Critical Modeling and Implementation Aspects for Seismic Incoherent SSI Analysis of Nuclear Structures with Surface and Embedded Foundations for Rock and Soil Sites

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The 1D seismic wave propagation assumption has been accepted in the nuclear engineering practice over the last few decades. Based on the 1D or vertically propagation assumption, the coherent motion at the ground surface is described by a "rigid body" motion in horizontal plane. In contrast to simplified representation of seismic wave field by coherent motion, the incoherent motion is a more accurate representation of the seismic wave field that realistically includes the 3D seismic wave propagation aspects. Incoherent motions represent realistic 3D wave motion simulations based on the stochastic models which are developed from real record databases.

The paper investigates the effects of motion incoherency (3D random wave propagation) on seismic responses of nuclear structures modeled by detailed FE models with elastic foundations and with and without embedment, founded on both rock and soil sites. A number of case studies are considered including nuclear complexes with different foundation sizes and baseslab thicknesses. We considered using both SASSI FE models and ANSYS FE models for the structural modeling. The ANSYS models were run directly for SSI analysis using the ACS SASSI Option AA (Advanced ANSYS integration capability). In addition, for some cases, the incoherent SSSI effects were also considered and compared with coherent SSI effects.

Firstly, basic theoretical aspects are reviewed. The roles played by the frequency-dependent coherency matrix (eigen) modes and their random phasing is discussed. Comparisons between different approaches, such as the stochastic simulation and the SRSS approach are presented for various cases. Comparative responses include acceleration in-structure response spectra (ISRS), relative displacements, and structural forces and moments. The Abrahamson coherency models are generally considered to be isotropic or radial models (as in EPRI studies), but herein we also considered also anisotropic or directional models for a large size nuclear complex.

The paper address motion incoherency effects for both the surface, shallow embedded and deeply embedded SSI models. For the deeply embedded models, the incoherent SSI analysis is performed using two assumptions: i) a single coherence function input for all embedment levels, and ii) different coherence functions at different levels..

The incoherency effects are also computed for seismic SSSI analysis. The incoherent SSI and SSSI analyses were performed using stochastic simulation with no phase-adjustment that is basically identical to the Monte Carlo simulation. The paper considers both rock and soil sites. It is shown that the motion incoherency could amplify significantly the SSSI effects for soil sites. The incoherent SSSI effects could impact significantly on ISRS, soil pressures and bending moments in foundation walls/mat.

The paper provides a number of useful insights and conclusions on important aspects related to incoherent modeling and effects that did not get sufficient attention in the past due to lack of advanced seismic SSI analysis engineering tools.