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Evaluation of Empirical and Simplified Methods for Estimating Kinematic Soil-Structure Interaction in Nuclear Facilities

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Conventional simplified and code-based approaches in design guidelines for estimating kinematic effects of soil-structure interaction (SSI) are focused on horizontal translational motions for shallowly embedded foundations with limited size ranges, making them potentially inadequate for vertical translational motions and larger, deeply embedded foundations. This study aims to improve our understanding of kinematic SSI effects, particularly for buildings with larger footprints like nuclear power plants. By analyzing residuals between empirical data recorded at five instrumented nuclear sites in Japan and the simplified code-based kinematic SSI methods, we suggest modifications to extend the current procedures to a broader range of translational motions and building configurations.

This study utilizes ground and foundation motion recordings to calculate the ratio of Fourier amplitude spectra (transfer functions). It compares empirical and simplified estimates of transfer functions, and residuals are used to develop regression equations. The analysis reveals that kinematic SSI can significantly reduce foundation motion spectral amplitudes relative to free-field ground motions, especially at higher frequencies. The results are used to propose regressed equations to reliably assess foundation motions for nuclear structures.

In addition, a simplified procedure is proposed for vertical translational motions, offering practicing engineers a new method for future development and use. Overall, the enhanced equations derived from this study offer a more accurate method for estimating kinematic SSI effects, ensuring a more reliable foundation motion prediction for buildings with extensive and deeply embedded foundations.

Furthermore, this study incorporates a series of 1-g shake table experiments as a complementary step. The experimental setup was designed to explore the kinematic SSI effects on foundations with different sizes and embedment depths. Using the Lutong experimental site in Taiwan as a prototype, the experiments aimed to simulate seismic behavior in a controlled laboratory setting. The study features foundation models subjected to 84 motion sequences in both horizontal and vertical directions, including sinusoidal waves and scaled real seismic events. Detailed results from this experimental study will be presented in forthcoming publications by the authors.