1D NONLINEAR SITE RESPONSE PREDICTION: ANALYSIS OF RESIDUALS AT A LARGE NUMBER OF KIK-NET VERTICAL SEISMOGRAPHS ARRAYS

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1. Introduction

- Engineering practitioners are faced with the challenge of selecting the appropriate level of model complexity for site response analyses (e.g., equivalent-linear vs. nonlinear).
- Many previous validation studies have attempted to quantify the levels of ground motion for which nonlinear site response analyses are necessary, but the assessment of fully nonlinear site response models is often limited to a relatively small number of sites and ground motions.
- In this study, one-dimensional (1D) total-stress nonlinear, equivalent linear, and linear site response predictions are calculated using an unprecedented number of sites and ground motions, allowing for more statistically significant conclusions to be drawn than in prior studies.
- This study builds upon Kaklamanos et al. (2013), which analyzed nonlinear and equivalent-linear site response models at a wide range of KIK-net sites, and Kaklamanos et al. (2015), which analyzed nonlinear site response at a subset of these sites.

2. Data and methods

- Nonlinear site response model predictions for 5626 ground motions at 114 vertical seismometer arrays of Japan's Kiban-Kyoshin network (KIK-net) are calculated using DEEPSOIL and are compared to observed ground motions and predictions from linear and equivalent-linear analyses in SHAKE.
- The intra-site residuals generally display similar behavior to the equivalent-linear residuals at large shear strains (at least 0.1–0.4%), but do not slope upward as significantly.
- The scatter in the nonlinear residuals is slightly less than that of the equivalent-linear residuals at large shear strains, suggesting that the nonlinear model is more precise than the equivalent-linear model at large shear strains.
- All models tend to underpredict Arias Intensity for small ground motions; for large ground motions, the trends in Arias Intensity are more consistent with the short-period PSA values.

3. Example site response predictions

- There are more significant differences among the model biases than among the model standard deviations.
- All 1D site response models (linear, equivalent-linear, and nonlinear) are biased towards underprediction of ground motions at short spectral periods, where nonlinear effects are strongest; however, the equivalent-linear and nonlinear model biases are smaller than the linear model bias.

4. Analysis of residuals

- The nonlinear residuals generally display similar behavior to the equivalent-linear residuals at large shear strains (at least 0.1–0.4%), but do not slope upward as significantly.
- The scatter in the nonlinear residuals is slightly less than that of the equivalent-linear residuals at large shear strains, suggesting that the nonlinear model is more precise than the equivalent-linear model at large shear strains.
- All models tend to underpredict Arias Intensity for small ground motions; for large ground motions, the trends in Arias Intensity are more consistent with the short-period PSA values.

5. Comparisons of model uncertainties

- The equivalent-linear and nonlinear site response models generally do not deviate from each other significantly until maximum shear strains of 0.05–0.1%. At larger shear strains, the nonlinear site response model residuals have less scatter and offer less severe underpredictions than the equivalent-linear model.
- Persistent model biases at short periods (shown in Figure 5) suggest that: (1) many of these sites may experience a breakdown in the 1D site-response assumptions; and/or (2) the site investigation data provided on KIK-net (i.e. velocity profiles and broad soil type) may be over-simplified.

6. Conclusions

- The equivalent-linear and nonlinear site response models generally do not deviate from each other significantly until maximum shear strains of 0.05–0.1%. At larger shear strains, the nonlinear site response model residuals have less scatter and offer less severe underpredictions than the equivalent-linear model.
- Persistent model biases at short periods (shown in Figure 5) suggest that: (1) many of these sites may experience a breakdown in the 1D site-response assumptions; and/or (2) the site investigation data provided on KIK-net (i.e. velocity profiles and broad soil type) may be over-simplified.

7. References


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