Pre-Stress (Random) Vibration Analysis of INTZE Water-Tank-Fluid-Soil System

Rahul Mishra[1] Rashmi Sakalle[2]
[1]M. Tech Scholar [2]Assistant Professor & Head of Dept.
[1,2]Department of Civil Engineering
[1,2]Truba Institute of Science & Information Technology (TIEIT), Bhopal, Madhya Pradesh, India

Abstract— Pre-stressed (Random) vibration analysis due to wind and seismic load in different filling condition of an elevated intze water tank fluid system has been studied using finite element method. In present work the pre-stress effect of seismic load on the free vibration of intze water tank up to 10th mode shape is compared with the pre-stress effect of wind load on free vibration of intze water tank fluid system in different filling condition. It is seen in the present work that the difference in pre-stress effect on frequencies of free vibration in intze water tank is very low or it can be negligible for different loading condition. The static analysis of tank due to seismic load and wind load of an intze type water tank fluid system in different filling condition are also studied using finite analysis. Stresses and deflection in static analysis due to seismic load and wind load and also compare with each other. The maximum stresses and deflections in all cases in present study are calculated.

Key words: INTZE Tank, Pre-Stress (Random) Vibration, Natural Frequency, Mode Shape, Static Analysis, Resonance

I. INTRODUCTION

A. *Water Tank*

The purpose of water tank is to contain water, thus the water tightness of concrete is of utmost importance. For underground tanks, contamination of stored water by ground water must be prevented. Hence high quality concrete is used for the construction of water tanks. Since shrinkage is normal behavior for fresh concrete, the construction sequence of tank should be designed to minimize the effect. Detailing of joints should be able to accommodate shrinkage, thus preventing shrinkage cracks. The high quality concrete mixes used should be designed for minimum shrinkage and strict quality control used in the field.

II. LITERATURE REVIEW

A. *Previous Study about the Water Tank*

There are so many investigations have taken place in the area of soil-structure interaction of over-head and underground water tanks. Many more investigators have proposed different approaches for solution of interaction problems to obtain more realistic analysis.

Some studies with their conclusions and year of studies are discussed below.

Moslemi, M. et al. (2011) evaluate the performance of elevated tanks under seismic loading. In this study, the finite element (FE) technique is used to investigate the seismic response of liquidfilled tanks. The fluid domain is modeled using displacement-based fluid elements. Both time history and modal analyses are performed on an elevated tank. Using the FE technique, impulsive and convective response components are obtained separately.

Neeraj tiwari & M.S. Hora (2015) Proposed the conventional analysis (non-interaction analysis) of overhead water tank assumes that columns rest on unyielding supports. In reality, the structure is supported by deformable soil strata which deforms unevenly under the action of loads and hence causes redistribution of forces in the components of overhead water tank. In the present work, 3-D interaction analysis of intze type water tank-fluid-layered soil system is carried out using ANSYS software to evaluate the principal stresses in different parts of the tank and supporting layered soil mass.

III. METHODOLOGY

A. *Finite Element Method*

The finite element method is a numerical analysis technique for obtaining approximate solution to a wide variety of problems in engineering and science. The FEM is ideally suited for problems involving complicated geometry, loadings & boundary condition, for which analytical mathematical solution is not possible. The method is similar to matrix displacement method of structural analysis in which skeletal structure is made up of one-dimensional member (bar, beam, frame) connected at joint.

Two features of finite element method are worth to be mentioned:

– Piece-wise approximation of physical filed on finite element provides good precision even with simple approximating.
– Locality of approximation leads to spares equation systems for a discretized problem. This helps to solve problem with very large number of nodal unknowns.

S.No.	Tank filling condition	Seismic load	Wind load
1	Empty condition	333.1 kN	106 kN
2	20% filled with water	392.99 kN	106 kN
3	40% filled with water	453.93 kN	106 kN
4	60% filled with water	515.18 kN	106 kN
5	80% filled with water	577.04 kN	106 kN
6	Fully filled with water	626.82 kN	106 kN

Table 1: Seismic and Wind Loads for Different Filling Condition in Tank

IV. RESULTS & DISCUSSION

A. *Introduction*

Two types of vibration will generated in the water tank such as free-vibration and forced vibration.

