Seismic Performance Evaluation of Elevated Intze Water Tank by Using Finite Element Analysis

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Abstract - *Reinforced concrete elevated intze water tank are very important structures. They are considered as main lifeline elements during and after earthquakes. An intze tank behaves like an inverted pendulum which consists of huge water mass at the top of a slender staging. This is most critical consideration for the failure of the tank during earthquake. Basically, support system, so called staging is formed by a group of columns and horizontal braces providing at column. Staging is responsible for lateral resistance of complete structure.*

This analysis is carried by finite element method as intze tank subjected to seismic loading on zone 4 according to the Geographical Survey of India. Comparison of principle stresses and deflection for different filling condition is done for seismic and wind loading is done. The analysis can be performed for different type of water tank with different capacity. Same analysis can be performed for different seismic zone in India. This analysis can also be performed with using different storing material instead of water.

Stresses are increase with increase the water level in tank due to FSI effect of fluid, stresses at tank full condition are found approximately double of the stresses in tank empty condition. Deflection are also increase with increase the water level in tank, Increments in stresses and deflections with increment of water level is very less in application of wind load, maximum stresses and deflection in different filling condition are almost same for wind loading.

Key Words*: *intze water tank; seismic and wind loading*, *FSI effect of fluid; Deflection; stresses

1. INTRODUCTION

Intze Tank

It is similar to Circular tank, the conical bottom is provided at the bottom. Many more forces and vibration is act on an water tank such as water pressure on the wall of tank, wind pressure, self weight of tank, earthquake forces on base tank, and also an sloshing behavior of liquid present in tank at different filling condition. Therefore for complete study of a water tank we have to study effect of all the forces on tank in different filling condition with fluid-structure-interaction or without FSI.

Earlier many studies are done for analysis of a water tank for different loading condition and using different methods for analysis. Such as static analysis of water tank for wind load and seismic load, free vibration analysis of a water tank, forced vibration analysis of water tank and much more studies are done. In this study static model analysis of water tank whose capacity is 1000m^3 is performed by using the ANSYS software is done. The finite element analysis of water tank for seismic loading in different filling condition including the effect of fluid-structure-interaction is done in present study for same water tank of capacity 1000 m^3.Seismic activity is a sudden movement of the earth's crust caused by a rapid release of earth crust energy. An earthquake is a relatively severe geological disaster, which destroys houses and buildings as well as results in secondary disasters.

Soil-structure interaction is a complex phenomenon which involves influence between various components such as foundation & supporting soil, fluid & walls of intze type water tank fluid-layered soil system. In normal design of intze water tank, interaction between soil, foundation and tank structure is neglected to simplifying the analysis. In general practice influence of settlement of supporting soil on superstructure of water tank is ignored. Earlier studies have indicated that interaction effects are also important study for analysis of stresses, particularly for the structure resting on highly compressible soils

2. LITERATURE REVIEW

Amani *et al.* (2010) evaluated resonant frequencies in an RC elevated spherical container partially filled with water using finite element method and verified the results experimentally. The overall dynamical response of elevated spherical tanks subjected to horizontal base motion and free vibration and containing water at different levels were carried out. He investigated that for spherical tank, essentially three independent mass-motions are necessary; translation (structural), sloshing (convective) and pendulum motions. Therefore, three degrees of freedom is required for the analysis.

Karamanos *et al.* (2006) proposed a methodology based on a ''convective-impulsive'' decomposition of the liquid-vessel motion and a semi-analytical solution of sloshing in non-deformable containers by which the seismic forces can be estimated. Additionally, the effects of the support structure flexibility are also considered.

Livaoglu *et al*. (2007) presented simplified procedures for seismic analysis for elevated tanks considering fluid-structure-soil interaction ten different models were analyzed using mechanical and finite element modeling techniques. The applicability of these ten models for the seismic design of the elevated tanks with four different subsoil classes is emphasized.

Chaduvula, U. *et al*. (2013) have an experimental investigation made on a 1:4 scale model of cylindrical steel elevated water tank subjected to combined horizontal, vertical and rocking motions, for earthquake excitation (accelerations) of 0.1g and 0.2g and increasing angle of rocking motion. It was investigated that the impulsive base shear and base moment increase with increase in earthquake acceleration, whereas, the convective base shear and base moment increase with increase in earthquake acceleration but decrease with increasing angular motion. Therefore, there is no considerable effect of rocking motion found due to sloshing of water. The nonlinearity is found in the structure, when the impulsive pressure of tank decreases with increase in tank acceleration.

