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Computational Fluid Dynamics Analysis of Elevated Circular Water Tank

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Abstract
Water storage tanks play a vital role in the society for the supply of water. Seismic study of elevated water tank under partially filled condition is a complex problem. The main purpose of the study is to perceive the seismic behavior of elevated reinforced concrete water tank in earthquake prone areas. For analysis, elevated circular water tank has been chosen because, due to high elevation and concentration of huge mass, elevated water tanks are more susceptible to horizontal accelerations and become more critical requiring a rigorous study. Various hydrodynamic pressures on the wall and base slab of water tank have been computed by using commercial Computational Fluid Dynamics (CFD) package. For partially filled condition, different water heights have been taken in to consideration for the analysis to study the effect of sloshing on the roof and walls of the water tank. Multiphase and Volume of Fluid (VOF) method were used to analyze the partially filled tank. Comparison has been made between different tank condition i.e. partially filled condition, full tank condition and empty tank condition under seismic forces in the workbench platform of ANSYS 18.

Keywords- Elevated Water Tank, CFD Analysis, Dynamic Analysis, Ansys Modeling.

1. Introduction

Water tanks are very common in India for supplying water as the water demand is not constant throughout the day. Elevated water tank attracts more seismic forces than ground supported tank due to huge lumped mass is assumed to be concentrated at very high elevation. The main causes of failure of water tank are shear failure in beams, column fails axially, sloshing. Earthquake causes horizontal ground motion which results in the free water movement inside the tank known as sloshing. Elevated water tanks are constructed in such a way that they provide the required head to the water to flow under the influence of gravity. For obtaining smaller base shears and base moments elevated tanks may be analyzed by considering them as a single lumped-mass model.

Housner (1963) first proposed the spring mass model for the elevated and ground supported tank. A partially filled tank was modeled as 2 DOF systems while full and empty tanks were considered as a single mass model. The results show that shaft staging proves better in reducing the sloshing displacement. Shrimali and Jangid (2002) investigated the soil and fluid structure interaction of elevated tank under artificial ground motion produced by Vanmarchke and Gasparini approach. Biswal et al. (2003) studied the partially filled fuel tank subjected to ground motion induced by the earthquake concluded that from the study that height of sloshing depends on the free board provided. Jain and Jaiswal (2007) presented the study of fluid structure interaction to acquire sloshing frequency and other hydrodynamic parameters. Algreane et al. (2009) investigated the effect of soil structure interaction on the sloshing phenomenon of water tanks. Patel et al. (2012) examined the sloshing behavior in a rectangular tank. The study was executed using ANSYS-FLUENT software. Multiphase and Volume of fluid (VOF) method was applied to indicate the free surface waves. Ormeno et al. (2015) studied the response of elevated overhead water tank using ANSYS software. The time history analysis was done ANSYS under real earthquake of EI Centro earthquake. Nayak and Thakare (2017) studied the performance of staging of the elevated water tank under Uttarkashi earthquake shows that retrofitting technique was found to be effective reducing the seismic response.

2. Physical Model

An RC circular water container of 50,000 L capacity has an internal diameter of 6000mm and height of 2000 mm (including freeboard of 500 mm). The tank is located on the hard soil in seismic zone III. A grade of staging concrete and steel are M20 and Fe415, respectively. Figure 1 shows the geometric modeling of elevated water tank.