B. Pre-Stress (Random) Vibration Analysis Due to Seismic Load

We applied seismic load on superstructure of the tank and performed static analysis then on same problem vibration analysis is performed up to ten mode shape. Different frequencies at different filling condition are obtained by this analysis and summarized below.

1) Tank 20% filled with water

S. No.	No. of Mode	Frequency (Hz)	Von-mises stress (N/mm^2)	Max Deflection (mm)
1	1	1.41E-05	0.1369	0.0422
2	2	1.0072	0.0309	0.04863
3	3	1.0091	0.03348	0.0502
4	4	1.0316	0.02766	0.05851
5	5	5.3562	0.12689	0.05966
6	6	5.3697	0.13224	0.05961
7	7	9.9451	0.351241	0.121736
8	8	9.969	0.323232	0.122522
9	9	11.612	0.31157	0.13660
10	10	16.109	0.464424	0.15707

Table 2: Stresses and deflection at 20% filling condition due to random vibration on different mode by seismic load

From above result of stresses and deflection it is clear that the maximum stresses and deflection is induced at the 10th mode shape and values are 0.464424N/mm^2 and 0.15707mm respectively.

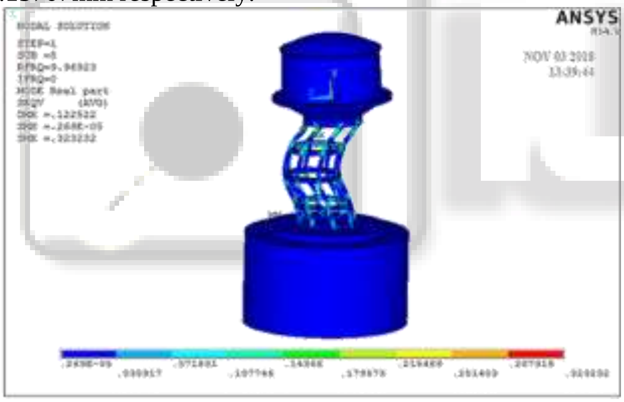

Fig. 1: Stress in 20% filling condition due to vibration by seismic load

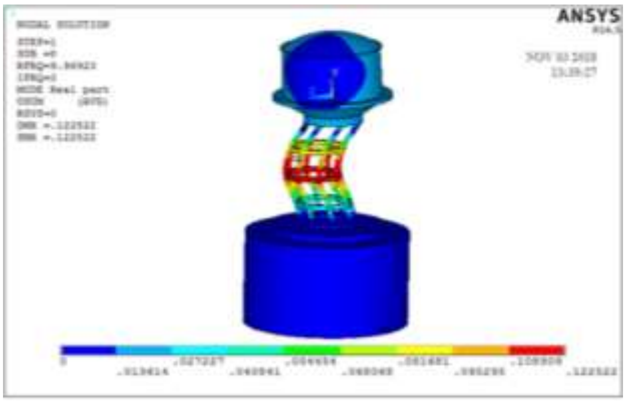

Fig. 2: Deflection and mode shape in 20% filling condition due to vibration by seismic load

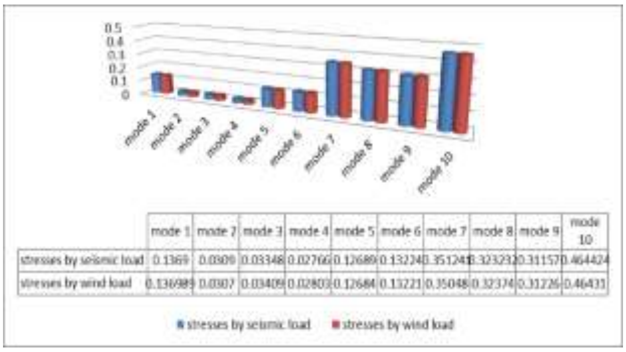

Fig. 3: Comparison of stresses developed by seismic load and wind load in pre-stress (random) vibration analysis at 20% filling condition

