EFFECT OF SOIL-STRUCTURE INTERACTION ON SEISMIC DEMANDS OF STRUCTURES IN DESIGN PROCEDURES

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In this research, both kinematic interaction (KI) and inertial interaction (II) effects of soil-structure interaction (SSI) on inelastic seismic demands of structures are investigated. Site effect is also considered only by applying ground motions recorded at site classes D and E (as defined in BSSC (2003) and FEMA-440 (2005)) that on them SSI effect is considerable. Carrying out a parametric study, the structure and underlying soil are modeled as a Single Degree Of Freedom (SDOF) structure with elasto-plastic behavior and a mathematical simplified 3DOF system, based on the concept of Cone Models (Wolf, 1994), respectively. Also the foundation is considered as a rigid cylinder embedded in the soil with different embedment ratios. Then the whole soil-structure systems are analyzed under 30 ground motion recorded at site classes D and E (as defined in BSSC (2003) and classified in FEMA-440 (2005), Appendix C). Then a comprehensive parametric study is performed for a wide range of following non-dimensional parameters defining SSI problem.

-A non-dimensional frequency as an index for the structure-to-soil stiffness ratio:

$$a_0 = \frac{\omega_{fix} h}{V_s} \tag{1}$$

Where ω_{fix} is the circular frequency of the fixed-base structure. This index can have values of up to 3 for conventional building-type structures resting on very loose soils; while infinitesimal values close to zero are representative of fixed-base structures (Ghannad (1998), Khoshnoudian and Behmanesh (2010)).

-Aspect ratio of the building h/r, an index for its slenderness ratio.

-Embedment ratio of the foundation defined as e/r.

-Ductility demand of the structure defined as:

$$\mu = \frac{u_m}{u_y} \tag{2}$$

Where, u_m and u_y are the maximum displacement caused by a specific base excitation and the yield displacement of the structural stiffness, respectively.

The effects of SSI on elastic and inelastic demands of structure are investigated. Comprehensive analyses are performed through statistical study. Results include both KI and II effects and are provided for models with four embedment ratio *e/r* = 0, 0.5, 1 and 2, three different aspect ratios, *h/r* = 1, 3 and 5 as the representatives of squat, medium and slender buildings and for three different values of non-dimensional frequency a_0=1 and 3 in comparison to the fixed-base structure (a_0 = 0). The effect of SSI on inelastic seismic demand are also investigated on structures undergoing two different ductility levels (μ

= 2, 4). The results for site classes D and E are indeed the average values for soil-structure systems subjected to 15 different strong motions recorded at those site classes, respectively. As an example of results, Figure 1 indicates effects of SSI on ductility demand of the structure located on site class D. Finally, by analyzing obtained graphs, the following conclusions are made:

1- SSI reduces the elastic and inelastic strength demand of structures. But when the structure undergoes more inelastic deformations (μ = 4), this effect becomes less important.

2- The SSI effect on SRF of structures located on soft soils (site-classes D and E) is particularly important. In this case, SSI reduces SRF, which in turn may result in larger design forces.

3- For structures with surface foundation (*e/r*=0), SSI increases the ductility demand of structure, as a part of soil-structure system, before a threshold period which is closely related to the predominant period of the ground motion. It is also observed that increasing the aspect ratio of the structure increases the SSI effect before the threshold period. But for embedded structures, the SSI effect is different. Though the embedment of structure generally reduces ductility demands of squat buildings with h/r=1, it results in higher demands for slender structures with *h/r*=3 and 5. The effect is intensified by increasing the embedment ratio, e/r and non-dimensional frequency, a_0.

4- Comparing the results with and without inclusion of KI effect reveals that the rocking input motion due to KI plays the main role in this phenomenon, because the rocking component produces larger acceleration input on the mass of super-structure and leads to more severe structural response.

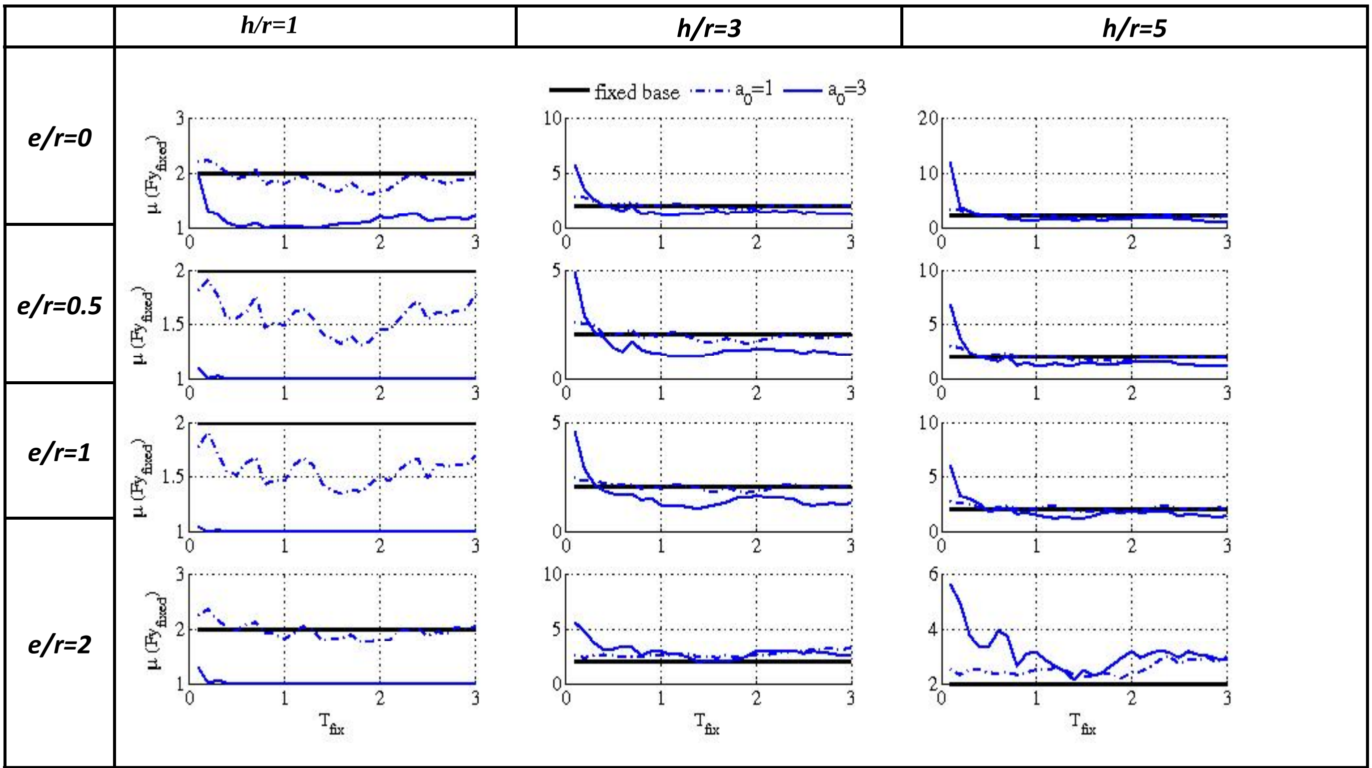

Figure 1. Averaged ductility demand of soil-structure systems located on site-class D. ($\mu_{fixed\text{-}base}$=2)

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