Behaviour of Elevated Water Tank under Sloshing Effect

Prof. Wakchaure M. R[a*] ,
[a]Dean & Asso. Professor, Dept.of Civil Engineering,
Amrutvahini College of Engineering,
Sangamner - 422608, Maharashtra
India

Besekar Sonal S.[b**]
[b]P.G.Student, Dept.of Civil Engineering
Amrutvahini College of Engineering,
Sangamner - 422608, Maharashtra,
India

***Abstract* - During the past few years in elevated service reservoir have undergone considerable developments, not only in the structural conception, modeling and method of analysis, but also in the materials employed and the methods of construction.This dissertation aims at developing an understanding of dynamic analysis & response spectrum solution for reinforced elevated service reservoir having sloshing behaviour in different four condition 1) circular ESR 2) circular with compartment ESR 3) rectangular ESR 4) rectangular with compartment . Liquid storage tanks are considered essential lifeline structures. Water tanks, in particular, are important to the continued operation of water distribution system in event of earthquakes. Most of the failures of large tanks after earthquakes are suspected to have resulted from the dynamic buckling caused by overturning moments of seismically induced liquid inertia and surface slosh waves. Recent earthquakes have shown that liquid storage tanks are found to be vulnerable to damage. It is noted that under nonlinear conditions, sloshing heights are larger than those calculated under linear condition. In the present study sloshing effect & dynamic analysis in elevated water tank is studied by using Finite Element Method (FEM) based computer software ANSYS. The main object of this paper is –1) T o compare the Static and Dynamic analysis of elevated water tank. 2) To study the dynamic response of elevated water tank by both the methods. 3) To study the hydrodynamic effect on elevated water tank.& behaviour of water in different state with change of depth of water in tank (15%, 30%,50% ,75% and full) 4) response spectrum analysis of elevated service reservoir.**

Keywords: Elevated Water tank; Finite Element Method, Response Spectrum, ANSYS, Modal Analysis, Sloshing Wave height of water.

1. INTRODUCTION

Seismic safety of ground based and elevated liquid filled containers is of great concern because of potential economic loss that might be incurred due to structural failure of the liquid container as well as the potential environmental impact the spilling of the contained liquid might have to surrounding area. The nonlinear wave approach was not attempted at initial stage, in predicting the seismic response of tank structures because of its mathematical difficulties determining the elevation of the unknown moving free surface and in evaluating the geometrically non-linear boundary conditions on the liquid surface. However with the use of computers and finite element techniques, the studies have been started and carried out on the sloshing effect. Therefore in the present study an attempt has been made to study the effect of sloshing on the wall and roof of the elevated tanks considering nonlinearity by ANSYS software

2. NUMERICAL 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 300x 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 II. Grade of staging concrete and steel are M25 and Fe500, respectively. Density of concrete is 25 KN/m3. Analyze the tank for seismic loads.

Solution:- Tank must be analysed for tank full and empty conditions.

Consider Zones II (as per IS 1893:2002 & IITK-GSDMA guidelines for seismic design of liquid storage tanks.) for analysis.

2.1 Formulation of Problems

Table 2.1 : Constants which are considered for calculation

Sr. No.	Constant	Values	Remarks
1	Z	0.1	Structure assumed in Zone II
2	I	1.5	Importance Factor
3	R	3	Response Reduction Factor
4	M-25		Grade of Concrete
5	Fe-500		Grade of Steel

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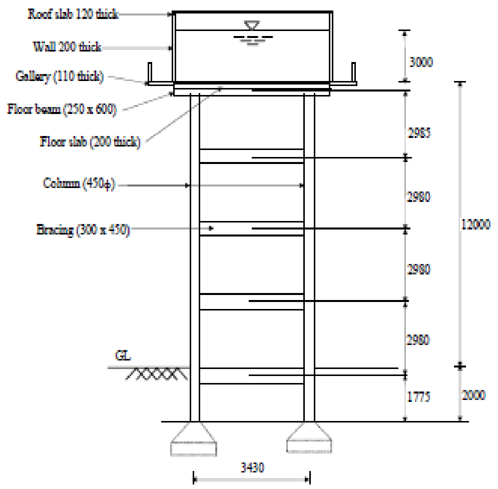