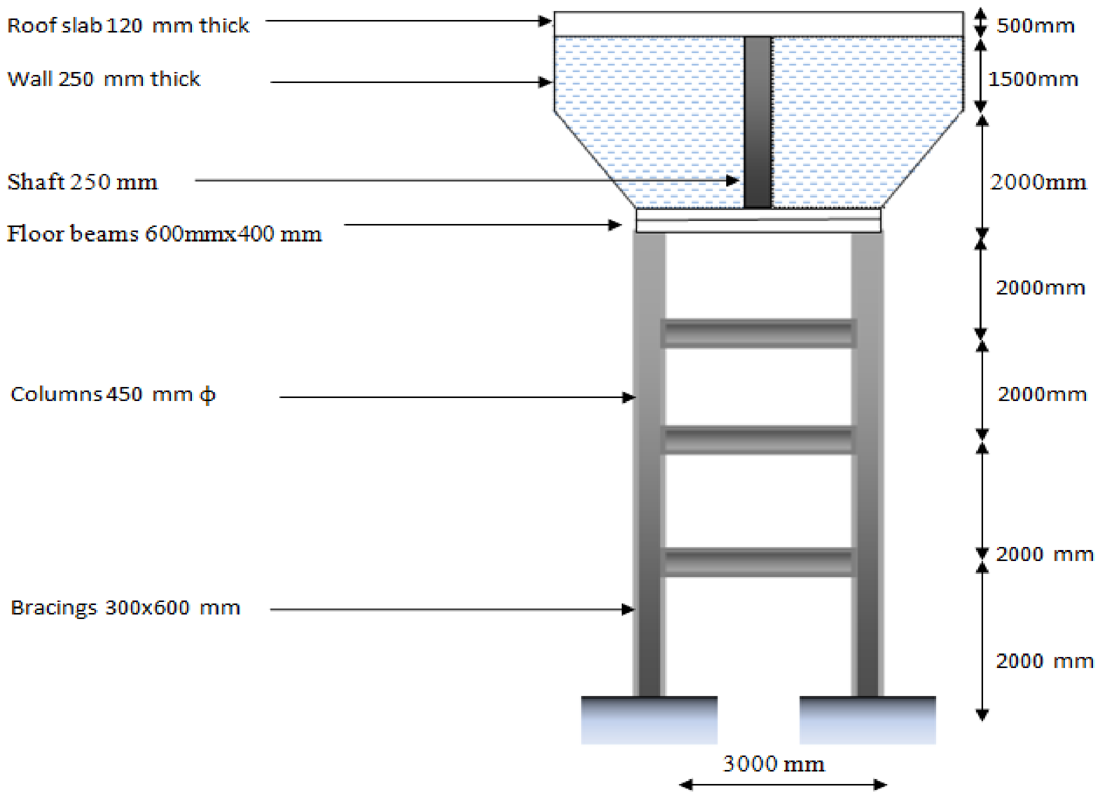

Figure 1. Model of elevated circular water tank

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Model of water tank was designed in ANSYS DESIGN MODULAR (Figure 2) Figure 3 shows the Meshing of water tank. Face sizing method is used for the faces and sweep method is used for the staging of the tank. The minimum size of meshing is 0.005m.

Figure 2. Model of elevated circular water tank in Figure 3 Meshing of water tank

3. Methodology

In the present study workbench platform in ANSYS 18 is used for the analysis of water tank. The methodology presents the application of computational fluid dynamics (CFD) in evaluating the seismic response of the water tank. Fluid flow (fluent) is used as the solver type for the analysis in the CFD physics. A real ground motion, Northridge earthquake 1994 is used for the time history analysis of water tank recorded at Simmi Valley Station of Peak ground acceleration (PGA) (g) 0.80. Horizontal component of ground motion is used for the analysis.

4. Results and Discussion

The results for analysis of water tank for three different tank conditions i.e empty tank, partially filled tank and full tank are discussed separately.

4.1 Analysis of Empty Tank Condition

Figure 4 shows mode shapes of the circular water tank with fixed support condition. Figure 5 shows the variation of total deformation from bottom of staging to the top of the water tank.

