thickness mm	Gallery Slab thick-ness mm	Floor Beam mm
200	550	06	300	175	225	225	110	300

m^3			* 550					* 600

4.1.1 Case No 04, Numerucal Problem Statement

A RC circular water container of 50 m^3 capacity has internal diameter of 4.65 m and height of 3.3 m (including freeboard of 0.3 m). It is supported on RC staging consisting of 4 columns of 450 mm dia. with horizontal bracings of 300 x 450 mm at four levels. The lowest supply level is 12 m above ground level. Staging conforms to ductile detailing as per IS 13920. Staging columns have isolated rectangular footings at a depth of 2m from ground level. Tank is located on soft soil in seismic zone III. Grade of staging concrete and steel are M20 and Fe415, respectively. Density of concrete is 25 kN/m^3.
Analysis the Tank by Static & Dynamic methods. Consider all Zones (as per IS: 1893-2002).

Table 6. Geometry details for Case. 4

Vol. Of tank	Dia. Of Col mm	No of Col.	Bracing beam Size mm	Roof Slab Thic mm	wall Thickness mm	Floor Slab thickness mm	Gallery Slab thickness mm	Floor Beam mm
50 m^3	450	04	300 * 450	120	200	200	110	250 * 600

5. Results

Table 7. Result comparison of Iteration No 1 for Case No 1

Sr. No.	Parameters	Static Analysis		Dynamic Analysis	
		Tank Full	Tank Empty	Tank Full	Tank Empty
01	Time Period at first Node in sec.	0.895	0.640	0789	0.640
02	Time Period at second node in sec.	N/A	N/A	2.258	N/A
03	Horizontal Acceleration at first node	0.077	0.104	0.084	0.104
04	Horizontal Acceleration at second node	N/A	N/A	0.0517	N/A
05	Base Shear V In KN	87.486	65.284	84.947	65.284
06	Base Moment in KN-m	1458.0	1087.6	1226.9	1087.6
07	Maximum Pressure in KN/m^2	N/A	N/A	3.013	N/A
08	Maximum Sloshing height in m $d_{max.}$	N/A	N/A	0.330	N/A

Table 8. Result comparison of Iteration No 1 for Case No 2

Sr. No.	Parameters	Static Analysis		Dynamic Analysis	
		Tank Full	Tank Empty	Tank Full	Tank Empty
01	Time Period at first Node in sec.	0.904	0.641	0.784	0.641
02	Time Period at second node in sec.	N/A	N/A	2.808	N/A
03	Horizontal Acceleration at first node	0.073	0.104	0.085	0.104
04	Horizontal Acceleration at second node	N/A	N/A	0.041	N/A
05	Base Shear V In KN	144.88	102.611	126.923	102.611
06	Base Moment in KN-m	2476.4	1753.89	1925.294	1753.89
07	Maximum Pressure in KN/m^2	N/A	N/A	3.188	N/A
08	Maximum Sloshing height in m $d_{max.}$	N/A	N/A	0.405	N/A

Table 9 Result comparison of Iteration No 1 for Case No 3

Sr. No.	Parameters	Static Analysis		Dynamic Analysis	
		Tank Full	Tank Empty	Tank Full	Tank Empty
01	Time Period at first Node in sec.	1.115	0.752	0.933	0.752
02	Time Period at second	N/A	N/A	3.16	N/A

	node in sec.				
03	Horizontal Acceleration at first node	0.059	0.088	0.071	0.088
04	Horizontal Acceleration at second node	N/A	N/A	0.0369	N/A
05	Base Shear V In KN	215.40	145.020	183.886	145.021
06	Base Moment in KN-m	3880.0	2615.42	2847.13	2615.42
07	Maximum Pressure in KN/m²	N/A	N/A	3.402	N/A
08	Maximum Sloshing height in m $d_{max.}$	N/A	N/A	0.4716	N/A

Table 10. Result comparison of Base Shear with Zone Factor for Case No 4

Sr. No.	Zone	BASE SHEAR (KN)			
		Static Analysis		Dynamic Analysis	
		Tank Full	Tank Empty	Tank Full	Tank Empty
01	Zone II	64.1408	46.930	60.264	46.930
02	Zone III	104.988	75.089	96.8713	75.089
03	Zone IV	157.426	112.633	145.665	112.633
04	Zone V	225.056	168.950	218.545	168.9505