Figure 2.1 Details of tank geometry

2.2 Fluid-Structure Interaction

As proposed by GSDMA guideline, spring mass analogue of tank-liquid system forms the basis for evaluating hydrodynamic pressure in most of the design codes across the globe. During lateral base excitation seismic ground acceleration causes hydrodynamic pressure on the tank wall which depends on the geometry of tank, height of liquid, properties of liquid and fluid-tank interaction.

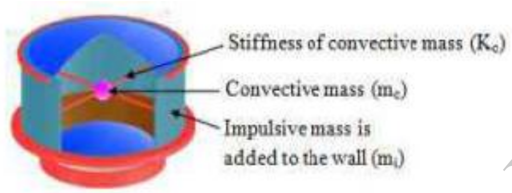


Figure 2.2 FEM model for fluid-strucutre-interaction added mass approach

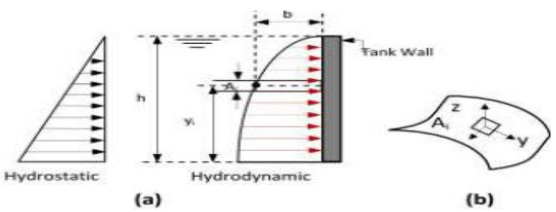
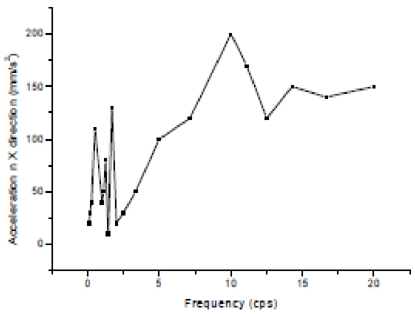


Figure 2.3 (a) Westergaard added mass concept (b)

2.3 Response Spectrum Analysis



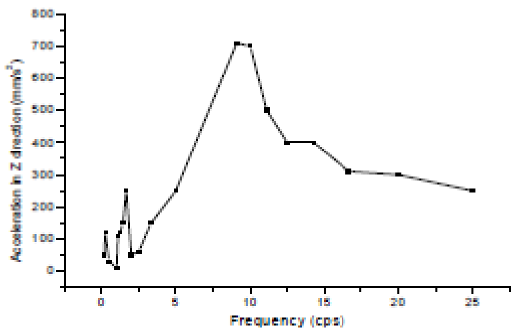


Figure. 2.4 Response Spectrum of Bhuj Earthquake (2001) in X direction and Z direction[2]

3.PROPOSED ESR MODELS

In this project different four RCC elevated service reservoir models proposed for study. Problem Considered for study is having same capacity, location, staging height, bracing interval and number of columns for all models.

Model 1: RCC Circular ESR.

Model 2: RCC Circular ESR with compartment.

Model 3: RCC Rectangular ESR

Model 4: RCC Rectangular ESR with compartment.

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Fig. 3.1 circular elevated reservoir & with compartment

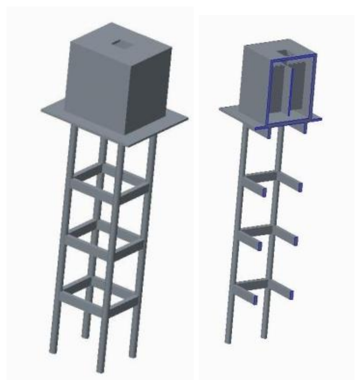

Fig.3.2 Rectangular elevated reservoir & with Compartment

4. RESULTS & DISCUSSION

Following results getting form different types of elevated service reservoir & comparison of different four tanks are below. From analysis following graphs are taken out by application of all the stresses ,deformation and forces & Results are carry out form ANSYS.

