Base-isolated reactor buildings: Is soil-structure-interaction analysis needed?

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Abstract

Soil-structure-interaction (SSI) analysis is mandated for the design of nuclear facilities in the United States, unless they are founded on very hard rock. The current rules and guidance for SSI analysis assume that reactor buildings are both massive and stiff, which are the two key ingredients for significant SSI on soil sites. Seismic isolation, which is being considered as an integral design feature in some advanced reactor designs, can mitigate the impact of the seismic load case by adding 2D or 3D flexibility at the base of a reactor building, removing a key component for significant SSI. This leads to a hypothesis that SSI effects may be negligible for seismically isolated reactor buildings. To identify whether the effects of SSI are significant for base-isolated nuclear structures, response-history analysis was performed for a total of 945 combinations of 1) three fundamentally different reactor buildings, 2) five isolation systems, three linear (L1, L2A, L2B) and two bilinear (B2, B3), 3) three ground motions, collectively covering a broad range of frequencies, 4) three intensities of shaking for each ground motion, associated with low, moderate, and high seismic hazard, covering sites across the U.S., and 5) seven generic soil columns from the Design Certification Documents that enabled the KEPCO APR1400 to be certified for use by the USNRC under the 10CFR Part 52 licensing framework.

To investigate the influence of SSI on seismically isolated advanced reactor buildings, response-history analysis was performed for three cases of Figure 1: 1) analysis of the coupled soil-structure systems to include the effects of SSI, if any, 2) site-response analysis (SRA) using the same soil domains and seismic inputs from Case 1 to determine surface free-field motions, capturing the amplification or de-amplification of ground motions from the base of a soil profile to the ground surface in the absence of a structure, and 3) analysis of the seismically isolated reactor buildings using the surface free-field motions from Case 2, without the supporting soil domains, that is, not considering SSI. Analysis results showed that SSI effects were inconsequential for the in-structure acceleration response across different monitoring locations in the three reactor buildings and the force-displacement behavior of their isolation systems. Figure 2 presents a summary of the results: Ratio of Case 3 to Case 1 peak isolation system displacements and in-structure horizontal accelerations. Data are organized by isolator type; values averaged across all five isolation systems are presented in the last row (i.e., Avg). The mean of the ratios and the corresponding COV are presented in parentheses. It is clear that the peak isolation-system displacements and peak horizontal in-structure accelerations are essentially identical in Case 3 and Case 1. The key conclusion is that surface-free-field representation of ground shaking can be used for the design of surface- and near-surface-supported base-isolated advanced reactor buildings, without the need for SSI analysis. More information is presented in Lal *et al.* (2024).

The presentation at the 2024 DOE-NRC NPH workshop will introduce the analysis methodology, analysis matrix (reactor buildings, isolation systems, seismic inputs, and soil columns), and present the key results and conclusion of the study, including a recommendation proposed for seismic analysis of surface- and near-surface-mounted base-isolated nuclear facilities

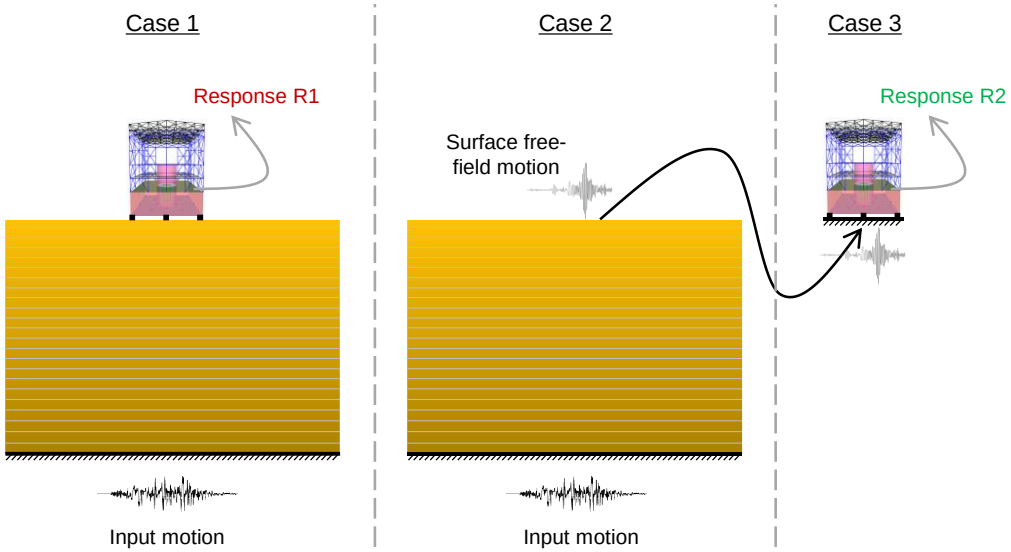
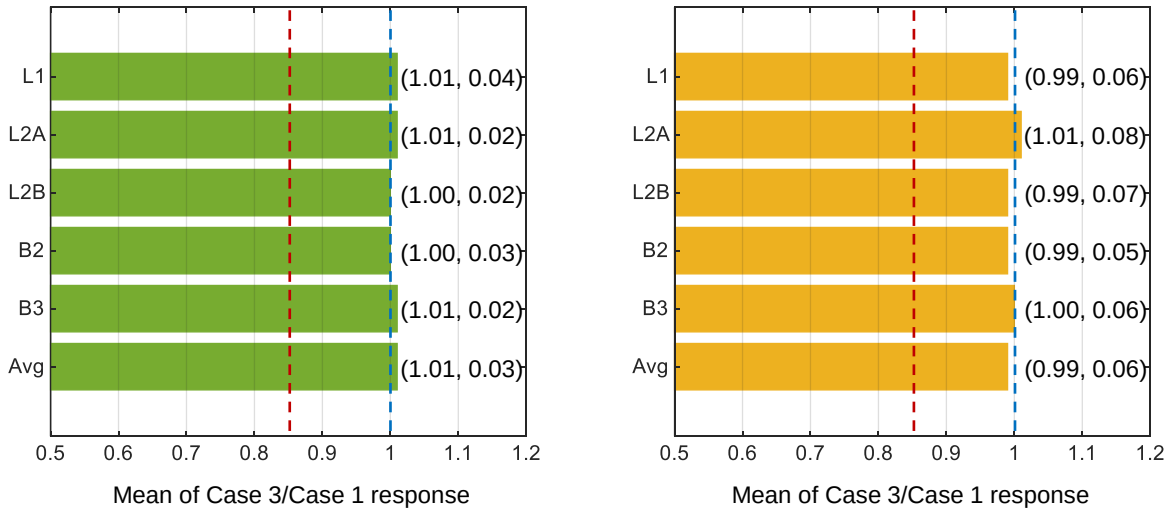


Figure 1. Response-history analysis cases to determine the influence of SSI on seismically isolated reactor buildings



a) isolation system displacements

b) in-structure horizontal accelerations

Figure 2. Ratio of peak responses for Case 3 to Case 1

Reference

Lal, K. M., Whittaker, A. S., Kosbab, B. D., Vahdani, S., Shirvan, K., and Parsi, S. S. (2024). "Considerations of soil-structure-interaction for seismically isolated nuclear reactor buildings." *Technical Report MCEER-24-0003*, University at Buffalo, State University of New York, Buffalo, NY.