3. THEORY

3.1. Theory of Soil-Structure Interaction

Soil Structure Interaction is the Interaction between Structure and soil it's called Soil Structure interaction. Soil structure interaction involves two mechanisms,(1) kinematic interaction and (2) inertial interaction. The "free-field" is the space far Sufficient from any understructure that the ground locomotion (called free-field ground locomotion) is not affected by the locomotion of nearby structures. In general, understructure locomotion do not match the free field ground locomotion at indicate distance that are shorter than the substructure dimensions. This effect is termed kinematic interaction. On the other hand, the structure has a wide mass and transmits inertial motion to the soil which induces soil displacement. This phenomenon is termed as inertial interaction (Wolf1985).A structure interaction with its surrounding soil layered and this causes changes in effect of dynamic waves. In Dynamic analysis, interaction between structure and soil should be considered. Dynamic response of soil-structure interaction system is a purpose of three constituent, seismic parameters of site, motion and stimulation and seismic model of the system when it is affected by a seismic loading. Seismic parameters of the site include supporting layered soil modulus of elasticity(E), density(D), Soil Poisson coefficient(μ), and damping in soil. Damping is also divided into two different type internal and radiation damping. Internal damping is caused by transit of motion waves through soil Layered and can be consider as factor is loss of energy due to residue in soil but radiation damping causes energy loss due to release of waves from footing of the structure to half-space and for this reason, such algebra dispensation of elastic motion is called geometrical damping. Proper seismic analysis of reaction of soil-structure interaction system requires for there are different components of the system and excitations which include determination of free field motion. Earth motion without presence of structure and calculation of scattering of earthquake waves due to the soil and structure interaction system. According to principle of superposition, excitations resulting from free field and interaction analysis with each other are added and seismic model of the system includes relation of dynamic model of the foundation environment. There are many models are available for consideration and analysis of interaction. Soil and structure interaction is generally classified into two direct and sub-structure approach and each is complicate separately.

3.2. Theory of Fluid-Structure Interaction

Fluid-structure interaction (FSI) is the complex Phenomenon between the laws that describe fluid and structural. This phenomenon is characterized by interactions -which can be stable or oscillatory-between a deformable or moving structure and a surrounding or internal fluid flow. When a liquid flow encounters a structure, stresses and strains pattern are exerted on the frozen part – forces that can lead to displacement. These displacements can be fully large or very small, determined by on the pressure and momentum of the flow and the material properties of the actual structure. there are two different type vibration occurred in tank upper parts of tank container is called convective mass it's always in sloshing motion effect and lower portion of part is called impulsive mass

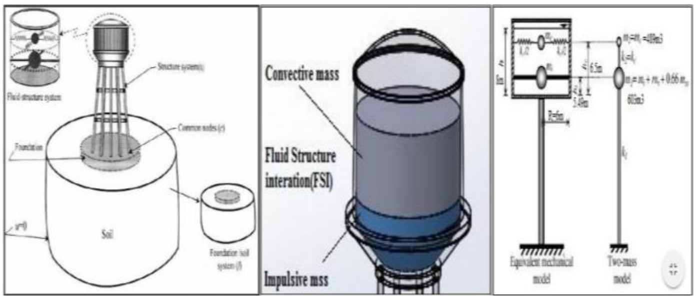

Figure1: Soil-Structure Interaction and FSI (Source.Livaoglu and A.Dogangün)

4. METHODOLOGY

4.1. FINTE ELEMENT ANALYSIS OF CIRCULAR INTZE TYPE WATER TANK

PREPROCESSING: -

Modeling of Circular Intze-Type-Water-Tank

The model of present problem of water overhead intze type water tank is shown below.

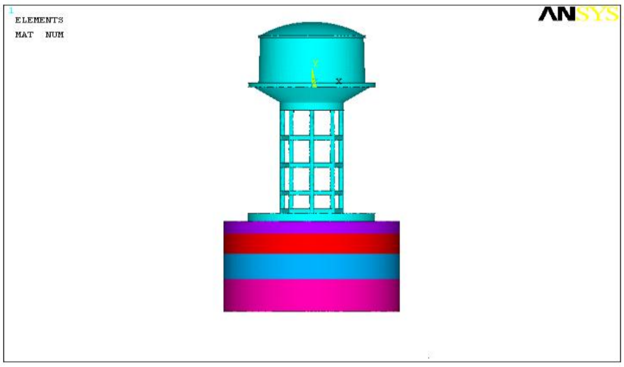

Figure 2: model of intz water tank by ANSYS

Element type:-

Solid 187 elements are used for concrete structure. And fluid 30 elements are used for showing the presence of water in tank.

Solid 187 element description: -

SOLID187 element is a higher order 3D, 10-node element. SOLID 187 has a quadratic displacement behavior and is well suited to modeling irregular meshes. The element is defined by 10 nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, hyper elasticity, creep, stress stiffening, big deflection, and large strain capabilities.

