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Soil Structure Inversions by Genetic Algorithm at a Borehole Station during the 2005 West Off Fukuoka Prefecture Earthquake, Japan and its Aftershocks

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Nonlinear behavior of soft soil observed during strong ground motions is now well established and the deployment of vertical array has contributed to detailed wave propagation analyses and assessments for quantitative physical parameters such as shear-wave (S-wave) velocity, P-wave velocity and damping factors with respect to shear strain levels.

The objective of this study is to present the inversion results by genetic algorithm of S-wave velocity and damping factors of the nonlinear response of a one-dimensional soil column at a borehole site located within a sedimentary basin during the 2005 west off Fukuoka prefecture earthquake, Japan. Spectral ratios performed during the S-wave portion of the main shock clearly show a shift toward low-frequencies of the resonant frequencies of the soil column as shown in Figure 1.

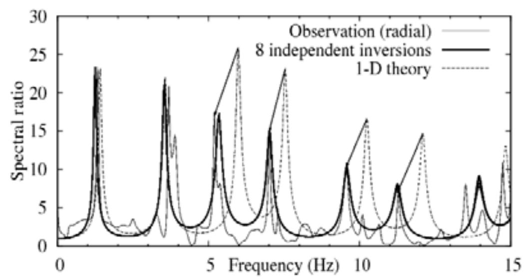

Figure 1: Spectral ratio observed in the radial direction during the S-wave portion of the main shock (thin solid line) plotted together with theoretical and inverted spectral ratios (dashed line and bold solid lines, respectively). Arrows indicate the shift toward low-frequencies of resonant modes due to soil nonlinearity.

In order to confirm that the shift of resonant modes is due to nonlinear behavior of soil, we first verify by using small aftershocks that the transfer function of the S-wave velocity logging is consistent with observed spectral ratios. That being the case, we attribute this shift to nonlinear behavior of the stress-strain relationship. Then, we invert by genetic algorithm S-wave velocity and damping factors by adjusting theoretical ratios computed via Thomson-Haskell propagator matrix method on observed ones. To show the robustness of the result, eight independent inversions are performed and lead to S-wave velocity structures shown in Figure 2. Corresponding inverted spectral ratios are shown in Figure 1 as a bold solid line.

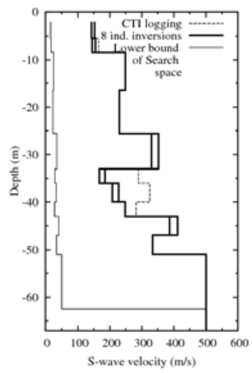

Figure 2: S-wave velocity structures found by eight independent inversions (bold solid lines) plotted with the S-wave velocity logging (dashed line) and the lower bound of search space (thin solid line).

Shear-modulus reduction ratios versus shear strain are shown in Figure 3 and are compared with laboratory tests (Seed et al. 1986). In general, reduction of shear-modulus found by inversion is inferior to laboratory results for soil layers in the shallower part of the soil column.

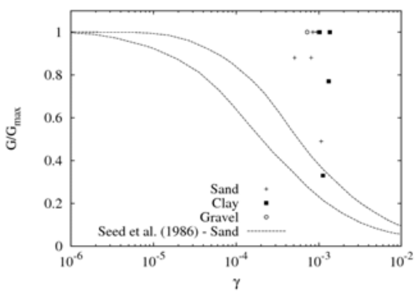

Figure 3: Shear-modulus reduction ratios (G/G_{max}) versus shear strain (γ).