Coupled Multiphysics Simulations of Seismic Response of Degraded Concrete Structures

Kyungtae Kim[1], Benjamin Spencer[1], Chandrakanth Bolisetti[1]

[1]Idaho National Laboratory, Idaho Falls, Idaho 83415

Abstract:

Alkali-silica reaction (ASR) is a common degradation mechanism in aging concrete structures and results in loss of strength and stiffness in concrete. This degradation consequently increases the vulnerability to failure under earthquake excitation. A pioneering effort is made to create a unified capability to analyze both ASR-induced concrete degradation and large-scale seismic analyses, by combining two existing open-source software developed at Idaho National Laboratory, BlackBear (for a concrete degradation analysis) and MASTODON (Multi-hazard Analysis for STOchastic time DOmaiN phenomena). To verify and validate this fully coupled simulation framework, a gravity concrete dam structure is benchmarked in a two-dimensional plane strain condition. The resulting ASR extent and stress fields in the structure are in good agreement with the benchmark model. Upon benchmarking, the structure model is expanded to evaluate the effects of the ASR-induced degradation after 10 years while including soil-structure interaction. Two input seismic conditions are simulated: 1) Ormsby wavelet with an amplitude of 0.1g is subjected at the base of soil domain to identify dynamic characteristics of the structure affected by ASR-induced degradation and 2) site-specific seismic wave-field is generated from a source-to-site wave propagation model from an 3 km long earthquake fault rupture scenario and input to the soil-structure model. In the scope of this study, the long-term effects of the ASR-induced material degradation slightly changed the dynamic behavior of the dam. Further demonstrations and validation efforts are warranted to understand longer-term effects of ASR, such as over a span of 50 years, which is a more representative scenario for critical infrastructure with ASR damage. Although the demonstrations of this study involve dams, the combined code can be used for any concrete structures including nuclear power plants and safety-critical nuclear facilities, which are also designed for long life spans and are therefore vulnerable to ASR-related degradation.