Table 11. Result comparison of Base Moment with Zone Factor for Case No 4

Sr. No.	Zone	BASE Moment (KN-m)			
		Static Analysis		Dynamic Analysis	
		Tank Full	Tank Empty	Tank Full	Tank Empty
01	Zone II	973.11	712.013	930.323	712.11
02	Zone III	1592.84	1139.22	1495.41	1139.22
03	Zone IV	2388.41	1708.83	2248.65	1708.83
04	Zone V	3414.45	2563.25	3373.78	2563.25

Maximum Hydrodynamic Pressure –

In all above tables Maximum Hydrodynamic Pressure (used for dynamic analysis only) has been calculated by using following formula-

$$P = \sqrt{(Piw + Pww)^2 + Pcw^2 + Pv^2}$$

Where,

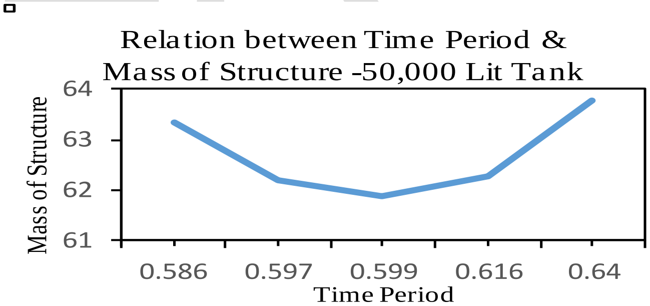
P_{iw} = Impulsive hydrodynamic pressure on wall.
P_{ww} = Pressure due to Wall Inertia.
P_{cw} = Convective hydrodynamic pressure on wall.
P_v = Pressure due to vertical excitation.

Table 12. Comparison of Impulsive and Convective hydrodynamic pressure results

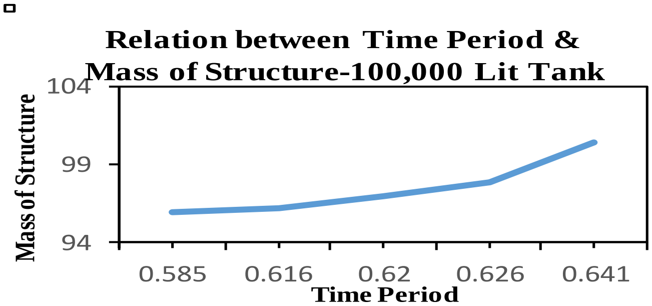
Sr. No	Iteration	P_{iw}	P_{ww}	P_{cw}	P_v	P
01	1.1	1.881	0.423	0.164	1.942	3.013
02	1.2	2.011	0.430	0.080	1.960	3.131
03	1.3	2.033	0.430	0.018	2.959	3.304
04	1.4	1.976	0.426	0.006	3.397	4.148
05	1.5	1.937	0.433	0.001	3.985	4.629
06	2.1	2.071	0.426	0.355	1.960	3.188
07	2.2	2.262	0.419	0.226	2.306	3.531
08	2.3	2.352	0.411	0.155	2.580	3.781
09	2.4	2.383	0.411	0.116	2.744	3.912
10	2.5	2.525	0.420	0.041	3.364	4.465
11	3.1	2.076	0.402	0.484	2.299	3.402
12	3.2	2.230	0.394	0.363	2.600	3.709
13	3.3	2.645	0.392	0.233	3.005	4.27
14	3.4	2.516	0.389	0.139	3.397	4.457
15	3.5	2.392	0.386	0.066	3.985	4.849

6. Iteration of Results.

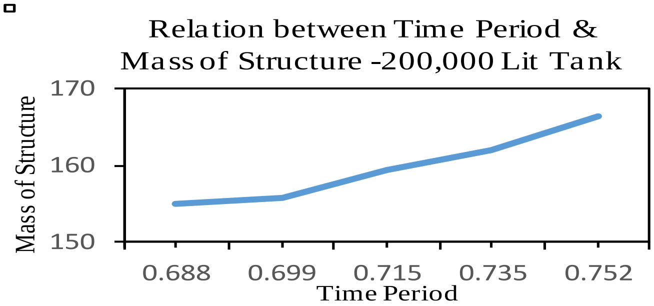
Iteration of results includes the graphical representation of output parameters which are calculated as a solution.