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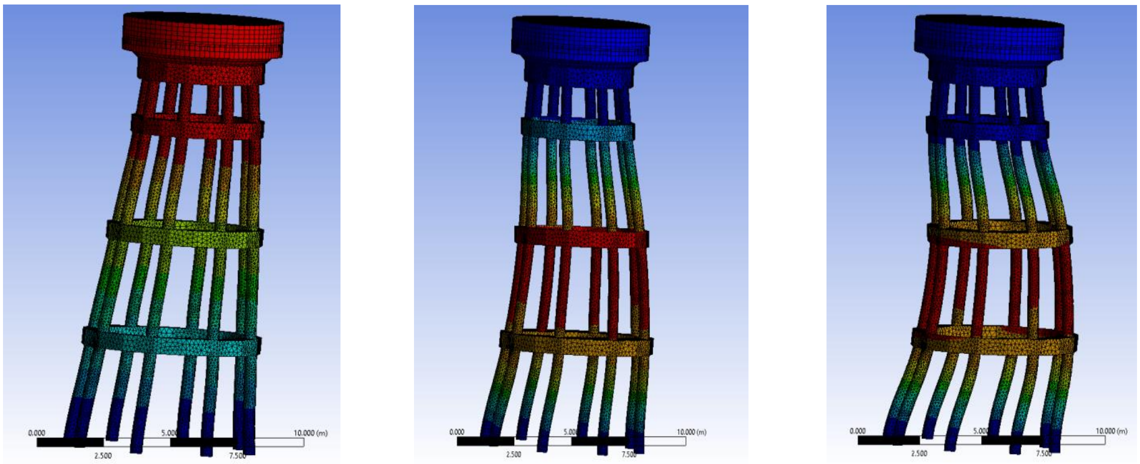

(a) (b) (c)

Figure 4. Mode shapes of elevated circular water tank (a) Mode 1 (b) Mode 2 (c) Mode 3

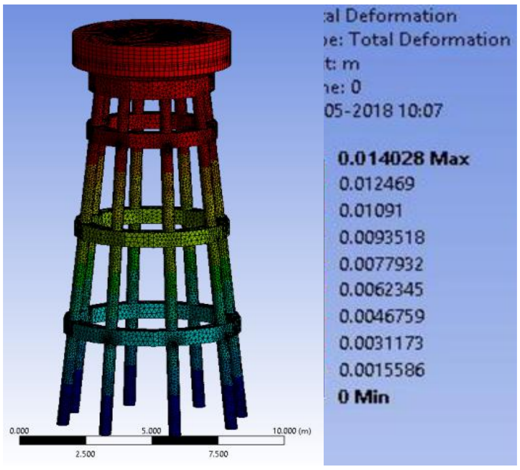

Figure 5. Total deformation of water tank

4.2 Comparison of Static Pressure of Partially Filled Tank and Full Tank

Static pressure is found to be more at the edges of wall and minimum at the centre part of top and bottom of the container (Figure 6)

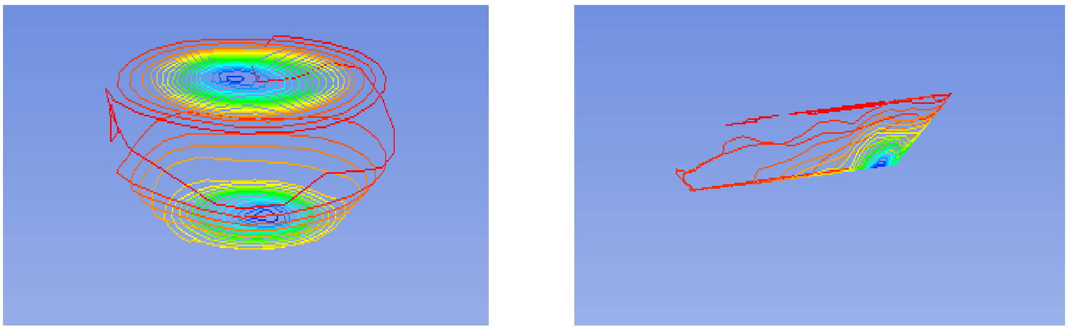

Figure 6. Static pressure of Elevated water tank (a) partially filled tank (b) full tank condition

