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Effects of Soil-Structure Interaction on Seismically Isolated Nuclear Power Plant

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Introduction

Seismic isolation has been used effectively in a number of critical applications to protect important civil infrastructure structures and systems from risks posed by earthquakes. Seismically isolated structures have performed as expected in major earthquakes in Japan, the US and elsewhere worldwide. Thus, it is prudent to consider more fully the potential benefits and limitations to be anticipated in applying seismic isolation to nuclear power plants (NPPs) and related facilities.

Because the effectiveness of an isolator system depends on the lateral flexibility of the isolation plane, it is likely that isolators will need to be designed considering the flexibility of the supporting soil. The possible complex interaction of the flexible soil, flexible isolators (in the horizontal direction) and stiff structure, needs careful study. It is possible that the effectiveness of the isolators is reduced, or perhaps the response is amplified by the interaction of the soil and isolated structure system. Isolation is not effective in the vertical direction, so response of the plant in the vertical direction will heavily depend on soil-structure interaction (SSI) effects. Some isolation systems (elastomeric) have frequencies in the vertical direction in the frequency range of interest to structural elements and components.

There is a Korean National Research Project which develops base isolation system for NPP. Simplified models developed for this project will be used to demonstrate and understand basic relations between site conditions, SSI and the response of the seismic isolation system and the NPP.

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While several studies of the effect of soil structure interaction have been carried out for seismically isolated bridges, few papers have been published related to building structures

(Spyrakos et al, 2009; Song et al, 2009; Gavin et al, 2012). It was shown that this topic is in its infancy and that additional research and development is needed.

There are three analysis procedures provided in draft NRC (Nuclear Regulatory Commission) NUREG guide for seismically isolated NPPs. Each procedure involves SSI analysis. The three analysis procedures are: 1) coupled frequency domain, 2) coupled time domain, and 3) multi-step. The multi-step method involves two analyses: propagation of ground motion into a soil-structure model for the purpose of generating a Seismic Isolation Design Response Spectrum (SIDRS) at the level of the foundation, and nonlinear time domain analysis of a model of the isolated superstructure using multi-component acceleration time series consistent with the SIDRS. Although comparison of these approaches is not the objective of this paper, simplified models analyzed using these approaches are used to 1) Determine if SSI reduces the effectiveness of isolation or if it makes the response worse; 2) Study effect of extended design basis events. As the intensity of ground motion shaking increases, the degree of soil nonlinearity and of nonlinear SSI interaction effects are expected to increase substantially. Thus, careful attention and assessment will be made of the behavior of the isolated system as the soil becomes more flexible due to these nonlinear effects.

Conclusions

The present work investigates the effects of SSI on seismically isolated NPP. Simplified models were used to demonstrate and understand basic relations between site conditions, SSI and the response of the seismic isolation system and the NPP.

References

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