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EVALUATING THE SPECTRAL ACCELERATION AMPLIFICATION EFFECTS ON THE SEISMIC RESPONSE OF ELEVATED STEEL WATER TANKS

Armen ASSATOURIANS
Earthquake Engineering Research Consultant, Yerevan, Armenia
ar_ast@hotmail.com
Sohrab FALLAHI
Senior Structural Designer, E.S.S. Consulting Eng. Co., Tehran, Iran
fallahi@essce.ir

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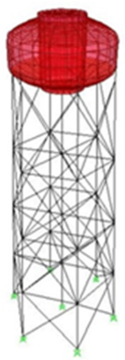
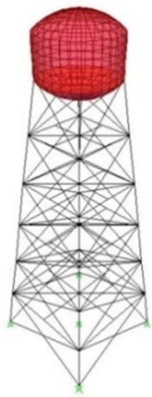
Water Tanks are amongst the most important structures which are used for storage and providing the water needed on the pick usage time in water supply networks. The Seismic behaviour of such special structures is the main objective of current research, which was motivated by raising demands for design and construction of elevated water tanks. Hence, two structural models of steel elevated water tanks in Armneia, with capacities of 134 m^3 and 160 m^3, demonstrating a height of 24 m and 30 m respectively are selected as shown in Figure 1. Each model is considered to be empty, 50% and 100% full and is designed according to Armenian SNIP II-6.02 seismic code for all filling strategies, taking into account the spectral acceleration level equal to S_a=0.40 g.

On each model, the information of Convective mass, Impulsive mass and the spring stiffness of the convective and impulsive masses are added, due to the Housner's Equivalent Mass-Spring theory, considering Soil-Structure Interaction (SSI) effects at the meantime. Earthquake Analysis procedures of the whole fluid-tank systems are completed by the means of Time History Analysis method, using 3 horizontal components of selected accelerograms, recorded on soil categories of Rock, Dense Soil and Loose Soil respectively, scaled to spectral acceleration levels of S_a=0.2 g ~1.0 g. Finally, the seismic response is computed for the filling strategy of Empty, 50% full and 100% full conditions for both models. Fluid-Soil-Structure Interaction analyses are completed using ADINA 9.40 FEM software.



(a)



(b)

Figure 1. Numerical Models: (a) 134 m^3 & h=24.0 m, (b) 160 m^3 & h=30.0 m.

The assumption of full reservoir in most cases is unreal, hence during the sloshing vibration mode of fluid, the behavior of the whole reservoir will vary to an extent. One of the well-known analysis methods of reservoirs by taking into account the sloshing mode of the fluid is proposed by Housner, illustrated in Figure 2. As could be observed, m_1 is the convective mass of the sloshing fluid and m_2 is the total mass of fluid+ empty reservoir + partial mass of the supporting structure.

