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# SOIL STRUCTURE INTERACTION EFFECTS ON THE NONLINEAR RESPONSE OF STRUCTURES BASED ON THE DAMAGE SPECTRA

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In spite of extensive studies since 1970 on Soil Structure Interaction (SSI), there is still controversy regarding the seismic performance of the structures rested on soft soil. SSI is known as a phenomenon influencing beneficial and sometimes detrimental effects on the response of structures. To have a better judgment on the structural performance, a comprehensive criterion with the ability of predicting the level of damage in the structure under design earthquake should be developed. Damage Index (DI) was then introduced in response to this need and a number of models were defined by different researchers.

It is expected that the structure experiences different values of damage when the effect of the soil is taken into account. In this research damage spectra on the basis of Park and Ang damage Index for the SDOF models are provided by considering and neglecting the SSI effects.

The bilinear SDOF models are supported by Beam on Nonlinear Winkler Foundation. Two non-dimensional parameters are used to control the modeling. (I) non-dimensional frequency $a_0$ which is a statement of the structure-to-soil stiffness ratio (II) the aspect ratio of the structure h/r. The system is subjected to Mexico City (SCT) earthquake ground motion. A parametric study is conducted for structures having a wide range of fixed-base period. For each period, first the yield strength demand of the structure is calculated by iteration in order to reach the specified target ductility in the fixed-base model within 1% of accuracy when subjected to the Mexico City ground motion. The nonlinear dynamic analysis have been performed using opensees software. The dissipated hysteretic energy in the structure is also calculated accordingly. Then, the ductility and the hysteretic energy demands are calculated for the soil–structure systems under different values of $a_0$ and h/r subjected to the same ground motion providing the same yield strength for the structure. Consequently, the damage index is calculated for the structure in the fixed-base state as well as for the structure when located on soil. In order to calculate the damage index a program has been written in Matlab software. The effect of SSI on damage index can then be studied by comparing the results for different cases. For this purpose, a family of soil–structure systems consisting of SDOF structures with fixed-base periods ranging from 0.1 to 4 s having two different values of aspect ratio (h/r = 2, and 4) and four values of nondimensional frequency (a0 = 0, 1, 2, and 3) are investigated for the input ground motion and each target ductility. It should be noted that cases with a0 = 0 are indeed related to the fixed-base state, whereas a0 = 2 and 3 are the representatives of cases with predominant SSI effect. The study is done for two values of target ductility in the fixed-base state (μfix = 3 and 6). The analyses are done directly in time domain using direct step-by-step integration method. The results are presented in the form of damage spectra for a wide range of key parameter variations.

Figure 1 displays the results for Mexico City ground motion. The graphs in the left and right of figure are presented for h/r values of 2 and 4 with the values of $a_0$ varying from 1 to 3 for each h/r. The horizontal axis displays the period of the fixed-base building.

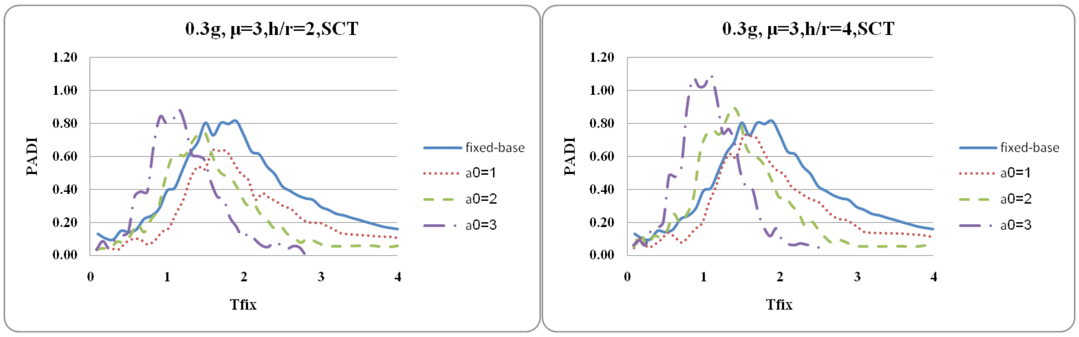


Figure 1. SSI effects on the nonlinear seismic response of structures based on damage spectra under the Mexico City earthquake for $\mu_{fix} = 3$, h/r = 2 (left) and h/r = 4 (right)

It is observed that for the systems with $a_0 = 2,3$ generally SSI increases the damage index before a threshold period which is closely related to the predominant period of the ground motion. It means that the conventional fixed-base model underestimates the damages sustained by buildings having periods less than this threshold period and It shows the detrimental effects of SSI on the response of structures. The results clearly show that the more flexible the base is, the greater will be the difference between the damage sustained by the fixed-base and flexible-base structures. But for the systems with $a_0 = 1$ the SSI leads to lower damage in structures. It shows the beneficial effects of SSI on the response of structures. In particular, the SSI substantially increases the damage index of short-period structures located on soft soils. However, the trend is reversed after the threshold period.

According to Figure 1 it is observed that the increase in the slenderness ratio leads to increase in the maximum damage. The spectra are also gradually shifted towards smaller periods.

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