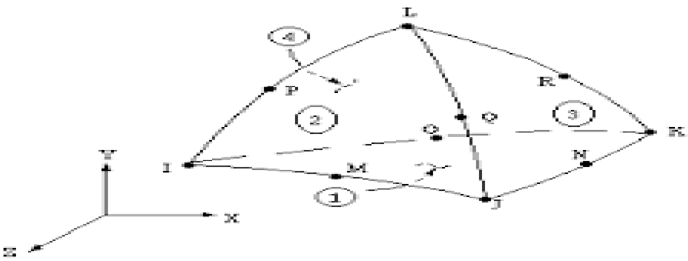

Figure 3: Solid 187 element geometry

Material model:

Table 1: Material Properties Used in Analysis.

Material Used	Young's Modulus Of Elasticity	Poisson's Ratio	Density
Concrete	25.49Gpa	0.2	25kN/m³
Soil 1	35Gpa	0.28	17kN/m³
Soil 2	40Gpa	0.29	17.4kN/m³
Soil 3	45Gpa	0.3	18kN/m³
Soil 4	55Gpa	0.32	19.2kN/m³
Soil 5	60Gpa	0.33	19.9kN/m³
Water			10kN/m³

Mashing:

Tetrahedral free mashing is used for the mashing of water tank. And the element size is taken 500 mm. Mashed figure of the analyzed water are shown below:

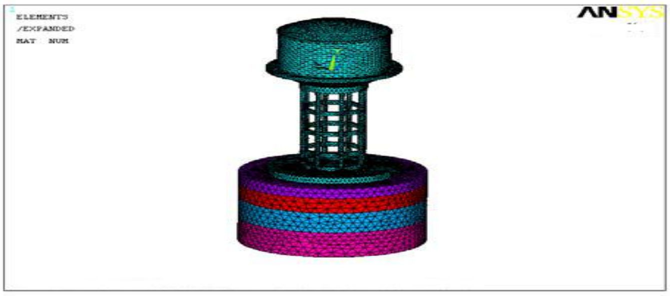

Figure 4: Mashing of tank full homogenous empty.

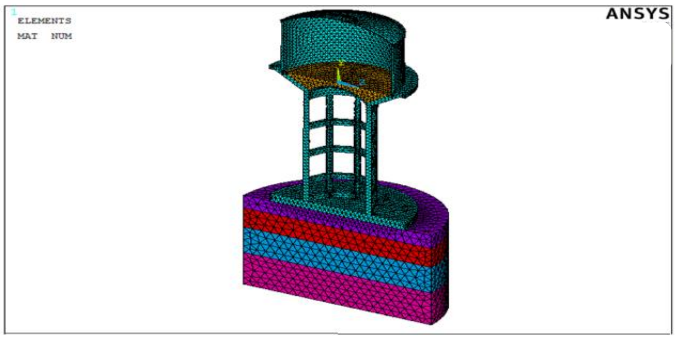

Figure 5: Mashing tank half homogenous 20% filled with water.

Analysis type: -

In present study we have to analyze the random vibration analysis of water tank due to seismic loading condition. Therefore analysis type used in this study is Static and Static and modal

Boundary condition: -

In present study the intze tank is fixed at base. For analysis of full tank only base are fixed but for analysis of same tank by half model we have to fix the base as well as symmetric boundary condition is also applied on symmetric portion.

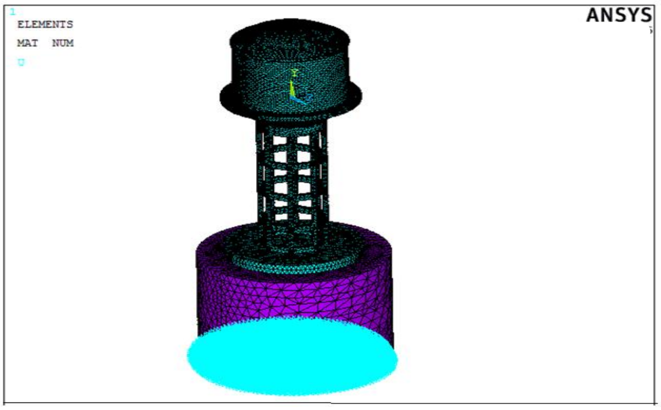

Figure 6: boundary condition for full tank (only base are fixed)

Applied load: - Seismic loads for the present research work are below.

Table 2: Seismic and wind loads for different filling condition in tank

S.No.	Tank Filling Condition	Seismic Load	Wind Load	Total Load
1	Empty condition	333.1kN	106kN	439.1kN
2	20% filled with water	392.99kN	106kN	498.99kN
3	40% filled with water	453.93kN	106kN	559.93kN
4	60% filled with water	515.18Kn	106kN	621.18kN
5	80% filled with water	577.04Kn	106kN	683.04kN
6	Fully filled with water	626.82Kn	106kN	732.82kN

Solve: -

This step is for Solve the problem for different loads and different filling condition.

