Seismic isolation of nuclear reactor vessels considering soil-structure interaction

Samyog Shrestha

The influence of soil-structure interaction on seismic isolation of nuclear reactor vessels is investigated using numerical simulations. This research is motivated by the nuclear industry searching for viable solutions to repurpose coal plants with advanced nuclear reactors. Seismic isolation of reactor vessels is a potential solution as it enables deployment of standardized reactor vessels irrespective of site seismic hazard thereby saving time and cost by allowing large-scale factory fabrication of standard modules and by eliminating the need for repeated approval of reactor vessel design. Seismic isolation is also a technology that has matured from successful implementation in buildings and bridges allowing easier transition to nuclear applications. Currently, the implementation of component-level seismic isolation in nuclear industry is challenging due to gaps in research and lack of specific guidelines.

In this research, the effectiveness and potential limitations of using conventional friction pendulum bearings for component-level isolation are investigated based on conceptual numerical models of seismically isolated reactor vessels at different nuclear power plant sites subject to a variety of ground motions. The numerical modeling and analysis approach presented in this research are checked using experimental data and results from multiple numerical codes to ensure reliability of the obtained analysis results.

Within the scope of this study, it is found that slender vessels are particularly vulnerable to rotational acceleration at the isolation interface. Rotational acceleration at the isolation interface is caused by rotation at the foundation level of the containment building housing the isolated reactor vessel and by excitation of higher horizontal translational modes of the seismically isolated system. Rotation of the building foundation increases with decrease in shear wave velocity of the soil surrounding the building foundation. When the containment building is embedded below the soil surface, the effect of embedment on peak horizontal acceleration of the isolated vessel depends on the amount of increase in shear wave velocity at the foundation level of the building. When em-

bedment does not result in any change in shear wave velocity, it is found to have negligible impact on the acceleration response of the isolated vessel.

The optimum location to support a vessel for seismic isolation is found to be on a plane passing through its center of mass. It minimizes horizontal acceleration in the isolated vessel as well as the tendency of isolator to uplift. Isolator uplift and exceedence of displacement capacity of the isolator during extreme events are possible drawbacks in using seismic isolation technology since they produce impact forces due to collision between the isolated system and the moat wall or due to uplift and re-engagement of the isolator. If such cases are avoided, seismic isolation of reactor vessel could provide more than 50% reduction in peak acceleration of vessel except for low-intensity motions that do not engage the isolator.