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a. Circular/with comprtment/rectangular/with compartment elevated service reservoir

In ESR following analysis taking out.

i) Static
ii) Modal(dynamic)
iii) Response spectra(seismic analysis) tanks

Table:- 4.1 Comparison of Parameters For Four Different

sr. no.	parameters		circular tank	circular with compartmen t tank	rectangul ar tank	rectangular with compartment tank
1	static	stress(max.)	4.386e+006 Pa	7.263e+006 Pa	8.1436e+0 06 Pa	8.4084e+006 Pa
		sress (min.)	3098.1 Pa	12442 Pa	9274.5 Pa	1987.9 Pa
		total deformation (max)	3.3701e-003 m	5.8525e-004 m	6.7232e-004 m	6.8548e-004 m
		total deformation (min)	0. m	0. m	0. m	0. m
		directional deformation (max.)	7.0016e-007 m	0. m	0. m	0. m
		directional deformation (min)	-1.0586e-003 m	-3.56e-004 m	-4.3722e-004 m	-4.5343e-004 m
2	modal	stress(max.)	3.1571e+00 6 Pa	1.0997e+007 Pa	1.0214e+0 07 Pa	9.6969e+006 Pa
		sress (min.)	195.06 Pa	390.49 Pa	489.77 Pa	743.25 Pa
		total deformation (max)	4.5208e-003 m	2.3654e-003 m	2.465e-003 m	2.3419e-003 m
		total deformation (min)	0m	0. m	0. m	0. m
		directional deformation (max.)	1.7021e-006 m	1.7136e-006 m	4.4808e-007 m	4.6286e-007 m
		directional deformation (min)	-1.6637e-004 m	-1.2808e-004 m	-9.8265e-004 m	-8.3915e-004 m
3	respon se spectru m	Equivalent Stress(max.)	1.1246e+00 6 Pa	3.5267e+006 Pa	3.6518e+0 06 Pa	3.9558e+006 Pa
		Equivalent Stress(min.)	289.28 Pa	805.7 Pa	833.87 Pa	1116.6 Pa
		normal stress(max.)	1.0084e+00 6 Pa	3.6953e+006 Pa	3.6897e+0 06 Pa	4.0269e+006 Pa
		normal stress(min.)	55.36 Pa	370.95 Pa	318.21 Pa	229.03 Pa
		shear stress(max.)	1.8951e+00 5 Pa	8.0149e+005 Pa	9.3923e+0 05 Pa	1.0366e+006 Pa
		shear stress(min.)	22.945 Pa	60.116 Pa	188.36 Pa	53.772 Pa
		Directional Deformation	1.5786e-003 m	8.4749e-004 m	8.8073e-004 m	9.6354e-004 m

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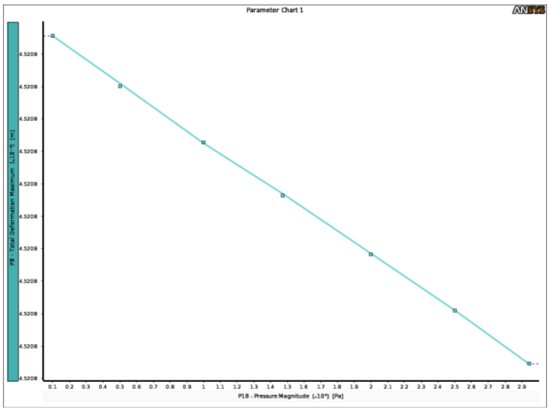
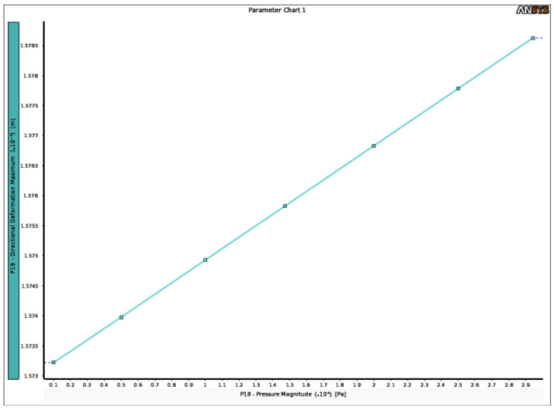
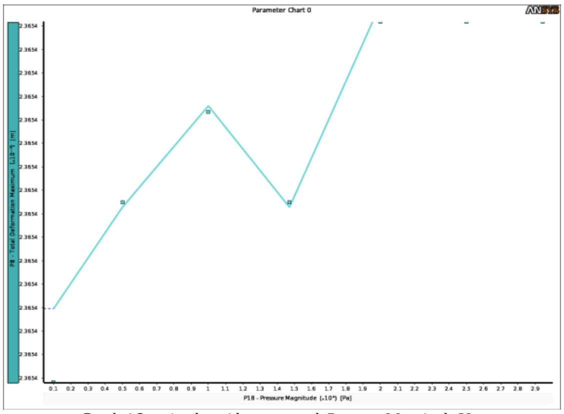


