Critical Parameters Affecting Bias and Variability in Site Response Analyses Using KiK-net Downhole Array Data

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ABSTRACT:

Due to the limited number of strong-motion records that have recorded ground response at large strains, any statistical analysis of seismic site response models is severely limited by the small number of observations. Recent earthquakes in Japan, including the recent M9.0 Tohoku earthquake, have substantially increased the observations of strong-motion records that can be used to compare alternative site response models at large strains. These observations subsequently provide new insights into the reliability and accuracy of site response models. Using the Kiban-Kyoshin network (KiK-net) downhole array data in Japan, we analyze the accuracy (both bias and variability) resulting from common site response modeling assumptions and identify key "problem characterization parameters" that contribute to the uncertainty in site response analyses. We apply the validation framework of Bradley (2011) to 100 KiK-net sites that have recorded 3720 large-amplitude ground motions using both linear and equivalent-linear site response methodologies. We find that the most helpful problem characterization parameters for site response are the maximum shear strain in the soil profile, and the observed peak ground acceleration at the ground surface. The strains at which linear analyses begin to break down (illustrating bias due to nonlinear soil behavior) is a function of period, and is between 0.01% and 0.1% for periods less than 0.5 s. Equivalent-linear analyses begin to break down at strains of approximately 0.15% over this range of periods. We find that, for the sites and ground motions considered, site response residuals at spectral periods greater than 0.5 s do not display noticeable effects of nonlinear soil behavior. The bias and standard deviations (sigmas) offered by linear and equivalent-linear site response models are similar, although equivalent-linear analyses exhibit a reduced bias at short periods (less than 0.1 s).