KINEMATIC SOIL-STRUCTURE INTERACTION EFFECTS ON INELASTIC SYSTEMS WITH EMBEDDED FOUNDATION

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The soil-structure interaction can affect the elastic and inelastic seismic response of buildings. In other words, the fixed-base assumption is not always correct to determine the dynamic response of structures. The soil-foundation-structure interaction initially changes the input motion applied to the system, which is known as kinematic interaction (KI). Its second effect is the change in the dynamic properties of the soil-structure system (longer natural period and usually higher damping). The radiation of energy of the propagating waves away from the structure in the semi-infinite soil media, generally increase the soil-structure damping. This effect is called inertial interaction (II) (Wolf, 1985).

In this paper, the effects of kinematic and inertial interaction on ductility demand of SDOF structures with embedded foundation are assessed. The SSI effect is simulated by beam on Winkler foundation approach. A comprehensive parametric study is also carried out and the effects of various parameters including design ductility, fundamental period of vibration, level of soil flexibility, embedment ratio and aspect ratio on the ductility demands are evaluated.

The SDOF structure is characterized by its fundamental period T_{fix}, design ductility ratio of the fixed-base model μ_{fix} and damping ratio ξ_s. The effective mass and the effective height of the superstructure are denoted by m and h, respectively. The soil beneath the foundation is replaced by a set of spring-damper elements (Figure 1). The Qzsimple2 material is used in the OpenSees platform to define the nonlinear inelastic behavior of the base slab vertical springs (Raychowdhury, 2008). Figure 1 shows the horizontal springs and dashpots representing sidewall–soil stiffness, k_{side}, and damping, c_{side}, respectively.

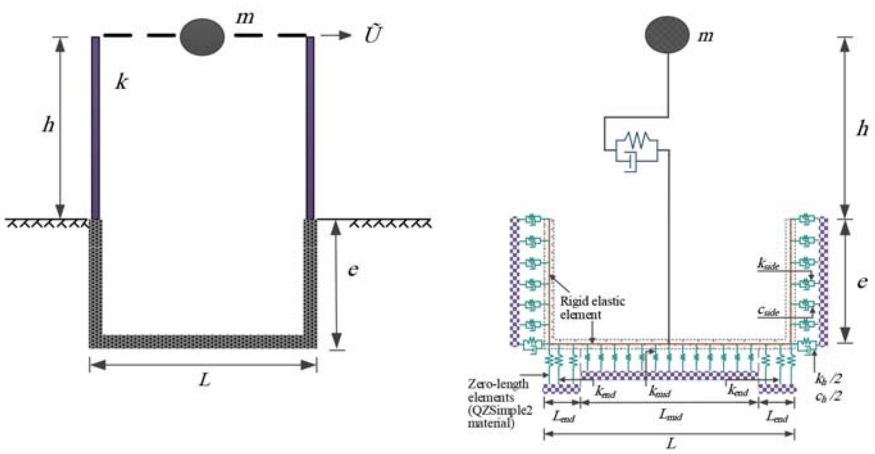

Figure 1. (a) The soil-structure system (b) Soil- SDOF structure model with embedded foundation.

The effects of kinematic and inertial interaction on the inelastic seismic demands have been examined by considering rotational component of foundation input motion. For this purpose, each of the soil-structure systems is analyzed with the inclusion of KI effects. The nonlinear dynamic analysis is conducted directly in the time domain using the open-source software OpenSees (Open System for Earthquake Engineering Simulation). Soil-structure systems are subjected to 33 ground motions recorded on site class D according to the NEHRP soil classification.

The effects of foundation embedment and soil-structure interaction on ductility demand of the soil–structure systems are explained in this study. The influence of the introduced key parameters is evaluated separately here. For example, the effect of embedment ratio λ_e on the ductility demand is shown in Figure 2. The results are mean values obtained from 33 ground motions. The results of the soil-structure system are given for systems with $\lambda_s = 3$, design ductility levels of 1 and 2, two values of dimensionless frequency ($a_0 = 1, 2$), three values of embedment ratio ($\lambda_e = 0.5, 1.0, 1.5$), as well as the model resting on the surface foundation. It can be concluded that the reduction of the ductility demand for the soil-structure systems is usually more noticeable for softer soil conditions. As seen, foundation embedment generally increases the ductility demand of the SDOF system. Ductility demands of structures having embedded foundation are greater than those with surface foundation. This observation is in agreement with the results presented by Mahsuli and Ghannad (2009).

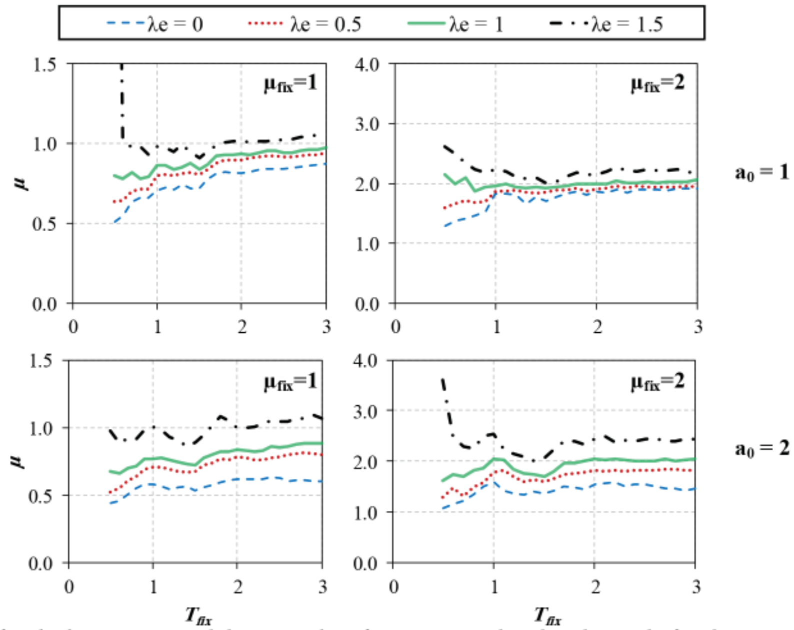

Figure 2. The effects of embedment ratio and dimensionless frequency on ductility demand of soil–structure systems with $\lambda_s = 3$.

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