Graph 1: Relation between Time Period & Mass of Structure 50,000 Lit Tank capacity



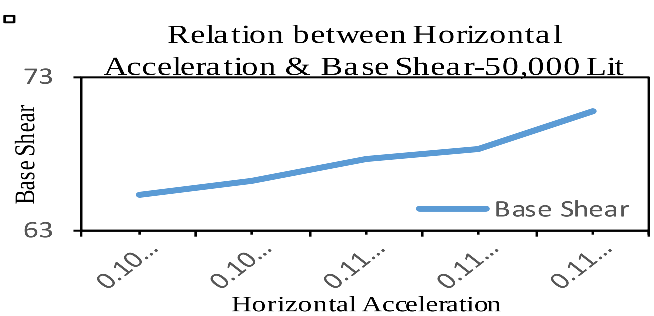
Graph 2: Relation between Time Period & Mass of Structure 100,000 Lit Tank capacity.



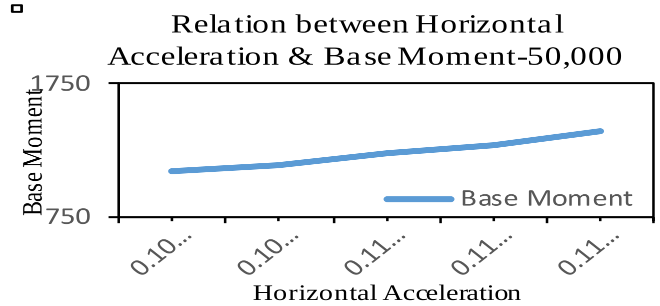
Graph 3: Relation between Time Period & Mass of Structure 200,000 Lit Tank capacity.

Above graphs shows the relation between Time Period & Mass of Structure. By observing all three graphs, following conclusion are made –

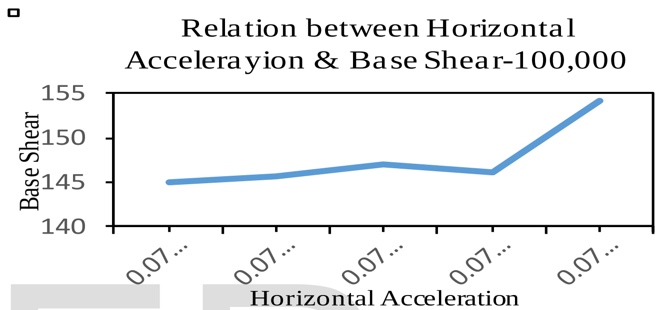
1. For Static analysis we observed that, maximum part of graph as Mass of Structure decreases Time period also decreases. At the starts even though Time Period is less Mass of Structure is more than the next one. This happens due to non-considerable of second node i.e. convective node. In Static analysis we considered only first node i.e. impulsive node that's why we get discontinuous results from which interpretation is difficult.
2. For Dynamic analysis, Time Period & mass of Structure are directly proportional to each other.
3. Natural Time Period is not only depends upon the Mass of Structure but also Mass of Water. Above graphs is plotted by five sets of readings, in which the capacity of the Tank has kept invariable.
4. Even though Tank capacity is same & Tank geometry has no such noticeable change, the response of a tank can vary.



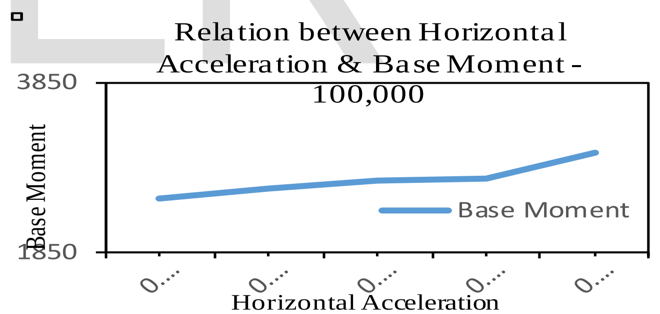
Graph 4: Relation between Horizontal Acceleration & base Shear for 50,000 Lit tank capacity.



