Empirical Transfer Functions for Kinematic Effects of Soil-Structure Interaction in Nuclear Power Plant Structures

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Recorded earthquake motions at free-field ground accelerometers and adjacent instrumented structures can provide insight into the extent of Soil-Structure Interaction (SSI) phenomenon and evaluate the collective response of the soil-foundation-structure system. Kinematic SSI effects result from the presence of stiff foundation elements on or in the ground, which cause motions at the foundation level to deviate from the free-field motions, mainly due to (1) base slab averaging, and (2) embedment effects. It has become increasingly common in recent years for structural engineers to take advantage of kinematic interaction effects to reduce foundation-level motions relative to those specified in the free-field.

Based on ASCE/SEI 41-17 and ASCE/SEI 7-16, kinematic interaction effects shall be permitted to be calculated for regular structures through either explicit modeling of the soil-foundation-structure system using advanced simulation software packages, which can account for spatial and depth variations in ground motions but relatively expensive, or simplified models which are mainly semi-empirical. The simplified models in these ASCE codes have been calibrated only for regular buildings with a limited width and embedment depth. As a result, its applications to the structures with much larger foundation footprint and deeper embedment depth, such as nuclear power plants, should be revisited. In this study, a dataset of recorded earthquake motions at the Kashiwazaki-Kariwa Nuclear Power Plant (KKNPP) during the 2007 Niigata-Chuetsu Earthquake was used to calculate the ratio of response spectra (RRS) between foundation motions and the corresponding free-field motions and compare with the recommended RRS based on ASCE/SEI 41-17. For this purpose, at first, earthquake data comprising pairs of foundation and free-field motions were processed and their corresponding RRS were calculated. Comparison is performed between the empirical and recommended RRS based on ASCE/SEI 41-17 followed by discussions on its applicability to the NPP structures which are unique in terms of dimensions (width and embedment depth) as well as dynamic characteristics (e.g. high fundamental frequency).