Country-wide Evaluation of Spent Fuel Storage Casks using a Phased Approach for Nonlinear Seismic Analysis

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Because spent nuclear fuel (SNF) will be stored at interim spent fuel storage facility installations (ISFSI) for an extended period of time, there is an unreviewed condition related to the behavior of the SNF within these dry storage systems during earthquakes. Thus, Sandia National Laboratory is leading a shake table test program to better quantify the potential damage an earthquake could inflict on spent nuclear fuel rods. Ground motions representative of the different seismic, tectonic and site conditions in United States have been developed for this test program. Given that the shake table testing will be limited to a single cask, soil-structure interaction (SSI) effects that capture the influence of the soil-concrete pad-multiple cask system are studied in order to generate realistic input motions for the single cask test program. A set of SSI analyses are performed with two main objectives: (1) generate realistic input motions for shake table testing, and (2) simulate the seismic cask behavior to inform the experimental program. A phased implementation is used for seismic simulations.

An ISFSI system consists of a relatively thin reinforced concrete pad founded on geomaterial with large, unanchored casks resting on the concrete pad. The global seismic behavior of the unanchored cask can be described simplistically as a rigid-plastic response dominated by the conditions of the contact surface between the cask and pad (i.e., the cask moves rigidly with the pad until cask sliding or tipping occurs at which time the contact stiffness significantly degrades). An analysis approach for these systems needs to consider the rigid-plastic nature of the seismic deformations. Thus, a phased equivalent linear / nonlinear approach is proposed.

Phase 1 is aimed at incorporating SSI effects into the representative ground motions to generate candidate input motions for cask shake table testing. Equivalent linear SSI analyses are performed considering the range of site conditions and a structural model representing the ISFSI: concrete pad and casks.

Phase 2 assesses the SSI input motions generated in Phase 1. The SSI motions generated in Phase 1 are used as input motions into a structural model that represent a concrete pad and a single cask. The interface between the cask and the pad is modeled with a nonlinear contact interface to explicitly simulate the potential sliding and/or uplift between the cask and pad.

Phase 3 generates SSI input motions for shake table testing for critical cases where the nonlinear interface meaningfully alters the concrete pad response below a given cask. Nonlinear SSI analysis for the selected critical cases identified in Phase 2 is envisioned for Phase 3.

This project is ongoing and this presentation focuses on the development and findings identified during Phase 1: the generation of representative inputs for a country-wide coverage area, significant results, as well as creation of a results database that allows initial seismic screening of ISFSIs in the United States.