Chapter XII

Inverse Analysis of Weak and Strong Motion Downhole Array Data: A Hybrid Optimization Algorithm

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Abstract

A seismic waveform inversion algorithm is proposed for the estimation of elastic soil properties using low amplitude, downhole array recordings. Based on a global optimization scheme in the wavelet domain, complemented by a local least-square fit operator in the frequency domain, the hybrid scheme can efficiently identify the optimal solution vicinity in the stochastic search space, whereas the best fit model detection is substantially accelerated through the local deterministic inversion. The applicability of the algorithm is next illustrated using downhole array data obtained by the Kik-net strong motion network during the Mw 7.0 Sanriku-Minami earthquake. Inversion of low-amplitude waveforms is first employed for the estimation of low-strain dynamic soil properties at five stations. Successively, inversion of the mainshock empirical site response is employed to extract the equivalent linear dynamic soil properties at the same locations. The inversion algorithm is shown to provide robust estimates of the linear and equivalent linear impedance profiles, while the attenuation structures are strongly affected by scattering effects in the near-surficial heterogeneous layers.
Introduction

Current state-of-practice site response methodologies primarily rely on geotechnical and geophysical investigation for the necessary information on density and low-strain shear wave velocity variation with depth. Even further, attenuation, a critical yet least explored mechanism of seismic energy dissipation and redistribution, is either approximated by means of empirical correlations or inferred based on limited laboratory data. At larger strains, which the material is anticipated to experience during strong motion events, soil properties are mainly evaluated through laboratory testing. Nonetheless, even the applicability of laboratory testing is limited, due to sample disturbance and difficulties in reproducing the in-situ stress-state and seismic loading.

The scarcity of near-surface geotechnical information, the error propagation of laboratory and in-situ measurement techniques, and the limited resolution of the continuum, usually result in predictions of surface ground motion that compare poorly with low amplitude observations. This discrepancy is even further aggravated for strong ground motion, associated with hysteretic, nonlinear, and potentially irreversible material deformations.

Seismic observations of site response may be a valuable complement to in-situ and laboratory geotechnical investigation techniques. Among others, ground motion recordings at various depths acquired through downhole instrumentation—increasingly deployed in seismically active areas over the past years—provides critical constraints on interpretation and prediction methodologies for site response assessment, as well as information on the real material behavior and overall site response over a wide-range of loading conditions.

In this chapter, a seismogram inversion algorithm is developed for the estimation of dynamic soil properties using downhole array data. Comprising a genetic algorithm in the wavelet domain complemented by a local least-square fit operator in the frequency domain, the hybrid scheme can efficiently identify the optimal solution vicinity in the stochastic search space, while the best fit model detection is substantially accelerated through the local deterministic inversion. Results, illustrated for multiple weak and strong motion recordings from the M_w 7.0 Miyagi-Oki earthquake, obtained at selected stations of the Japanese strong motion network Kik-Net, highlight the role of efficient numerical techniques in understanding complex physical phenomena, such as strong motion seismic wave reverberation and scattering in the near surface, leading to the evaluation and improvement of current site response methodologies.

Background:
Observational Evidence Of Site Effects

The destructiveness of ground shaking during earthquakes can be significantly enhanced by local soil conditions, a term that refers to the mechanical properties of the surficial geological formations. In particular, documented evidence during past events reveals that the variability in seismic intensity and structural damage severity correlates strongly to the variability of soil stratigraphy at a given area, and examples include—among others—the nonuniform...
A Revisit to Seismic Hazard at Uttarakhand
www.igi-global.com/article/a-revisit-to-seismic-hazard-at-uttarakhand/159216?camid=4v1a