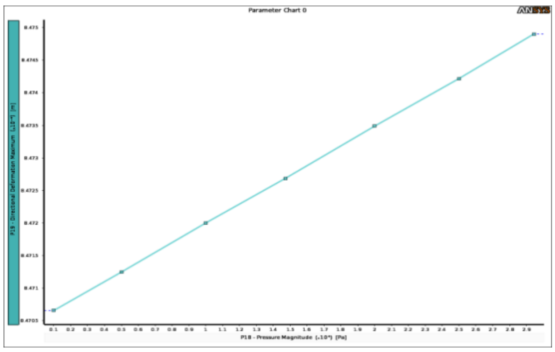
Graph 4.1 :- circular tank Pressure Magnitude Vs Total Deformation maximum(modal)



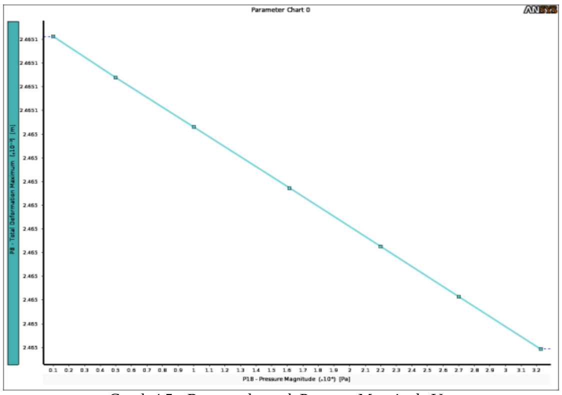
Graph 4.2 :- circular tank Pressure Magnitude Vs Directional Deformation maximum(responce spectra)



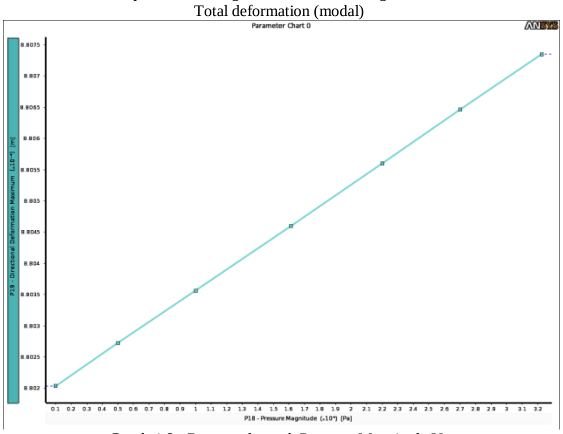
Graph 4.3 :- circular with compt. tank Pressure Magnitude Vs Total deforamtion maximum(modal)



