Treatment of Epistemic Uncertainty in Site Effects in Probabilistic Seismic Hazard Analyses

Student: Kristin Ulmer

Faculty Advisor: Russell A. Green (rugreen@vt.edu) and Adrian Rodriguez-Marek (adrianrm@vt.edu)

Sponsors: US Geological Survey, US Defense Nuclear Facilities Safety Board

Start/Completion Dates: May 2017 / August 2019

Project Background

Performing a Probabilistic Seismic Hazard Analysis (PSHA) typically necessitates the evaluation of site effects (i.e., the influence of a site's geologic profile on ground motions as they propagate up from a reference horizon at depth to the ground surface). In 2012, the Electric Power Research Institute (EPRI) published a report that includes a detailed approach for formally incorporating site effects in a PSHA for nuclear power plants, to include the treatment of aleatory variability and epistemic uncertainty. Per the EPRI approach, epistemic uncertainty characterizes the uncertainty in the geologic profile and dynamic properties of the strata (i.e., things that could be determined with certainty given an unlimited amount of time, effort, and budget). One guiding principle in estimating epistemic uncertainty is that the less you know, the larger the estimated uncertainty should be. Implied in this principle is that higher uncertainty will result in a higher computed seismic hazard. This is reflected in the EPRI approach in the development of the best estimate (or mean), lower range, and upper range base case small strain shear wave velocity (Vs) profiles for a site. The lower and upper range base case Vs profiles correspond to the 10^{th} and 90^{th} fractiles of the assumed distribution around the mean base case Vs profile. A larger logarithmic standard deviation is assigned to profiles inferenced form geotechnical/geologic information as opposed to profiles developed from data gathered from a detailed site investigation. A weighted average of the amplification curves associated with the three profiles is then used to predict the surface ground motions.

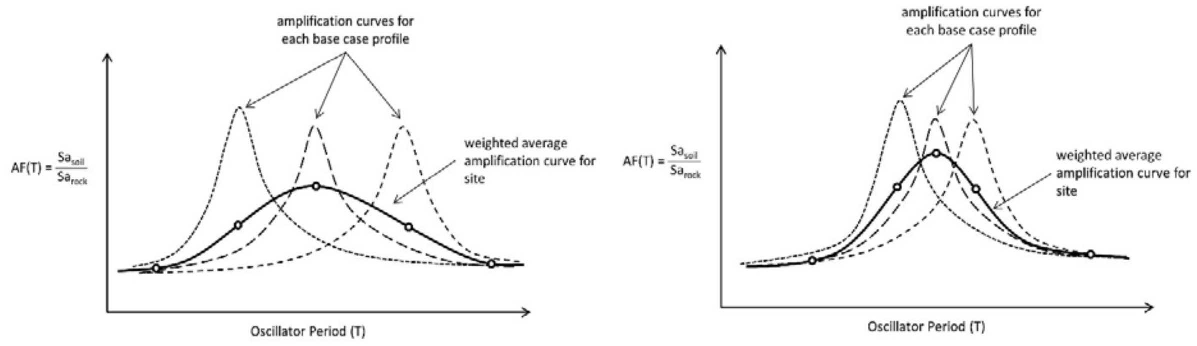
Figure 1 shows conceptual plots of the amplification curves for each base case profile (for a given mean annual frequency of exceedance) and the weighted average amplification curves for the two assumed values of epistemic uncertainty. In both instances, the bandwidth of the weighted average amplification curve is much wider and has amplitudes that are much lower than the individual base case profiles. Additionally, (a) has a larger bandwidth and lower amplitudes than (b). Thus, the results of the EPRI approach are counter to the guiding principle discussed above, which is clearly a shortcoming of the approach.

Goal and Objectives

The objective of this project is to develop an improved approach to account for epistemic uncertainty in site effects in PSHA. Specifically, the approach will adhere to the principle that the higher the epistemic uncertainty is the higher the computed seismic hazard will be.

Research Methodology

The proposed research will develop an improved approach for accounting for epistemic uncertainty in site effects in PSHA. This will be accomplished by conditioning the site amplification functions for the base case profiles on variables that have a significant influence in the site response (e.g., Figure 2). The conditioned amplification functions will then be used to compute hazard curve for surface of the soil profile. The developed approach will be demonstrated using an actual case study from the investigators' project files. The analyses and results will be presented in detail to allow this case study to be used as a model for others to follow. Also, the analyses will be repeated using the EPRI approach for treating epistemic uncertainty to allow an assessment of the significance of the identified shortcomings in current practice.



(a) (b)

Figure 1: Amplification curves for each base case profiles and weighted average amplification curve for: (a) large assumed epistemic uncertainty, and (b) small epistemic uncertainty.

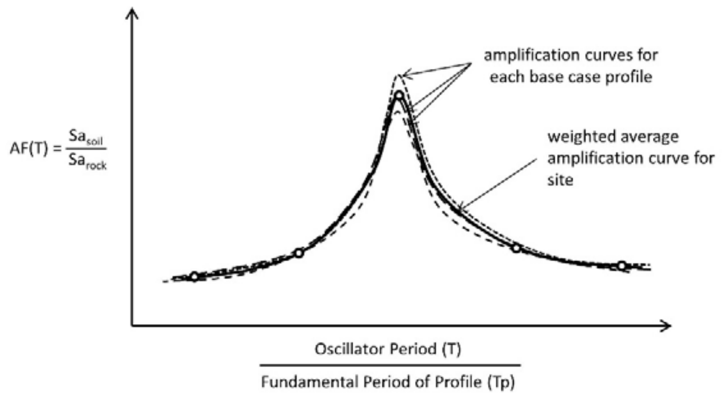


Figure 2: Amplification curves for each base case profiles expressed as a function of the ratio of oscillator period to fundamental period of the soil profiles.

Research Plan and Progress

The research plan tasks and status are listed below:

1. Select a case study from the Investigators' files to use for this project (*completed*).
2. Implement the EPRI approach for accounting for epistemic uncertainty using both estimated geologic profiles (i.e., inferred from geotechnical/geologic data) and using data from a detailed site characterization investigation. Use the results to illustrate the identified shortcoming in the EPRI approach (*completed*).
3. Re-compute the weighted average amplification functions from Step 2 by first conditioning the site amplification functions for the base case profiles on variables that have a significant influence in the site response. As a first attempt the amplification curves for the base case profiles are being conditioned on the fundamental period of the profile (e.g., Figure 2). (*completed*)
4. Develop a joint probability density function between amplitude of rock motions and fundamental period of the soil profile. (*completed*)
5. Compute the soil surface motions using the conditional amplification curves and joint probability density function. Compare the computed motions for the two levels of epistemic uncertainty.
6. Modify the conditioning scheme until the trends in the amplitude of the computed soil surface motions are commensurate with the epistemic uncertainty.