Post-Processing: -

This step is for Read the results and plots the deflected shape for extract different frequency.

Convergence of Element Size: -

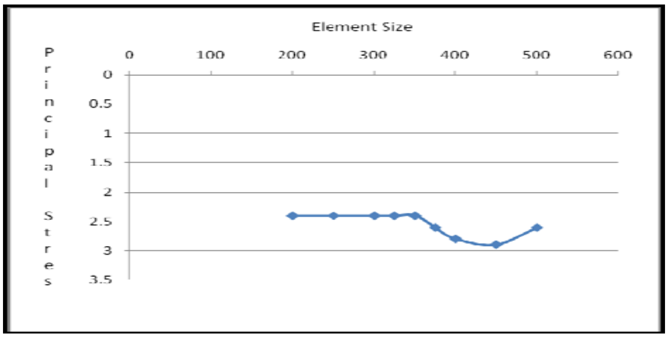

Chart1: Principal Stress v/s Element size

The graph shows the convergence of element size with respect to principal stress. From above convergence graph it is observe that the value of principal stresses are constant for element size 350mm. and after that values are not constant and varying with element size therefore we have taken the size of element is 300mm for present analysis.

5. RESULTS AND DISCUSSION

5.1. Static analysis of elevated intze water tank for seismic loading including FSI effect

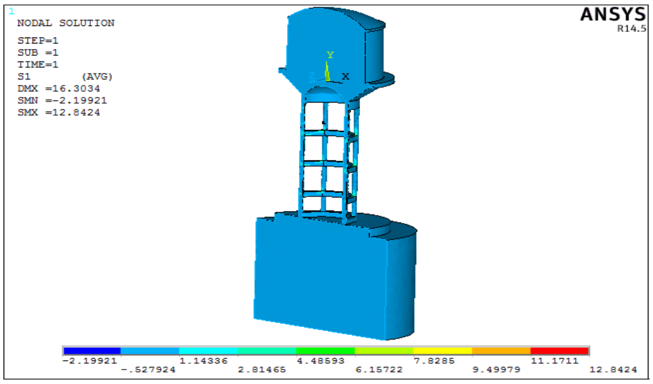

Figure 7: Principle stresses in various component of tank at tank full condition for seismic loading.

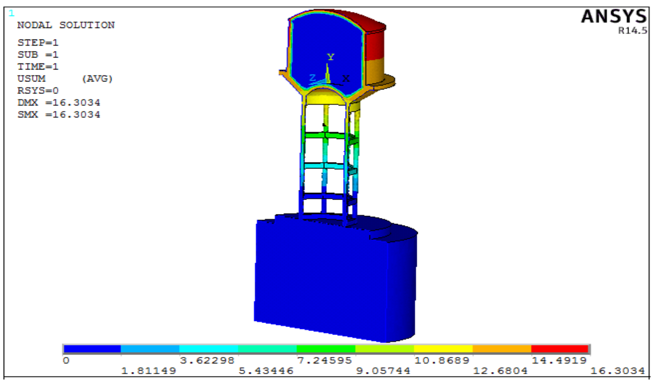

Figure 8: Deflections in various component of tank at tank full condition for seismic loading

Table 7: Stresses and deflections of the tank due to seismic loading

Filling condition of tank	1st Principal stress (N/mm^2)		Max deflection
	+ve	-ve	(mm)
Empty condition	6.5350	1.4171	8.6548
20% filled with water	8.428	1.7710	10.9822
40% filled with water	8.86	1.8182	11.8342
60% filled with water	10.0	2.0862	13.372
80% filled with water	11.3	2.4539	14.987
Fully filled with water	12.8	2.1992	16.3034

Maximum stress in tank due to seismic loading is generated at full tank condition and the value of stress is 12.842 $N/mm^2$and permissible stress of concrete which is used is $25N/mm^2$, Stress generated in tank is approximately half of the permissible stress of tank therefore we can conclude that the tank is safe in stress due to seismic loading in all filling condition. And maximum deflection 16.3034mm occurs at top dome in tank full condition which is also acceptable.

6. CONCLUSIONS

Stresses are increase with increase the water level in tank due to FSI effect of fluid, stresses at tank full condition are found approximately double of the stresses in tank empty condition. Deflection are also increase with increase the water level in tank, maximum deflection occurs at top dome of tank in tank full condition at critical condition (combined seismic & wind load condition) are found 166% of minimum deflection at top dome in same condition.

Increments in stresses and deflections with increment of water level is very less in application of wind load, maximum stresses and deflection in different filling condition are almost same for wind loading.

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