Seismic Performance of Dry Casks Storage for Long-Term Exposure

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ABSTRACT

This research will evaluate the mechanical performance of dry-cask storage (DCS) under seismic loading for mid-term operational periods. The spent fuel at nuclear power plants (NPPs) is initially stored in pools to control fuel-assemblies temperature. Thereafter, the spent fuel is transferred to DCSs at sites contiguous to the plant, known as Interim Spent Fuel Storage Installations (ISFSIs). DCSs are usually designed as free-standing structures resting on a reinforced concrete foundation pad, or casks anchored to a foundation pad. The casks can also be designed to be placed in concrete bunkers in horizontal or vertical position.

Numerical seismic analyses of ISFSIs are usually performed assuming a compliance periods of 20 years. The consideration of DCSs for storing spent fuel for hundreds of years has created new challenges that have only recently started to be addressed. In the case of seismic hazard, longer-term operating periods result in i) very large horizontal accelerations, ii) destabilizing effects of vertical accelerations, and iii) aging material deterioration. The first two factors affect the overall seismic performance of DCSs, whereas material degradation reduces the capacity of the casks. Large earthquakes can lead to casks tipping over, impacting the concrete pad or adjacent casks. The casks may also slide and collide with other casks or structural components. The mechanical stresses and strains caused by these impacts are important even if the overpack does not breach. The DCSs performance should ensure fuel-rod integrity and canister integrity because eventually the spent fuel-rods need to be shipped either to a reprocessing plant or a repository.

Experimental and numerical tests will be performed to evaluate the long-term seismic performance of DCSs. Numerical analyses using finite element programs with explicit time integration will be performed for freestanding, anchored, and vaulted casks considering several cask-pad-soil systems. Coupled effects of mechanical stresses caused by seismic events, and aging material degradation will be included in the simulations. The experimental tests will evaluate the dynamic seismic response of freestanding and anchored DCS prototypes on a six Degree-of-Freedom (DOF) Shaking Table. This will be the first time that an experimental seismic simulation of DCSs will include seismic accelerations in three orthogonal directions. The study will estimate the seismic accelerations that lead to tip over, the parameters that most contribute to DCSs damage, provide recommendations for optimal ISFSI designs for freestanding and anchored DCSs.