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SEISMIC ASSESSMENT OF OIL RESERVOIRS USING NUMERICAL FEM AND ANALYTICAL FORMULATION OF DESIGN STANDARDS

Hassan DEZGANI
M.Sc. Student, University of Kashan, Kashan, Iran
hasan.dezgahi@gmail.com

Hossein TAHGHIGHI
Assistant Professor, University of Kashan, Kashan, Iran
tahghighi@kashanu.ac.ir

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The importance of earthquake effects on the storage reservoir forces researchers to investigate the seismic response of reservoirs. Despite recent advances in design standards, there is no acceptable method for time-history analysis for such structures, with high structural stiffness. The seismic codes such as Standard No. 2800 and ASCE/SEI 7 for conventional structures just minimize the difference between the selected response spectrums and the design spectrum in the preset period range. Seismic codes have differences in their scaling methods. In this context, many studies have been carried out (e.g. Hamdan, 2000; Goodarzi and Sabbagh-Yazdi, 2009; Kalogerakou et al., 2017; Dezgani and Tahghighi, 2019; etc.). The current article aims to calculate the scale factor based on the Standard No. 2800 and ASCE codes. Furthermore, the seismic response of the reservoirs is obtained according to API650 (2013) and Iranian oil ministry code 038 (2017). Then, numerical modeling has been done in ANSYS WORKBENCH. Finally, the seismic response of the numerical model is compared with the seismic response from standards.

This paper studies the seismic response of several reservoirs in storage complexes in Kashan, Iran. The linear analysis of steel storage tanks and its modeling using ANSYS WORKBENCH is explored. The storage reservoirs are assumed without a roof. In the reservoir model, FLUID 80 and SHELL181 are used for liquid and walls respectively by the ANSYS software. Figure 1 presents the FEM modeling of a representative steel oil storage tank. A cylindrical coordinate system has been used to define fluid and shell boundary conditions, and the movements and fluid turbulence inside the reservoir are more realistically defined. To ensure the accuracy of numerical results, validation is done in three steps. In the first step, static analysis of the model with an analytical formula and the numerical analysis of the reservoirs is shown in Figure 2. Then, the convective vibration frequencies obtained from the finite element method are compared with the Haroun analytical formula given as Equation 1. Figure 3 compares the frequencies.

$$\omega_s^2 = \frac{1.841g}{R}\tanh\left(\frac{1.841H}{R}\right) \tag{1}$$

where g is the specific gravity, R is the radius of the tank, and H is the maximum design product level. Finally, the last validation relates to fluid surface fluctuations during loading under seismic excitation. For this purpose, two points of the fluid surface that are in line with the loading of the acceleration time histories are selected (Figure 4).

Base shear and overturning moment values computed by the criteria of the design standards code 038 and API650 are compared with numerical analysis values by ANSYS software. The dynamic hoop stresses obtained from both design standards are also compared. The results show that in some cases there are weaknesses in design standards and seismic regulations, which require further research in the future. For instance, the base shear and the dynamic hoop stress have been shown in Figure 5 and Table 1, respectively. As shown, the scale factors have significantly affected on the obtained results. Furthermore, the scale factors of the 2800 code have increased higher values to ASCE. The values of the scale factors are just one aspect of computing the applied load, and the other aspect is the records. Thus, the seismic responses of the considered tanks have been assessed to evaluate the effects of these two aspects.

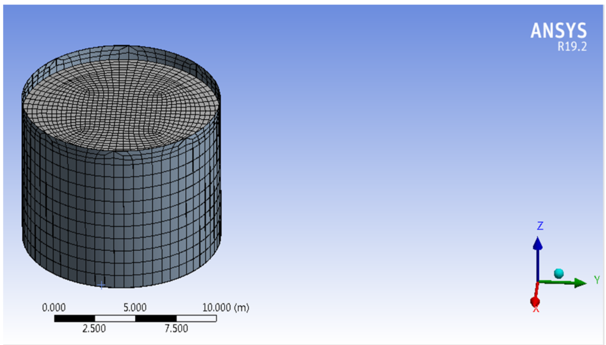

Figure 1. The FE model in ANSYS WORKBENCH

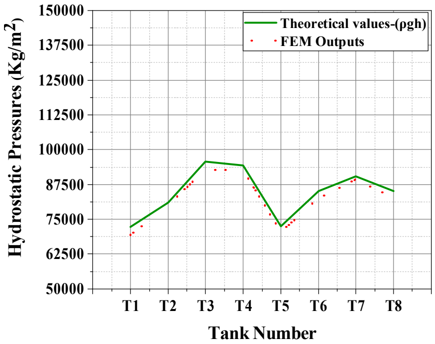

Figure 2. Comparison of numerical and theoretical hydrostatic pressures

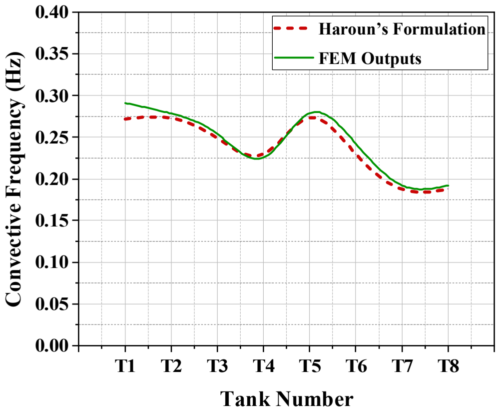

Figure 3. Comparison of the convective frequency of the Haroun's formulation and the FEM results.

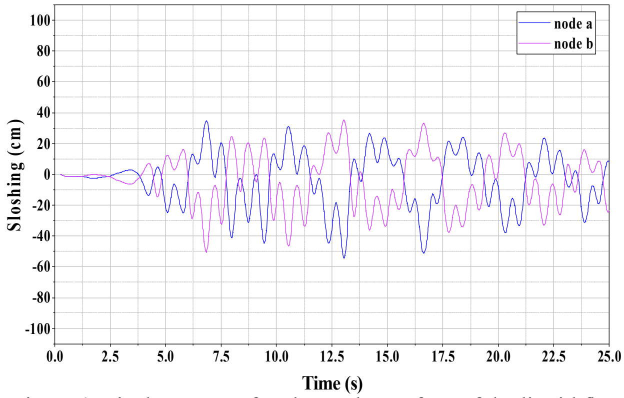

Figure 4. Displacement of nodes at the surface of the liquid flow under time-history loading.

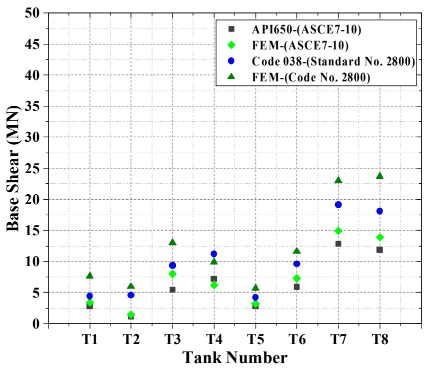

Figure 5. Average values of the base shear from numerical analysis and design standards.

Table 1. Dynamic hoop stress.

Tank No.	σ_s (MPa)	
	ASCE/SEI 7-10	Standard No. 2800
T1	39.86	41.9
T2	41.12	42.76
T3	60.82	64.15
T4	68.85	73.25
T5	28.21	28.62
T6	45.59	47.97
T7	70.28	75.88
T8	53.95	58.01

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