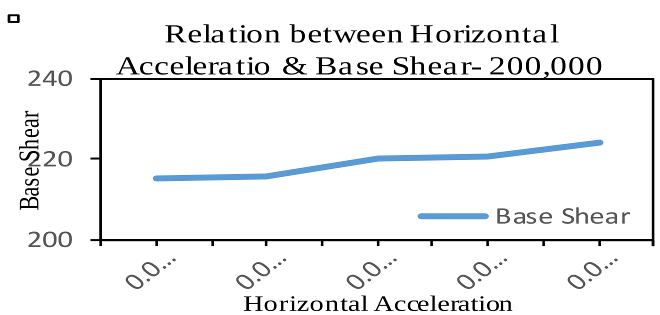
Graph 5: Relation between Horizontal Acceleration & base Moment for 50,000 Lit tank capacity.



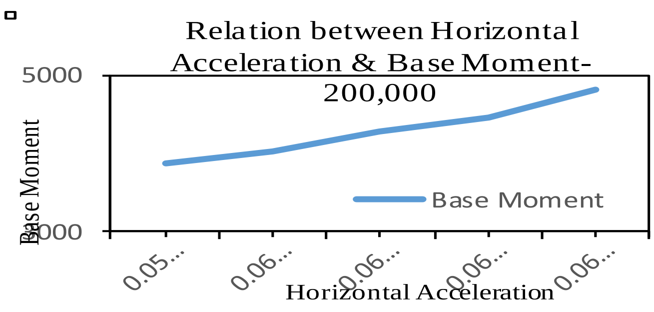
Graph 6: Relation between Horizontal Acceleration & base Shear for 100,000 Lit tank capacity.



Graph 7: Relation between Horizontal Acceleration & base Moment for 100,000 Lit tank capacity.



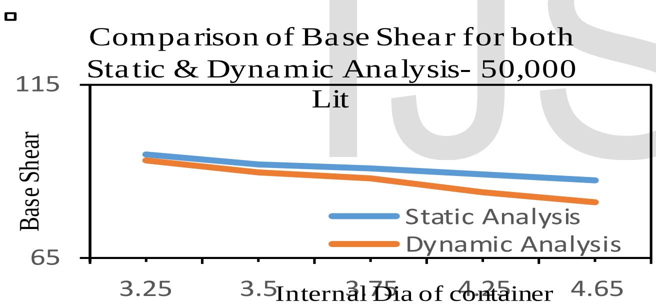
Graph 8: Relation between Horizontal Acceleration & base Shear for 200,000 Lit tank capacity.



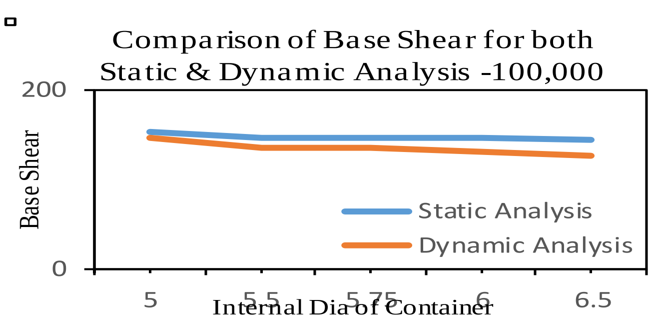
Graph 9: Relation between Horizontal Acceleration & Base Moment for 200,000 Lit.

All above graphs (Graph 4 to 9) shows the relation between Horizontal Acceleration & Base Shear and also between Horizontal Acceleration & Base Moment. These graphs are drawn on the basis of 15 iterations.

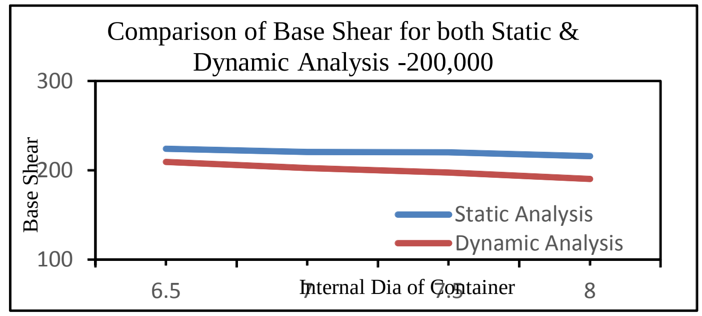
From above graphs, it clearly shows that even though the vales of Base Shear & Base Moment are different the profile of graphs is same.



