Adjustments to Small-Strain Damping and Soil Profile Assumptions to Improve Site Response Predictions

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Seismological Society of America (SSA) 2017 Annual Meeting
April 18-20, 2017 • Denver, Colorado
Abstract No. 17-232
Session: Closing the Gap between Laboratory-based Damping Models and Observed Attenuation of Seismic Waves in the Field

ABSTRACT:

Site response models have often been shown to be biased at high frequencies, where nonlinear soil behavior exerts its greatest influence on ground motions. Specifically, linear, equivalent-linear, and nonlinear site response models tend to underpredict high-frequency ground motions in the aggregate, and this bias persists for different types of constitutive models. We hypothesize that the reasons for this persistent bias are breakdowns in the one-dimensional (1D) site response assumptions and/or poorly characterized soil properties. Using 398 ground motions at 10 selected sites in Japan's Kiban-Kyoshin network (KiK-net), we test four physical hypotheses for this bias by performing a range of site response analyses in SHAKE and DEEPSOIL. Specifically, we (1) decrease the small-strain damping ratio, (2) increase the small-strain shear modulus, (3) apply a depth-dependent shear-wave velocity (V_S) gradient within layers, and (4) randomize the V_S profile. We find that the reduction of the small-strain damping ratio and the usage of a depth-dependent V_S gradient most greatly reduce the high-frequency bias; that the randomized V_S profiles sometimes improve predictions at the fundamental site frequency but often lead to greater issues at high frequencies; and that the adjustment of the small-strain shear modulus has a minimal effect. With regards to 1D site response model improvement, rather than solely focusing on the constitutive model type (e.g. equivalent-linear frequency domain vs. nonlinear time domain), this study suggests that greater attention should be paid to soil profiles and material parameters, as some of these physical adjustments are more successful at reducing model bias than changing the model type. The results of this study provide a framework for adjusting small-strain damping and soil profile input parameters to improve 1D site response model predictions.