EVALUATION OF SOIL-STRUCTURE INTERACTION EFFECTS USING SEISMIC CODES

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Seismic codes nowadays include design requirements in order to taking soil-structure interaction (SSI) into account for realistic modelling and dynamic response analysis of structures against earthquake. These codes describe how to estimate kinematic interaction effects, flexibility to the soil-foundation system and damping ratio of soil-structure system for a nonlinear static and dynamic analysis. We are going to assess the behaviour of steel structures including the effects of SSI. In this assessment, the Iranian seismic code of practice (Standard No. 2800) and Federal Emergency Management Agency (FEMA) have been used. Steel frame buildings are assumed to have three, six, and twelve-story. Moreover, each building has two different resistant systems; moment resistant frame (MRF) and braced frame (BrF). The buildings are supported by soil type II and IV according to the classification of 2800 code. The strong ground motions are selected and scaled according to 2800 code as well.

Seismic analyses are conducted for all buildings with fixed-base and also flexible-base conditions using nonlinear static and dynamic procedures. Both kinematic and inertial interaction effects are considered. The foundation input motion has been determined by incorporating kinematic interaction effect and foundation damping ratio defined in (FEMA-440, 2005). The calculated kinematic interaction effect was compared with the results from an approximate analytical transfer function that developed for a finite soil layer (Elsabee and Morray, 1977). It is concluded that the overall agreement between both methods is quite satisfying. However, FEMA-440 underestimates the kinematic interaction effect in high frequency portion of the selected earthquake records.

The present study focus on the effects of foundation flexibility on the structural response in terms of base shear, story displacement and drift demand. The OpenSees finite element framework was employed for simulation (OpenSees, 2013). For this purpose, an equivalent spring-dashpot method on the basis of nonlinear Winkler beam concept proposed by Raychowdhury (2011) is adopted. The results are compared with those from fixed-base and design codes provisions. Figure 1 illustrates the period ratio of flexible to fixed-base for the representative three-story buildings. As shown in the figure, period lengthening occurs in all building cases due to the incorporation of soil-foundation flexibility, especially when they are located on soil type IV. Also, the period elongations of BrF structures are sufficiently greater than the MRFs. In comparison, the simulated results are in agreement with those obtained from the design codes, except from BrF structure on soil type IV where the regulations underestimate the period lengthening.

In addition, numerical results show that when SSI is considered, the base shear and inter-story drift demand reduces; indicating a beneficial effect of the foundation flexibility. However, the story displacement demand is observed to increase with SSI. It is noted that for the chosen structure and soil type, the results may differ from each other and the most significant effects are related to BrF structures on soil type IV (see for instance Figure 2). Thus, modelling the SSI effects shows that it may play an important role in altering the force and displacement demand, indicating the necessity for consideration of foundation flexibility behaviour in the seismic structural design. The study still needs to be verified for additional structures with a wide range of natural periods, different soil conditions and earthquake records before the findings could be generalized and used for design recommendations. The discussion will appear in future publications.

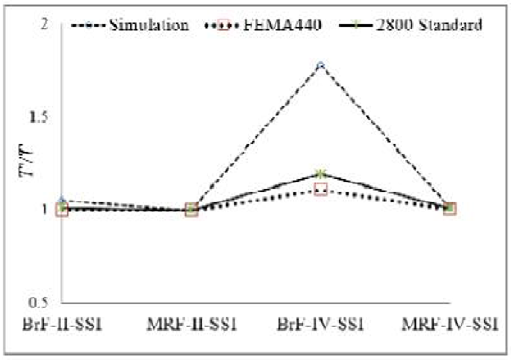

Figure 1. Period lengthening for three-story MRF and BrF buildings located on soil types II and IV

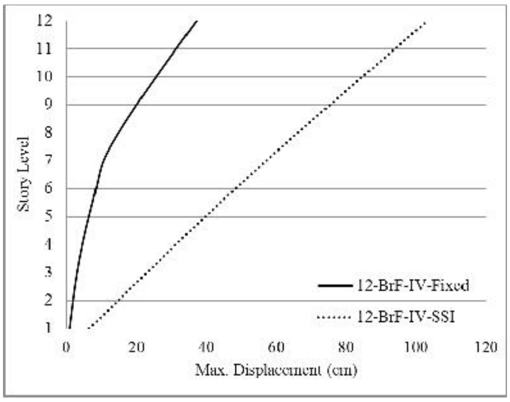

Figure 2. Average peak story displacements of twelve-story BrF building on soil type IV subjected to four assumed earthquake records with and w/o SSI effect

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