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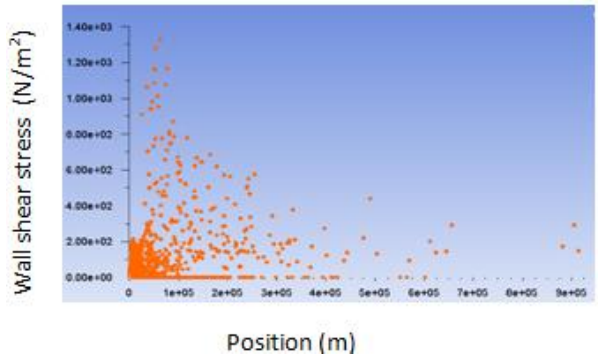
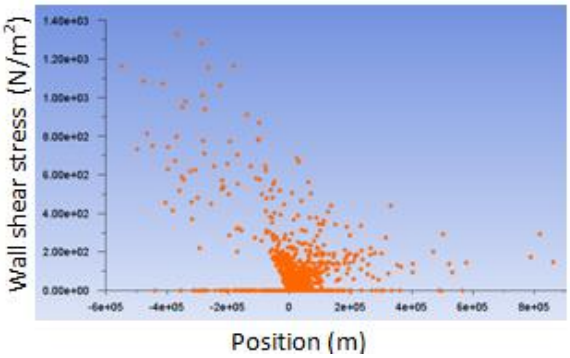
4.3 Comparison of Wall Shear Stress of Partially Filled Tank and Full Tank Condition

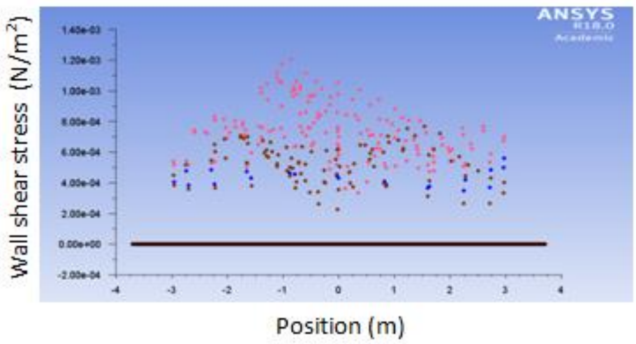
Wall shear stress are compared for partially filled tank (1 m and 1.8m) and full tank condition (Figure 7).



(a)



(b)

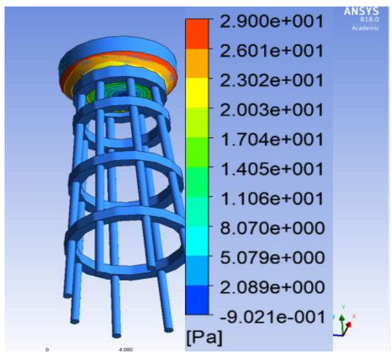


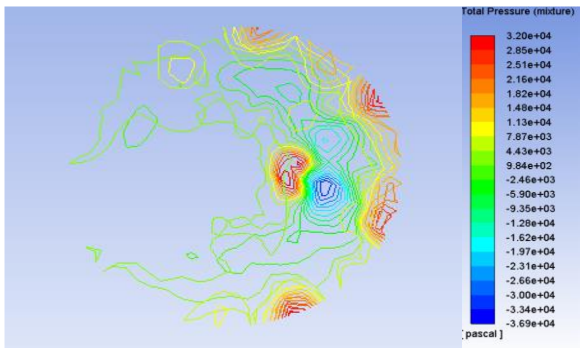
(c)

Figure 7. Wall shear stress v/s positions. (a) When water height is 1m. (b) When water height is 1.8m. (c) Full tank condition

4.4 Comparison of Total Pressure of Water Tank

Figure 8 shows the comparison of total pressure of partially filled tank and full tank condition.