Graph 10: Comparison of Base Shear for both Static & Dynamic Analysis for 50,000 Lit Tanks.

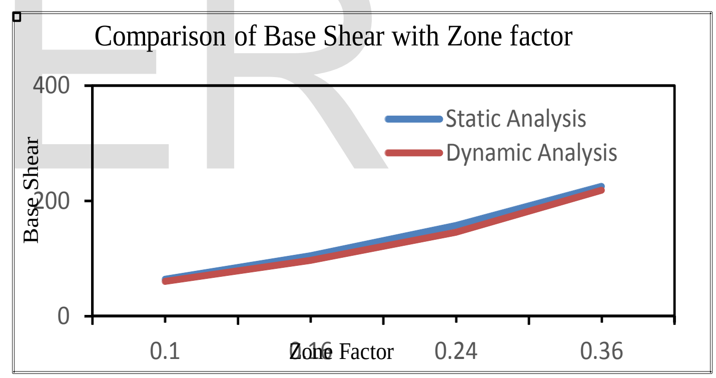


Graph 11: Comparison of Base Shear for both Static & Dynamic Analysis for 100,000 Lit Tank.

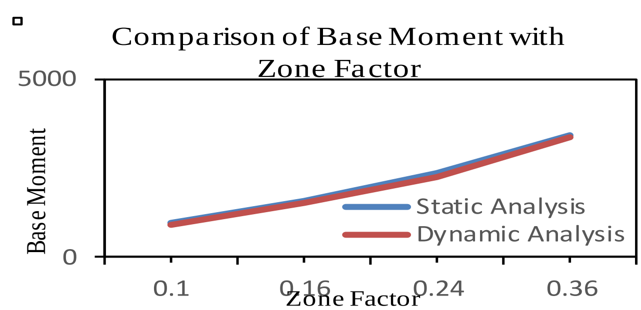


Graph 12: Comparison of Base Shear for both Static & Dynamic Analysis for 200,000 Lit Tank

Above graphs (Graph – 10 to 12) are showing Comparison of base Shear for same volume of water for Static as well as Dynamic Analysis. Interpretation of above graphs can be done as follows –
[1]. Graphical lines are getting steeper as capacity increases.
[2]. Difference between two lines goes on increasing as capacity increases.
[3]. Base Shear increases as the capacity increases.



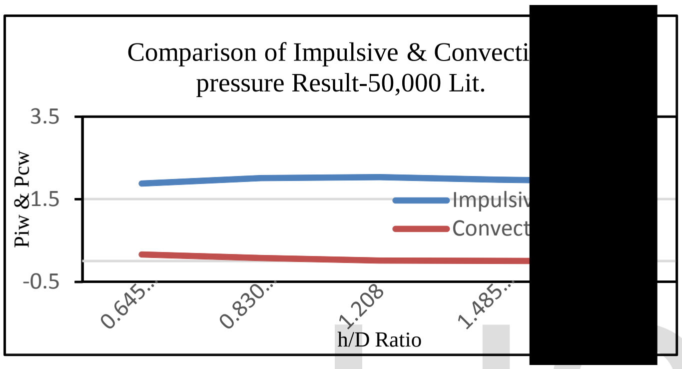
Graph 13: Comparison of Base Shear with Zone Factor.



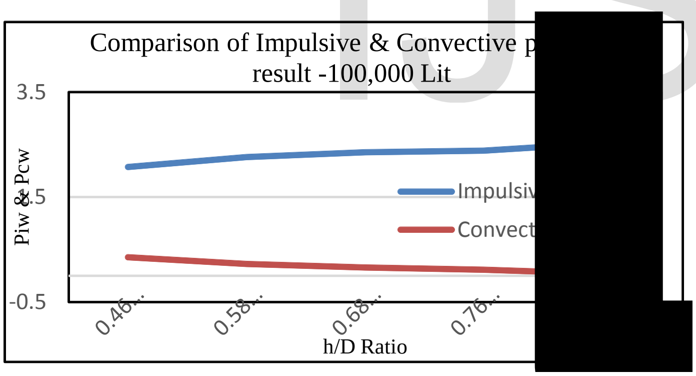
Graph 14: Comparison of Base Moment with Zone Factor.

