SHAKE TABLE TESTS ON THE STEEL FLUID STORAGE TANK MODELS

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Dynamic behaviors of storage tanks under seismic loads are generally complex, which has been studied by many researchers. This issue was first introduced by Housner for cylindrical rigid Tanks. He assumed that the seismic response of rigid tanks is divided into two impulsive and convective components. Impulsive pressure according to the coordinated movement is part of the generated rigid tanks walls. Convective pressure is also the other part of created fluid at the free surface of tanks contents. In this paper, dynamic behavior of a steel cylindrical tank model with diameter of 1.2m and height of 1.25 meters and with fixed roof condition have been tested on the International Institute of Earthquake Engineering and Seismology (IIEES) shaking table. In this research, experimental tank model with three different level of liquid height subjected to three different earthquake records. Experimental results including frequency contents, damping values, and sloshing amplitudes have been compared with AP1650-2008 and ASCE regulations.

Alaska earthquake in 1964 imported intense damages to the fluid tanks. The results of this earthquake indicated that the flexibility of the tank walls was one of the main reason extensive tank damages. Therefore, Housner, 1954; Housner, 1957a; Housner, 1957b; Haroun, 1980; Haroun and Housner, 1982a; Haroun and Housner, 1982b and other researchers started to extensive investigation and analyzing the interaction of fluid and structure issues using numerical and experimental methods. Based on these investigations, a simplified model was presented to indicate the effects of flexibility of the tank walls. The results of extensive investigations regarding seismic behavior and seismic design of fluid tank presented in the API Standard 650 (2008), and ASCE regulations (2003).

In this paper, dynamic behavior of a steel cylindrical tank model with fixed roof condition have been tested on the International Institute of Earthquake Engineering and Seismology (IIEES) shaking table. Due to the experimental limitations, including the size of the shaking table and the capacity of the hydraulic system it is necessary to use scaled models for the experimental test of the desired tank. By considering all the constraints, the geometric scale factor λ_L=16 is intended for the tank model and finally the diameter of 1.2m and height of 1.25 meters is considered for test model.

A summary of the sloshing height results obtained from the experimental test model presented in table 1 and compared with API650 regulations determined from equation 1. Parameters D and A_f in this equation are the nominal diameter (inner diameter) of the tank, and acceleration coefficient, respectively. It should be noted that the response spectrua of ASCE design regulation is different from the result of the input earthquake records considered in this research. The results presented in this table show that the experimental values are generally higher than the values of the code regulations. Based on the test results, the maximum height of the sloshing under Tabas Earthquake at heights of 60, 80 and 100 cm are equal to 23.2, 24.3, and is 23 cm. API 650 regulations relating 7 to get the maximum height of sloshing has proposed:

$$S_S = 0.5 \times D \times A_f \tag{1}$$

Table 1. Maximum sloshing heights obtained from experimental tests and API650-2008 regulation

Fluid height(cm)	Earthquake	Maximum sloshing height(cm)	
		Experimental Results	API650 -2008 regulation
60	Tabas	23.2	12.51
	Elcentro	8	
	Irpinia	10.2	
80	Tabas	24.3	12.74
	Elcentro	4.85	
	Irpinia	11.5	
100	Tabas	23	12.80
	Elcentro	5	
	Irpinia	11.5	

In this research, vibration frequencies of the impulsive modes and the convective modes, and also the height of the sloshing of the tested tank model subjected to the various earthquake records obtained and compared with the values values of API650 regulations. Following findings can be presented from this research:

1. Convective and impulsive frequencies of the tested tank obtained from experimental results are in good agreement with the results of API650 regulation. This agreement in the convective mode is more than in the impulsive mode.
2. Experimental damping values for the convective modes are in the range of 0.3% to 0.5%. This value according to the API650 regulations is 0.5%. Therefore, experimental results indicate lower values between 10% to 20% percent.
3. The maximum height of the fluid sloshing in the tank subjected to the Tabas earthquake is about 2 times the API650 regulations. Therefore more investigation of code requirements it necessary.

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