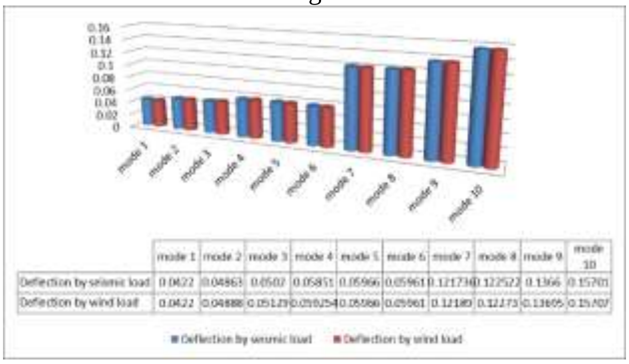

Fig. 4: Comparison of deflection developed by seismic load and wind load in pre-stress (random) vibration analysis at 20% filling condition

V. CONCLUSION

A. Conclusions from Pre-Stress Vibration Analysis

Pre-stress vibration analysis due to seismic loads and wind loads are performed on elevated circular intze-type-water-tank-fluid system for different filling condition in tank by using ANSYS MECHANICAL APDL software package. The analysis is extended to study the effect of pre-stressing due to seismic and wind loads on the natural frequency of elevated intze water tank.

1) Frequency of pre-stress vibration is gradually increases with increasing the mode shape of analysis.
2) Maximum frequency of pre-stress vibration occurs at tank empty condition and gradually decreases with increasing the water level in the tank, but frequency at 60% filling condition are also same as the maximum frequency occurs at tank empty condition due to FSI effect of fluid in tank.
3) The maximum von-mises stresses take place between 20to 60% filling condition for all most all ten modes because in this condition sloshing behavior is maximum. with the increase of mode shape deflection and von-mises stresses are also increases.
4) The natural frequency of the interaction system decreases with the increases level of water in the tank.so criteria of failure will be different for different filling condition. The natural frequencies are very useful for harmonic, transient and random (present work) analysis of the structure.
5) Resonances will occur when the frequency and deflected shape of tank due to external loading (pre-stress) match

with natural frequency and deflected shape of free vibration of tank. So resonance condition is different for different filling condition.

6) If we compare our results with static analysis results, we conclude that there is huge difference's the value of stresses and deflection for same loading. The value of stresses and deflection's are very low in case of vibration analysis and almost same for seismic and wind loading, we can understand it with the help of graph's also. It means that we can analyse there will be no or very less effect of external load in case of pre-stress (random) vibration analysis.

VI. FUTURE SCOPE OF RESEARCH WORK

The future scopes of research work are:

1) The analysis can be performed for different type of water tank with different capacity.
2) Same analysis can be performed for different seismic zone in India.
3) This analysis can also be performed with using different storing material instead of water.

REFERENCES

[1] Moslemi M., Kianoush M. R., Pogorzelski W. 2011. Seismic response of liquid-filled elevated tanks. Engineering Structures. 33: 2074-2084.

[2] Neeraj tiwari, M. S.Hora 2015, Transient analysis of elevated intze water-tank-fluid-soil system. ARPN Journal of Engineering and Applied Sciences VOL. 10, NO. 2.

[3] Pedro A. et. al. (2008) Failure analysis and remedial measures applied to a RC water tank. Engineering Failure Analysis 16 (2009) 1674–1685

[4] R. Livaoglu et al. 2006 Simplified seismic analysis procedures for elevated tanks considering fluid–structure–soil interaction. Journal of Fluids and Structures 22 (2006) 421–439.

[5] R. Livaoglu et al 2007 Effect of foundation embedment on seismic behavior of elevated tanks considering fluid–structure-soil interaction. Soil Dynamics and Earthquake Engineering 27 (2007) 855–863

[6] Resheidat RM, Sunna H. 1986. Behavior of elevated storage tanks during earthquakes. In: Proceedings of the 3rd US National Conference on Earthquake Engineering. pp. 2143–54.

[7] Shekari M.R. et al. 2008 A coupled BE–FE study for evaluation of seismically isolated cylindrical liquid storage tanks considering fluid–structure interaction. Journal of Fluids and Structures 25 (2009) 567–585