From above two graphs (Graph No -13 & 14) we conclude that for any Zone the Response for Static analysis is on higher side than that of Dynamic analysis. This happens because in Static analysis water mass sticks to the container and hence the peak of water mass & structure are achieved at same time period. On the other hand Dynamic responses of water tank gives lesser values because due to sloshing of water tank both the peaks (i.e. for structure and water mass) are reaching at different time periods.

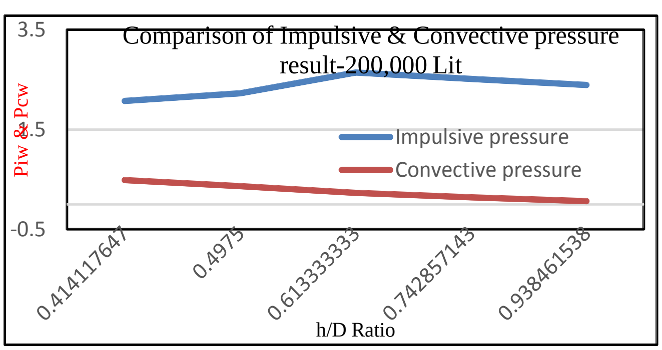
In above graphs it is also observed that increment in Base Shear & Base Moment is approximately 60% for Zone II to Zone III and 50% for Zone III to Zone IV and Zone IV to Zone V. Hence design based on dynamic calculations is of optimum value and safe.



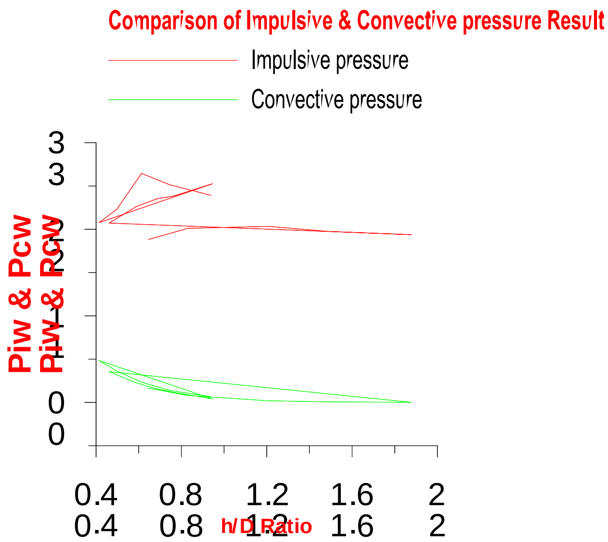
Graph 15: Comparison of Impulsive & Convective Pressure result for 50,000 Lit Tank.



Graph 16: Comparison of Impulsive &Convective Pressure result for 100,000 Lit Tank.



Graph 17: Comparison of Impulsive &Convective Pressure result for 200,000 Lit Tank.



Graph 18. Comparison of Impulsive and Convective Pressure for all Iterations

Above graphs shows the relation between ratios of maximum height of water (Excluding free board) and Internal Dia. of container with Impulsive & Convective pressure on the walls. Above graph actually represent all 15 iterations. We can see that for any combination of diameter & height, Impulsive pressure is always more on the wall than that of the Convective pressure.

The one reason to justify above statement is, during earthquake water body in Convective is always in thesloshing position, hence convective force is unstable to exert any convective force on the wall region. But on the other hand water in the impulsive region is quite stable: hence it is able to exert enough pressure on the wall.

But if we see the profile of graph it shows as it is heading towards large capacity region it goes on increasing for convective pressure and it goes on decreasing for Impulsive pressure. We can also see that the Impulsive pressure for different capacities varies with big difference; but at the same time Convective pressure for different capacities meet at the same point

7. CONCLUDING REMARKS-

From above mentioned detailed study and analysis some of the conclusions can be made as follows ……..

For same capacity, same geometry, same height, with same staging system, in the same Zone, with same Importance Factor & response reduction factor; response by Equivalent Static Method to Dynamic method differ considerably. It also state that even if we consider two cases for same capacity of tank, change in geometric features of a container can show the considerable change in the response of elevated water tank. At the same time Static response shows high scale values that of the Dynamic response. It happens due to the different picks of time periods. For Static analysis water- structure interaction shows that both water and structure achieve a pick at the same time due to the assumption that water is stuck to the container and acts as a structure itself and both structure and water has same stiffness, while in Dynamic analysis we considered two mass model which shows two different stiffness for both water and structure hence pick of time for both the components are different hence fundamental time periods are different for both static and dynamic analysis. But secondary time period in dynamic analysis is greater than both fundamental time period because water in the upper region (Convective region) remains in undamped condition (sloshing condition) for some more time.

