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Research Motivation

Dam owners and regulators are moving toward risk, but face challenges in quantifying the seismic risk of dams in an efficient manner. The current practice of estimating seismic risk for dams ranges from relatively simple qualitative screening approaches to highly quantitative dynamic analyses that are costly they are generally only performed on the highest profile dams where a retrofit is expected. Whether a qualitative or quantitative approach is used, epistemic uncertainties in the hazard and dam response are typically not accounted for and final risk numbers are often reported as mean risk without uncertainties.

The objective of this research is to develop a simplified method to calculate seismic risk for earthen dams that has all of the components of a quantitative seismic risk analysis, but can be run quickly.

• Efficient enough that a utility or regulator with a suite of dams could calculate and regularly update mean seismic risk with uncertainties for all of their dams using a consistent approach that provides a basis for comparisons
• Flexible enough that it can accommodate the complete description of the ground motion and be used in various tectonic environments and with future non-erodible ground motions
• Works for a broad range of intensities and extrapolates in a reasonable way

Building Transfer Function Model

If we know the transfer function of the potential sliding mass of the dam, we can feed in any ground motion and calculate a deformation using a Newmark sliding block analysis. We'll run a suite of ground motions through a series of representative dams using the 2D finite element equivalent-linear code Quad4MU and build the model by matching the transfer function from the Quad4MU results to the Fourier Amplitude Spectrum (FAS) from a Single Degree of Freedom (SDOF) oscillator subjected to an impulse motion.

Transfer Function Model

Calculate deformation from output/input

The model captures the shift in the first mode frequency of the dam. The peak of the transfer function increases.

Model Behavior

For each ground motion, the transfer function of each sliding mass is calculated from the Quad4MU output and the SDOF is matched to create the transfer function model. The results presented here are for a single representative dam with a height of 50 ft, a shear wave velocity profile ranging from 625 – 900 ft/s, and a deep failure surface.

The model captures the changing shape of the transfer function, which is narrow and peaked at low intensity levels and becomes broader and less peaked as the intensity of the ground motion increases.

Implementation

Incremental Dynamic Analysis (IDA) or Conditional Scenario Spectra (CSS) Approach

The transfer function model can be used to quickly compute deformations for a suite of selected time histories. The deformations can then be combined with the seismic hazard curves to develop deformation hazard curves, and the deformation hazard curves can be used with fragility curves to compute risk.

Direct Probabilistic Deformation Hazard Analysis

We are working on incorporating the deformation model into a probabilistic deformation hazard analysis, where the probability of exceeding a deformation is estimated for every earthquake scenario. This eliminates the need for time history selection. For this implementation we need a model for the FAS of the ground motion and a statistical model of the phase. We also need to use vibration theory to estimate the deformations.

Example Application

This example application uses a site-specific probabilistic seismic hazard analysis for a dam site and the SDOF model to estimate dam deformation. The three deformation hazard curves use the median dam response and the 5%, median, and 95% hazard. All combinations of the logic tree would produce 81 deformation hazard curves and can be combined with a logic tree on the fragility curves to calculate mean risk with uncertainty.