Scoping Analyses to Inform Seismic Risk Assessment: A Case Study Using Nonlinear Time Domain Simulations

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This presentation summarizes the methodology and insights from recent scoping analyses to inform the seismic risk assessment of a DOE facility, accounting for nonlinearities in the structure and underlying soil responses to earthquake shaking. DOE facilities use performance-based criteria to characterize seismic safety where the target performance goal is given in terms of seismic risk (i.e. annual probability of seismic-induced failure) as introduced in industry standards such as ASCE 43-05. Determination of seismic risk is performed using structure reliability calculations involving site-specific seismic hazard curves, compatible force and deformation demands on components and structures of interest, realistic capacity estimates of failure modes affecting functional performance, and the uncertainties associated with each of the hazard, demand, and capacity parameters. Simplifications and idealizations of hazard, demand, and capacity estimation are appropriate and commonplace for typical seismic risk calculations. Several such simplifications are considered permissible in industry standards and guidance documents. However, cases exist where common simplifications can lead to excessive bias, such that a more rigorous seismic risk computation is warranted. Scoping analyses are useful to ascertain the relative effect of such simplifications or idealizations, and alternative methodologies, for determining which phenomena are important to capture rigorously in the seismic risk assessment. In-depth scoping analyses for one such DOE facility is presented, where a series of sensitivity studies is performed for the estimated seismic risk using a simplified “proxy” computational model of the facility.

The seismic behavior, and thus seismic risk estimates, of the DOE facility studied here is known to be sensitive to assumptions regarding the nonlinear dynamic properties of the structure and underlying soil. Therefore, the scoping analyses presented here centers around addressing several topics: (1) What specific characteristics of the soil and structure behavior govern seismic risk? (2) How does uncertainty in soil and structure properties affect seismic risk estimates? (3) What ground motion levels dominate seismic risk? (4) How many probabilistic simulations are necessary to produce stable risk estimates given the different uncertainties?, and (5) What is the net effect of alternative seismic risk computation mathematical approaches and corresponding implementation details? An efficient series of sensitivity studies was organized to progressively and systematically answer these questions. The scoping analyses use a simple time-domain finite element model comprised of a nonlinear 1D soil column coupled with a SDOF mass-spring system having nonlinear backbone behavior analogous to inelastic shear wall behavior. The insights gained from this scoping study are being used to optimize the probabilistic analysis of the computationally intensive simulations needed for the detailed 3D finite element model employed in the seismic risk calculation of this facility. The case study demonstrates that it is feasible to use sensitivity studies using relatively simplified analysis models to economize complex seismic risk calculations that may otherwise appear intractable.