As the capacity increases difference between response increases. Increase in the capacity shows that difference between static response and dynamic response is in increasing order. Itself it shows that for large capacities of tank static response not precise but it is somewhat on the higher side, and if analyzed by static method and designed by the same can give over stabilized or say over reinforced section but it will be uneconomical. Hence IS code provision of static analysis are restricted for small capacities of tanks only.

During the earthquake Impulsive pressure is always greater than Convective pressure for small capacity tanks, but it is vice-versa for tanks with large capacities. Hence Static analysis for large capacities tanks can be uneconomical as all the water mass acts itself as a convective. This statement denotes that if large capacities tanks are designed by static method distortion in the container can be seen at the same time of collapse ofstaging. Large capacities are liable of producing high stresses on the wall and the slabs of the container, if the hydrodynamic factors are ignored during the analysis they will affect vigorously and collapse of the structure can takes place.

From graphs 18, we can also say that the Impulsive pressure for different capacities varies with big difference; but at the same time Convective pressure for different capacities meet at the same point.

8. Acknowledements

I wish to thank the Management, Principal, and Head of Civil
Engineering Department and Staff of Jawaharlal Nehru Engineering College and Authorities of Dr. Babasaheb Ambedkar Marathwada University for their support.

• Gaikwad Madhukar V.

P. G. Student, Dept. of Structural Engineering, Jawaharlal Nehru Engineering College, Aurangabad-431003, Maharashtra, India.
Email: madhukar.jnec@gmail.com

• Prof. Magulkar Madhuri N.

Asst. Professor, Dept. of Structural Engineering, Jawaharlal Nehru Engineering College, Aurangabad-431003, Maharashtra, India.
Email:mangulkarm@yahoo.com

References

[1]. George W. Housner, 1963 "The Dynamic Behaviour of Water Tank" Bulletin of the Seismological Society of America. Vol. 53, No. 2, pp. 381-387. February 1963

[2]. Jain Sudhir K., Sameer U.S., 1990, "Seismic Design of Frame Staging For Elevated Water Tank" Ninth Symposium on Earthquake Engineering (9SEE-90), Roorkey, December 14-16, Vol-1.

[3]. Sudhir K. Jain and M. S. Medhekar, October-1993, "Proposed provisions for aseismic design of liquid storage tanks" Journals of structural engineering Vol.-20, No.-03

[4]. Sudhir K Jain & Sajjed Sameer U, March-1994,Reprinted from the bridge and structural engineer Vol-XXIII No 01

[5]. Sudhir K. Jain & O. R. Jaiswal, September-2005, Journal of Structural Engineering Vol-32, No 03

[6]. R. Livaoğlu and A.Doğangün May 2007 "An Investigation About Effects of Supporting Systems on Fluid-elevated Tanks Interaction" SS: Special Structures Paper ID: SS148, Tehran, Iraq.

[7]. S. A. Osman, O. Karim and A. Kasa, 2008 "Investigate The Seismic Response Of Elevated Concrete Water Tank" Engineering Postgraduate Conference (EPC)

[8]. Lyes Khezzar, Abdennour Seibi, Afshin Goharzadeh. "Water Sloshing In Rectangular Tanks – An Experimental Investigation & Numerical SIMULATION" International Journal of Engineering (IJE), Volume (3) : Issue (2)

[9]. W.H. Boyce "Vibration Test on Simple Water Tower"

[10]. M.K.Shrimali, R.S.Jangid "Earthquake Response of Isolated Elevated Liquid Storage Tank"

[11]. Dr.Suchita Hirde & Dr. Manoj Hedaoo, "Seismic performance of Elevated Water Tank", International Journal of Advanced Engineering Researchand Studies/Vil. I/2011.

[12]. IITK-GSDMA guidelines for seismic design of liquid storage tanks.

[13]. I.S 1893-2002 criteria for earthquake resistant design of structures.

[14]. IS: 3370 (Part II) – 1965 code of practice for concrete structures for the storage of liquids part ii reinforced concrete structures.