Modeling Nonlinear One-Dimensional Site Response at Six KiK-net Validation Sites

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ABSTRACT:

Vertical seismometer arrays represent a unique interaction between observed and predicted ground motions, and they are especially helpful for validating and comparing site response models. In this study, we perform comprehensive linear, equivalent-linear, and nonlinear site response analyses of 191 ground motions recorded at six validation sites in the Kiban-Kyoshin network (KiK-net) of vertical seismometer arrays in Japan. These sites, which span a range of geologic conditions, are selected because they meet the basic assumptions of one-dimensional (1D) wave propagation, and they are therefore ideal for validating and calibrating nonlinear site response models. Because we focus on sites that are well-modeled by 1D wave propagation, much of the misfit can be attributed to the nonlinear soil behavior model (and not other factors, such as three-dimensional effects; although the results suggest that these factors are still likely apparent to some degree). We use the equivalent-linear site response program SHAKE, the nonlinear site response program DEEPSOIL, and an overlay model within the general finite element program Abaqus/Explicit, which allows for a multilinear representation of any backbone stress-strain curve. The results from this broad range of ground motions allow us to quantify the prediction accuracies of the alternative site response models, measure the strain levels at which the models break down, and provide general recommendations for performing site response analyses. Across all sites, ground motions, and spectral periods, one of the most consistent findings is that the differences in accuracy are largest between the linear model and the other models, and that there are relatively small differences in accuracy between equivalent-linear and nonlinear site response models. However, nonlinear site response models are shown to exhibit a slight improvement over equivalent-linear site response models for shear strains greater than about 0.05%.