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PREDICTING STRAIN DEMAND HISTORIES IMPOSED ON BOX-SHAPED UNDERGROUND STRUCTURES IN SEISMIC EVENTS

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Conventional methods for seismic analysis of underground structures, namely, equivalent static analysis, close formed solutions, and investigation under statically imposed deformation cannot reflect the deference of seismic behaviors under various excitation frequencies. On the other hand, although the time history analysis provides more accurate results in the study of seismic response of soil-structure systems in the time domain, because of its significant required analysis time, its application is usually restricted to specific cases. Hence, no comprehensive study for determining the behavior of the underground structures in the time domain, even in the linear range, has been accomplished yet. Amorosi et al. (2014) showed that in spite of a good agreement between ground responses in experimental and numerical models, there were undeniable differences between observations in centrifuge test and predicted results using traditional seismic analysis for transient loadings acting on the lining. Besides, Tsinidis (2017) carried out a parametric study on several tunnel sections, which led to results, focusing on maximum racking distortion at specific time steps. That study marked the point that the conclusions are dependent on the frequency content of the record in addition to its intensity. Fattahi (2017) in a frequency domain study, drove transfer functions that could turn every input record to lining internal strain demands directly. Based on this recent research, the current article reviews the possibilities of developing approximate equations to predict such transfer functions. This latter achievement would enable every user to estimate seismic strain histories in linings just knowing the input record and several dimensionless parameters of the system. It is important that in this stream, the user does not need to be engaged in sophisticated modelings of the target soil-structure system.

To provide those approximate and meanwhile, enough accurate equations, a set of probabilistic optimization analysis in MATLAB platform, is conducted here. The study is carried out using an ensemble of 43 ground motions, and it is tried to guaranty the accuracy of proposed equations for all selected ground motions. The domain was considered as a homogeneous, isotropic, and linear 2D medium. Several nondimensional parameters like aspect ratio, flexibility ratio along with different wavefield incident angles are considered here. The optimization method used in this study has initially been introduced by Guader and Iwan (2006) and was later applied to soil-structure interaction systems by Esmaeilzadeh et al. (2017). The outcomes show the successful derivation of approximate target equations, which could predict the strain demand histories nearly exact. Here, a sample comparison between the accurate time history response obtained by a numerical method with the approximate solution is depicted in Figure 1.

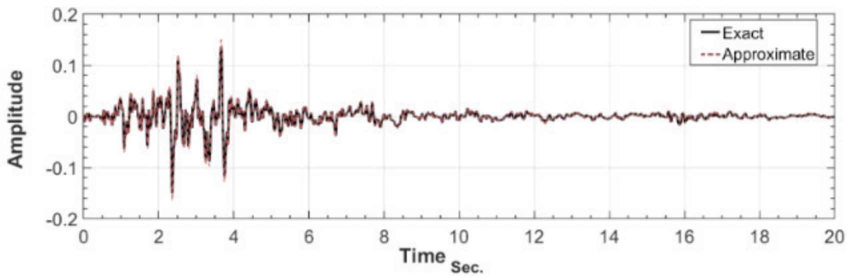

Figure 1. Comparison between the strain history achieved by the probabilistic algorithm and the one computed by the numerical model.

The error measure has been defined in such a way that distinguishes between conservative and nonconservative predictions. For any given soil-structure system and base excitation, the contour values of error over the two-dimensional parameter space can be drawn, as shown in Figure 2. Vertical and horizontal axes in this figure show the variable corner points, in terms of excitation frequency, that each pair of them can introduce a specific target equation. The best pair is the one which brings about a minimum error about benchmark results.

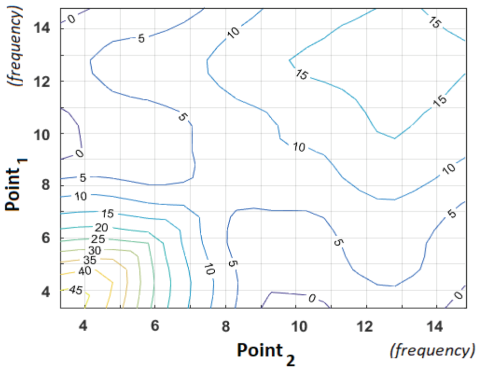

Figure 2. Schematic contour values of error for a given soil-structure system over two-dimensional parameter space under a single ground motion. The contour values are shown in percentage.

The results are reported for each of the tops, down and side edge elements of the structure, including various structural aspect ratios and flexibility ratios. Based on these recent compact results, approximate equations are presented which guide to upper bound levels of dynamic strain demands in a linear analysis.

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