Are We Ready to Couple Physics-Based Numerical Seismic Simulations with Local SSI Analysis in a Basin?

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Physics-based numerical seismic codes have been relevant for a few decades, but they gained traction when high-frequency large-scale simulations became achievable with the advent of High-Performance Computing (HPC). Geophysicists can now carry out simulations with maximum computable frequency up to 10 Hz that are of great interest to the engineering communities. There is still some struggle to represent the exact site conditions in the simulations due to (a) lack of comprehensive geotechnical in-situ data for a large area/domain, and (b) exponential increase in the HPC resources needed to compute high-frequency response from basin layers with very low shear wave velocity (Vs_{min}). Considering these limitations, soil-structure interaction analyses in a basin remain a challenge.

The objective of this research under the sub-domain approach was to apply ground motions from large-scale numerical simulations carried out in SW4, a fourth-order finite difference scheme to compute seismic wave propagation, to a local finite element model of a nuclear reactor building in LS-DYNA. The seismic event simulated is an aftershock from the 2007 Niigata Chuetsu-Oki earthquake and the ground motions recorded at Kashiwazaki Kariwa Nuclear Power Plant (KKNPP) in Japan are used to validate both the finite difference and finite element-based numerical simulations. Additionally, the free field motions from SW4 and LS-DYNA are juxtaposed against each other for an inter-code comparison.

Three subsurface models are created for simulations in SW4 and the ground motions extracted at the corresponding downhole level of the free field borehole are applied to the LS-DYNA model. The subsurface models are of increasing complexity in terms of a 3D geological structure and representation of the basin around KKNPP, which we know affect the duration and frequency content of the simulated ground motions. These input motions in turn affect the shaking response in LS-DYNA. The simulations discussed in this study have a maximum computable frequency of 3 Hz and 12 Hz which provide further insight into important considerations for high-frequency response under a coupled sub-domain approach.

As the scientific community is gearing toward the establishment of simulated ground motion databases, one must be mindful of their limitations in application toward structural shaking and SSI analyses. The key finding of this research is how a bad input motion can affect the simulations in a good finite element model.