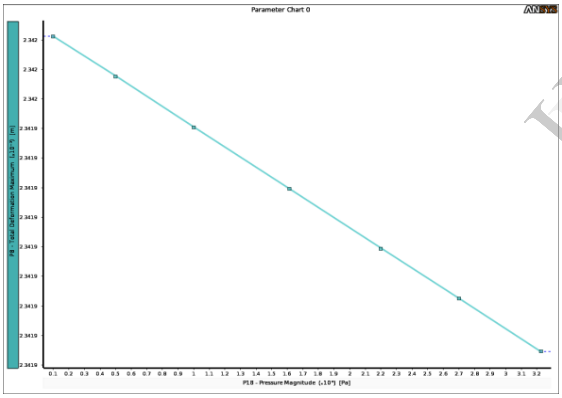
Graph 4.4 :- circular with compt. tank Pressure Magnitude Vs Directional Deformation maximum(responce spectra



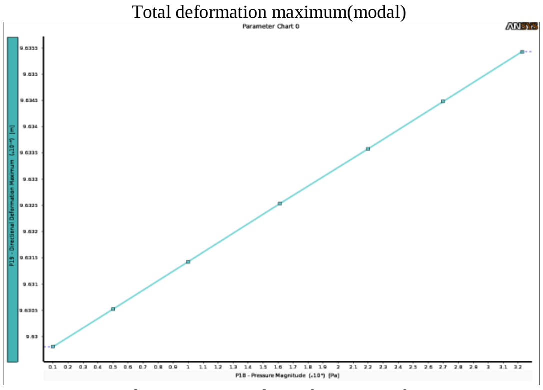
Graph 4.5:- Rectangular tank Pressure Magnitude Vs Total deformation (modal)



Graph 4.6:- Rectangular tank Pressure Magnitude Vs Directional deformation (responce spectra)



Graph 4.7 :- Rectangular with compt. tank Pressure Magnitude Vs Total deformation maximum(modal)



Graph 4.8 :- Rectangular with compt. tank Pressure Magnitude Vs directional deformation maximum(response spectra)

4. 2 Discussion About Results

From above result we see that due to sloshing effect of water on tank,

1. The maximum stresses in static condition in circular water tank is 4.386e+006 Pa which is lower than the max. stresses in circular with compartment is 7.263e+006 Pa. in similar way in rectangular tank the max. stresses is 8.1436e+006 Pa which is lower than the rectangular with compartment is 8.4084e+006 Pa. this is due to the increases of load of compartment in that tank. We also find similar result in modal & response spectrum condition.

2.The total deformation of tank in static condition the deformation in circular tank is 3.3701e-003 m & which is less in circular with compartment is 5.8525e-004 m. also in rectangular and rectangular with compartment we find same result in static, & modal (dynamic) analysis .

3.The directional deformation in static condition zero value in all types of tanks, but in response spectrum analysis in circular tank is 1.5786e-003 m & which is less in circular with compartment is 8.4749e-004 m. similar result in rectangular tank & rectangular with compartment which is 8.8073e-004 m & 9.6354e-004 m. above results are for sloshing effect of 100% filled.

4. For 50% filled tank the directional deformation in response spectrum condition are 1.5758e-003 m & & which is less in circular with compartment is 8.4727e-004 m. similar result in rectangular tank & rectangular with compartment which is 8.8046e-004 m & 9.6325e-004 m.

5. CONCLUSION

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On the basis of the results obtained in the study, although it is apparent that certain aspects of behavior of water tank are not yet clearly understood a number of conclusions may drawn .Following are the important conclusions:

1. Generally if the water tank is excited due to earthquake ground motion the displacement of water in the tank depends upon the volume of water contained in it.
2. Sloshing frequency is an important parameter in the seismic analysis of tank-liquid system. For the regular tank geometries, such as circular and rectangular, the analytical expressions for sloshing frequency are quite well known.
3. The critical response of elevated tanks does not always occur in full condition, it may also occur under half condition. The critical response depends on the earthquake characteristics and particularly frequency content of earthquake records.
4. The critical response of the elevated tank due to fact that the hydrodynamic pressures of container in half condition as compared with the full condition are higher. In addition to the critical response, depends on the earthquake characteristics and particularly frequency content of earthquake records. Thus, Structure response to each record in addition to the dynamic properties of the structure also depends on the above mentioned properties.
5. Elevated water tank with compartment reduce the sloshing effect & stress, deflection, deformations of the tank.

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