Periodic Material-Based Seismic Base Isolators for Small Modular Reactors

PI: Yi-Lung Mo: University of Houston
Program: Nuclear Energy Enabling Technologies Crosscutting Technology Development, Advanced methods for Manufacturing (NEET-1)

Collaborators:
Yu Tang: Argonne National Laboratory
Ken Barry: Electrical Power Research Institute
K.C. Chang: National Center for Research on Earthquake Engineering, Taiwan

ABSTRACT:

Seismic isolation systems currently under development employ high-damping rubber bearings, lead rubber bearings, or friction pendulum bearings. These systems are effective in reducing the damaging effects of the horizontal components of an earthquake, but they are not well suited for protection against the vertical components of seismic loads. Current seismic isolation systems also cause large relative horizontal displacement between the foundation and the supported structure, which occurs during a seismic event, further complicating the design. A gap, sometimes called a moat, is usually provided between the isolated structure and the surrounding non-isolated structures to avoid hammering. The need for a moat, however, requires very careful design detail to avoid any rigid connection between the isolated and non-isolated portions of the plant throughout its lifetime. A design that eliminates the need for such design restrictions would be very attractive.

This study will attempt to overcome the disadvantages existing in current seismic isolation systems by developing innovative three-dimensional (3D) seismic base isolators. These 3D seismic base isolators, in effect, use the foundation of the nuclear island as the base isolation system. The foundation is made of a new material, called periodic material, which can block, or reflect, the damaging seismic motion being transmitted to the superstructure. Both analytical and experimental studies will be performed to demonstrate the feasibility and effectiveness of the proposed 3D seismic base isolators. Guided by solid state physics, the 3D seismic base isolators can be made by the periodic material to exhibit special characteristics that are useful in resisting the loads imposed on structures from earthquakes. Possessing distinct frequency band gaps, this periodic material will block, or reflect, the incoming seismic motion with the frequencies falling between these gaps. The frequency band gaps in the x, y, and z directions can be controlled by their design and manufacture, exactly what is needed for 3D seismic base isolators. One can properly design the frequency band gaps to match the fundamental frequency of the nuclear island so that its dynamic response will not be amplified; alternatively, one can design the frequency band gaps to match the strong energy frequency components of the design earthquake. 3D seismic base isolators have been proposed for Small Module Reactors (SMR) to mitigate the potential damage caused by the earthquake and to increase the safety margin of the nuclear power plants. Also, 3D seismic base isolators can enhance the design of standard plants, which can be licensed and built at lower costs.

A diverse team will lead this study, with participants from the University of Houston, Argonne National Laboratory, Electrical Power Research Institute, and the National Center for Research on Earthquake Engineering (NCREE), Taiwan. The analytical work and experimental program will be the joint responsibility of the participating institutions. The proposed 3D seismic base isolators for the SMR will be tested at the NCREE using the shake table. The test results will be used to verify the design theory and design procedures of 3D seismic base isolators suitable for nuclear power plants.