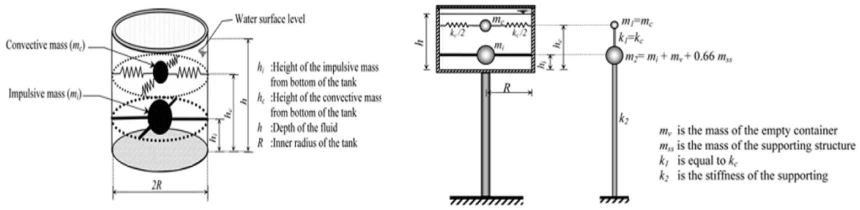
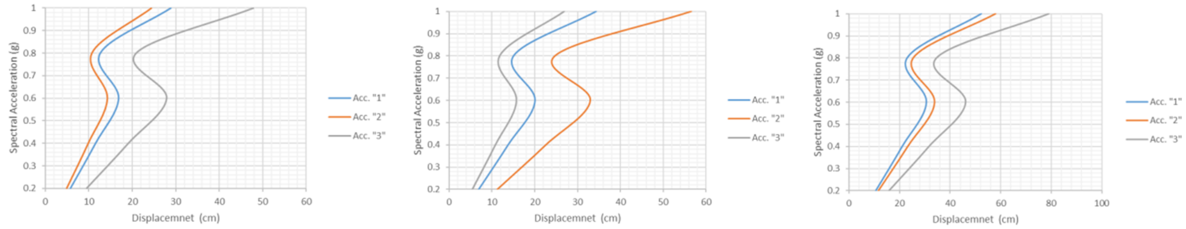
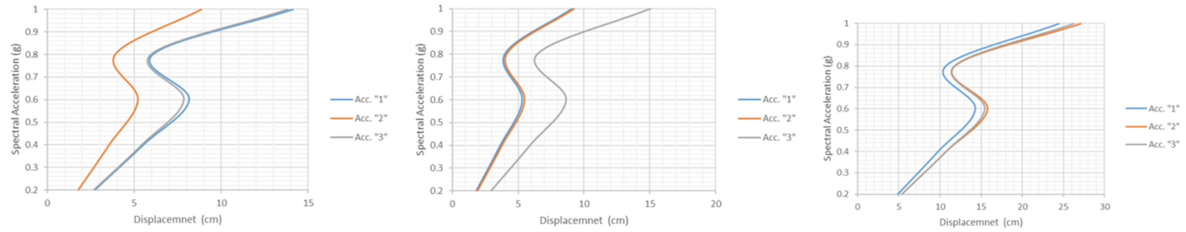


Figure 2. Two mass model and equivalent Mass-Spring.



(a) (b) (c)

Figure 3. Diagrams of Spectral Acceleration versus Displacement for Filling Strategy of 100% for soil categories of: a) Rock, b) Dense Soil and c) Loose Soil for model "a".



(a) (b) (c)

Figure 4. Diagrams of Spectral Acceleration versus Displacement for Filling Strategy of 50% for soil categories of: a) Rock, b) Dense Soil, and c) Loose Soil for model "b".

The computational results of FEM analysis of the whole Fluid-Soil-Structure system in Figue 3 and Figure 4 illustrate that by degrading the soil category, the lateral displacement amplification due to filling percent of tanks converts to be nonlinear for all soil categories, regardless of the frequency content effects of used earthquake records. All diagrams of spectral acceleration versus displacmenet show two turning points at 0.60 g and 0.78 g. Generally, the randomness of results decrease while the soil category degrades containing a few exceptions, which demonstrates the lower effects of frequency content of the earthquake records. The displacement amplification decreases due to soil degradation which illustrates the high filtering effect of convective mass sloshing mode in case of low frequency content of selected accelerograms. The SSI effect also causes the sloshing mode of convective mass to operate as a more powerful frequency filter, when the soil categoty degrades.

REFERENCES

Chopra, A.K. (2012). Dynamics of Structures: *Theory and applications to Earthquake Engineering* (4^{th} ed.), Prentice Hall, Englewood Cliffs.

Dogangun, A., Ayvaz, Y., and Durmus, A. (1997). Earthquake Analysis of Water Tanks, *4^{th} International Conference on Civil Engineering*, Vol 1, Sharif University of Technology, 400-409.

Haroun, A.H. and Temraz, M.K. (1992). Effects of Soil-Structure Interaction on Seismic Response of Elevated Tanks, *Soil Dynamics and Earthquake Engineering*, *11*, 73-86.

Housner, G.W. (1963). Dynamic Behavior of Water Tanks, *Bulletin of the Seismological Society of America*, *53*, 381-387.

Shaaban, S.H. and Nash, W.A. (1976). *Finite element analysis of a seismically excited cylindrical storage tanks, ground supported and partially filled with liquid.* Report NSF/RA-760261, University of Massachusetts.

SNIP II-6.02 (2006). *Armenian Code of Practice for Seismic Resistant Design of Buildings.*