(a) **(b)**

Figure 8. Total pressure of water tank (a) partially filled tank with staging (b) water tank container in full condition

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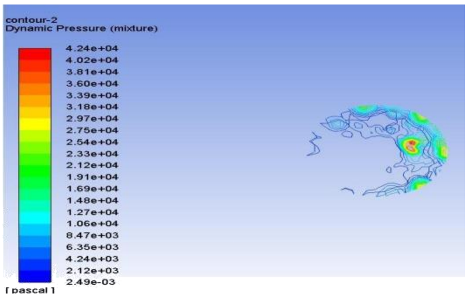
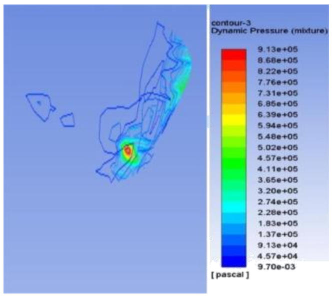
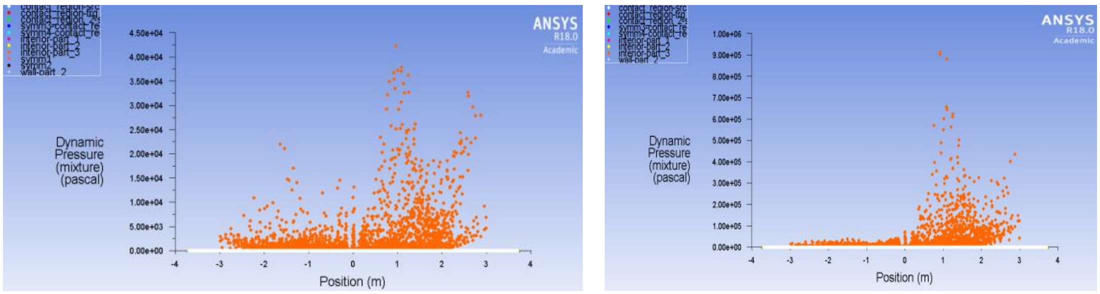
4.5 Comparison of Hydrodynamic Pressure in Tank Container with Different Tank Condition

Figure 9 shows the comparison of dynamic pressure of partially filled tank and full tank condition. As the water tank is in full condition, the only impulsive hydrodynamic pressure is generated (Figure 9)





(a) **(b)**

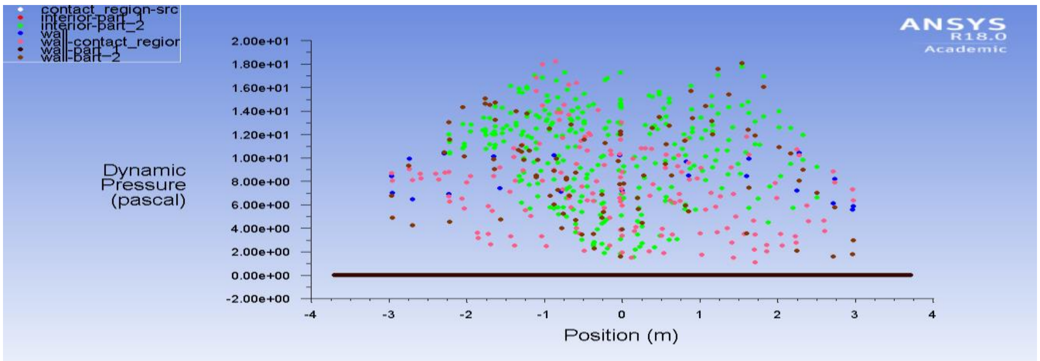


(c)

Figure 9. Hydrodynamic pressure v/s position tank (a) when water height is 1m (b) when water height is 1.8 m (c) Full water tank condition

4.6 Comparison of Dynamic Pressure Of Tank Container Partially Filled Water Tank And Full Tank

In partially filled tank convective and impulsive hydrodynamic pressure are generated (Figure 10a and 10b). In full tank condition only impulsive hydrodynamic pressure is generated (Figure 10c)



(a)

