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EXTENDED ABSTRACT

Dynamic Behavior Evaluation of FPS Isolated Liquid Storage Tanks Subjected to Pulse- like Excitations

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1. Introduction

On-grade liquid storage tanks are vulnerable to strong ground motions, as some recent major earthquakes have demonstrated. Seismic base isolation is one of the most efficient techniques to mitigate earthquake damage in these structures. Among the various base isolation devices, the Friction Pendulum System (FPS) provides several benefits: the independence of isolation period from superstructure mass/weight which can be varied in some structures such as liquid storage tanks, re- centering related to the spherical surface, and high energy dissipation based on velocity-dependent friction (Mokha et al., 1991; Zayas et al., 1990). Although the base isolation has been known as an efficient technique to protect civil structures, the performance of base-isolated structures under near-fault ground motions containing long- period pulses has been questioned in recent years. In this paper, a parametric study is carried out to investigate the seismic behavior of FPS isolated liquid storage tanks under near- fault ground motions represented by analytical pulse-like functions. For this purpose, the liquid storage tanks are modeled using equivalent mechanical models and then dynamic analyses of the models are done using pulse-like excitations. The effects of the tank type, isolator specifications and the input excitation characteristics on the various response parameters are investigated.

2. Methodology

2.1. Simplified representation of pulse-type excitations

In this study, a mathematical representation of the near-fault ground velocity pulses proposed by Mavroeidis and Papageorgiou (2003) is used for nonlinear dynamic analyses. It is based on a modified Gabor wavelet transform and is expressed as:

$$v(t)=\begin{cases}\frac{A}{2}\left[1+\cos\left(\frac{2\pi f_p}{\gamma}(t-t_0)\right)\right]\cos[2\pi f_p(t-t_0)+v], & t_0-\frac{\gamma}{2f_p}\le t\le t_0+\frac{\gamma}{2f_p}\\ 0, & \text{otherwise}\end{cases} \tag{1}$$

where parameter A controls the amplitude of the signal, f_p is the prevailing frequency of the signal, ν is the phase of the signal, γ is a parameter that defines the oscillatory character of the signal, and t_0 specifies the epoch of the envelope's peak.

2.2. Simplified model of isolated tanks

The mathematical model of the isolated tank used in the present study is the simple, yet accurate, and more generally applicable equivalent mechanical model of the tank- liquid system proposed by Malhotra et al. (2000)

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which is resting on a base isolation system. Two cylindrical steel tanks with different aspect ratios, one broad and one slender, have been used for numerical studies. Nonlinear dynamic analyses of the models are done by solving the governing equations of motion with a provided MATLAB routine. The numerical results are presented in terms of the overturning moment (M), vertical displacement of the liquid surface due to the sloshing motion (dx), and the bearing displacement (u_b).

3. Results and conclusions

The obtained results indicate that by increasing the number of input pulses in both broad and slender tanks, the response parameters increase considerably when the pulse period is near to the effective periods of each response. It is also seen that when the input pulse period is near the convective (sloshing) period, the vertical sloshing displacement of the liquid near the free surface is affected more and when it tends to the isolation period or even less, the overturning moment are affected more (Fig. 1). The isolation displacement is affected in both aforementioned ranges of the pulse period. Therefore, it is recommended that the isolation period is chosen enough longer than the impulsive period yet not close to the convective period. It will lead to a considerable reduction in the overturning moment response of the tank due to the isolation while the bearing displacement is controlled in a reasonable range. It is also recommended to avoid very small values of friction coefficient.

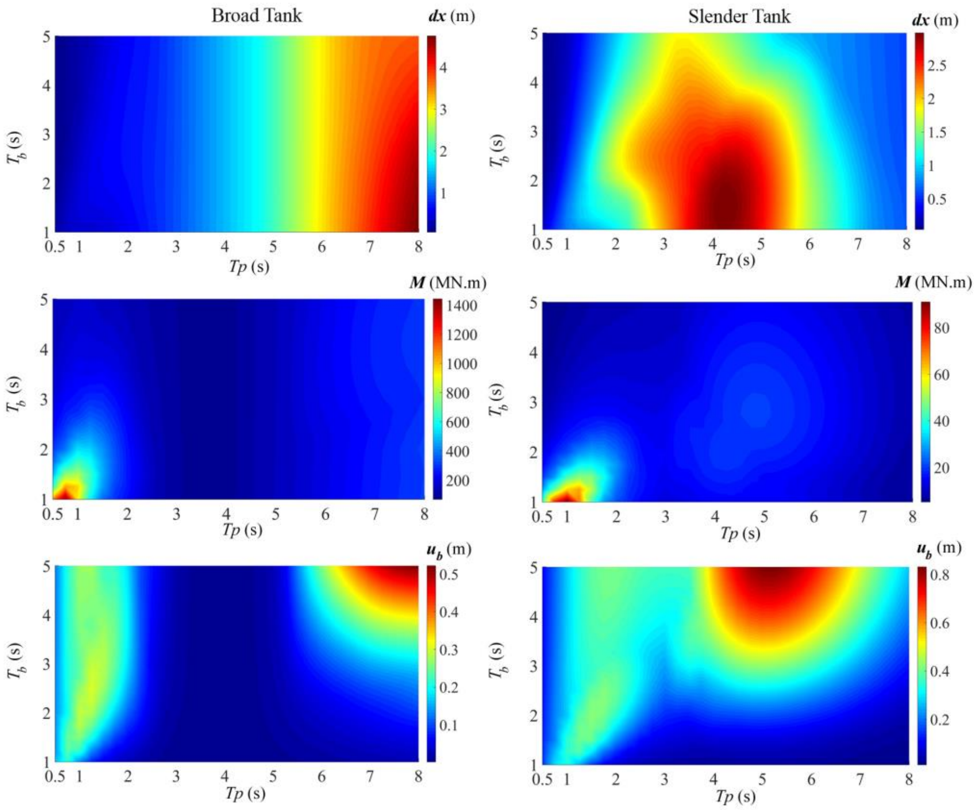

Fig. 1. Variation of selected response parameters with isolation period and input pulse period

4. References

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