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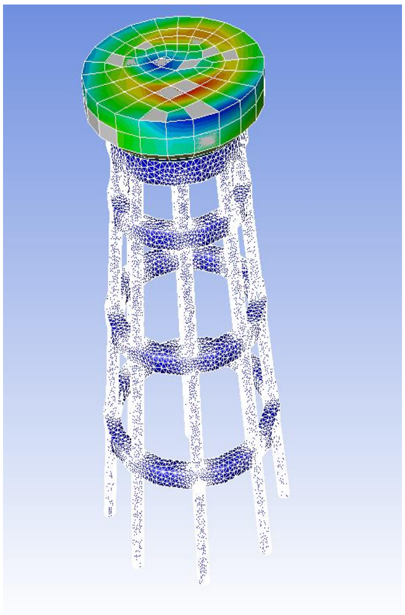

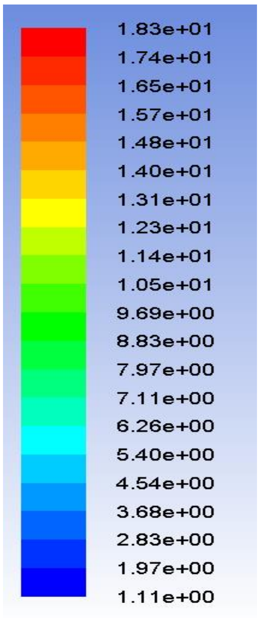

(b) **(c)**

Figure 10. Dynamic pressure of water tank (a) when water height is 1m (b) when water height is 1.8 m. (c) Full tank condition with staging

5. Conclusion

In case of partially filled water tank under the seismic excitation, the convective hydrodynamic pressure is found to be more at the top of the wall, and its value decreases toward the bottom of the tank. Impulsive hydrodynamic pressure is found to be more at the base of the wall. Impulsive hydrodynamic pressure on wall decreases from base of the wall to top of the wall (excluding freeboard).Impulsive hydrodynamic pressure and convective hydrodynamic pressure on base slab increase as the horizontal distance (in the direction of seismic force), from the reference axis at the center of tank increases. The hydrodynamic pressure of water tank with water height 1.8m is almost double than water tank with water height 1m.

In full water tank condition, the entire liquid is impulsive hydrodynamic pressure. The dynamic pressure on the wall in any tank condition is maximum at the center of the tank and tends to reduce towards the edge of the tank.

The wall shear stress is maximum at the center of the base slab and decreases as the distance to the top of the tank increases.

The total pressure of water tank in full condition is found out to be more than partially filled tank condition. The total deformation is found to be increasing from bottom of the staging to top of the water tank.

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References

Algreane, G. A., Osman, S. A., Karim, O. A., & Kasa, A. (2009). Dynamic behaviour of elevated concrete water tank with alternate impulsive mass configurations. In WSEAS International Conference. Proceedings. Mathematics and Computers in Science and Engineering (No. 2). WSEAS.

Biswal, K. C., Bhattacharyya, S. K., & Sinha, P. K. (2003). Dynamic characteristics of liquid filled rectangular tank with baffles. Journal of the Institution of Engineers. India. Civil Engineering Division, 84(AOU), 145-148.

Housner, G. W. (1963). The dynamic behavior of water tanks. Bulletin of the seismological society of America, 53(2), 381-387.

Jain, S. K., & Jaiswal, O. R. (2007). IITK-GSDMA guidelines for seismic design of liquid storage tanks. National Information Centre of Earthquake Engineering, Kanpur.

Nayak, C. B., & Thakare, S. B. (2017). Investigation of corrosion status in elevated water tank by using nondestructive techniques in Baramati region. In International Conference on Construction Real Estate, Infrastructure and Project Management, NICMAR, Pune (pp. 1-17).

Ormeno, M., Larkin, T., & Chouw, N. (2015). Evaluation of seismic ground motion scaling procedures for linear time-history analysis of liquid storage tanks. Engineering Structures, 102, 266-277.

Patel, C. N., Vaghela, S. N., & Patel, H. S. (2012). Sloshing response of elevated water tank over alternate column proportionality. International Journal of Advanced Engineering Technology, IJAERS, 3, 60-63.

Shrimali, M. K., & Jangid, R. S. (2002). Seismic response of liquid storage tanks isolated by sliding bearings. Engineering Structures, 24(7), 909-921.