STUDENTS AT GEORGIA INSTITUTE OF TECHNOLOGY:

Alexandros Kalos, MS (2008)

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PEER REVIEWED PUBLICATIONS

Assimaki D., Kalos A. and Li W. (2010). A wavelet-based seismogram inversion algorithm for the in-situ characterization of nonlinear soil behavior, *Pure and Applied Geophysics* (in press)

Li W. and **Assimaki D.** (2010). Simulating soil stiffness degradation in transient site response predictions, Soil Dynamics and Earthquake Engineering 30(5), pp. 299-309

PRESENTATIONS

A wavelet-based seismogram inversion algorithm for the in-situ characterization of nonlinear soil behavior, Invited Speaker, Workshop on Inverse Problems and System Identification of Geo Systems, Inverse Problem Center at RPI, 29-30 March 2010

A wavelet-based seismogram inversion algorithm for the in-situ characterization of nonlinear soil behavior, American Geophysical Union (AGU) Fall Meeting, San Francisco, CA, 13-18 December 2009

A wavelet-based inversion for in-situ characterization of nonlinear soil behavior, Kalos A and **Assimaki D**., NEES 7th Annual Meeting 2009 Seismic Mitigation in a Flat World, June 23-25, Honolulu, Hawaii

Estimating nonlinear dynamic soil properties in-situ via full-waveform inversion: Parameterization and synthetic seismogram implementation, **Assimaki D.** and Kalos A, Sixth NEES Annual Meeting, Portland, OR, 18-20 June 2008.

DESCRIPTION: NONLINEAR SOIL PROFILE INVERSION

We developed a stochastic search algorithm to estimate the nonlinear properties of soil from 1D downhole array recordings. By enlarge, nonlinear soil properties are extracted from laboratory small-scale experiments that need to be extrapolated to the in-situ state of stress for implementation in site response analyses. In turn, extrapolation of the experimental data substantially increases the prediction uncertainty due to effects of sample disturbance, sample size, equipment compliance, loading conditions etc. On the other hand, there exist few studies where the nonlinear soil properties are extracted from field recordings of the true seismic motion, yet the assumptions of linearity and homogeneity made in these studies limit their merit to back-analyses of past events rather than allowing predictions of site response for hazard assessment and mitigation in future events.

We advanced the state-of-the art in nonlinear soil property identification in-situ by developing a full 1D waveform inversion algorithm of strong motion seismogram recordings that can be used to estimate the constitutive model parameters of soils from downhole array strong motion recordings. This allows our algorithm to be employed for future event predictions at the site. To achieve this goal, we assume an idealized monotonic behavior and a set of rules for loading and unloading with unknown soil parameters as the forward model of the inversion. We conducted sensitivity analyses for the optimal constitutive model and hysteretic rules, and validated the selected hysteretic formulation by comparison with downhole array recordings.

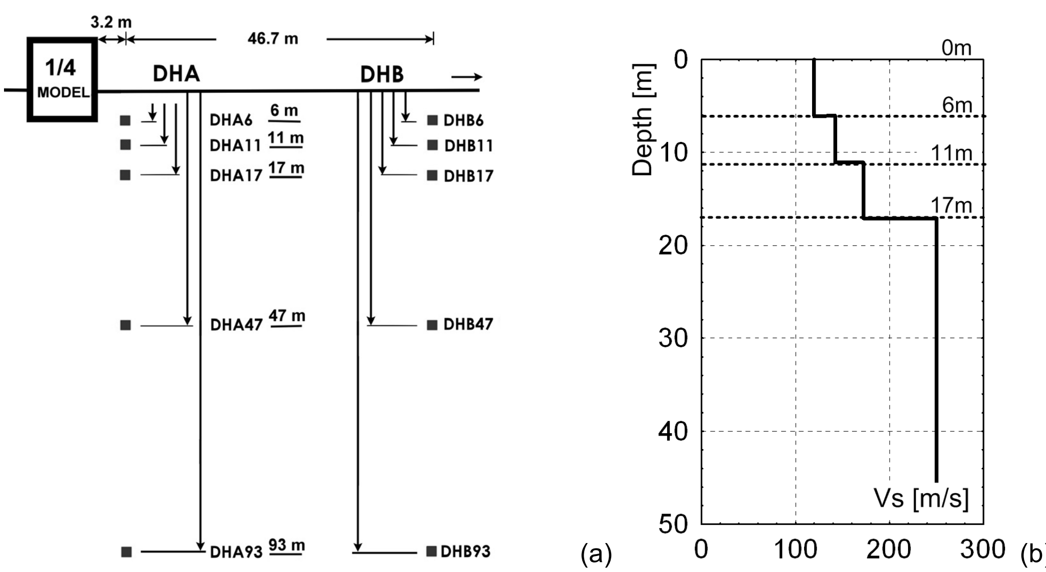
Two novel features were implemented in the forward model of the inversion algorithm by means of finite differences:

(i) **a frequency-independent approximation of soil hysteretic damping** based on the work by Liu and Archuleta (2006), which is removed from the target nonlinear hysteretic behavior in the inversion process, and added in the evaluation of the model error to allow consistency between modulus degradation and damping vs shear strain response for the idealized constitutive model formulation; and

(ii) a **new hysteretic model** developed by Assimaki et al. (2010), modified from **Muravskii's hysteretic formulation** (Muravskii, 2005), and capable of matching simultaneously the G/Gmax and ξ curves.

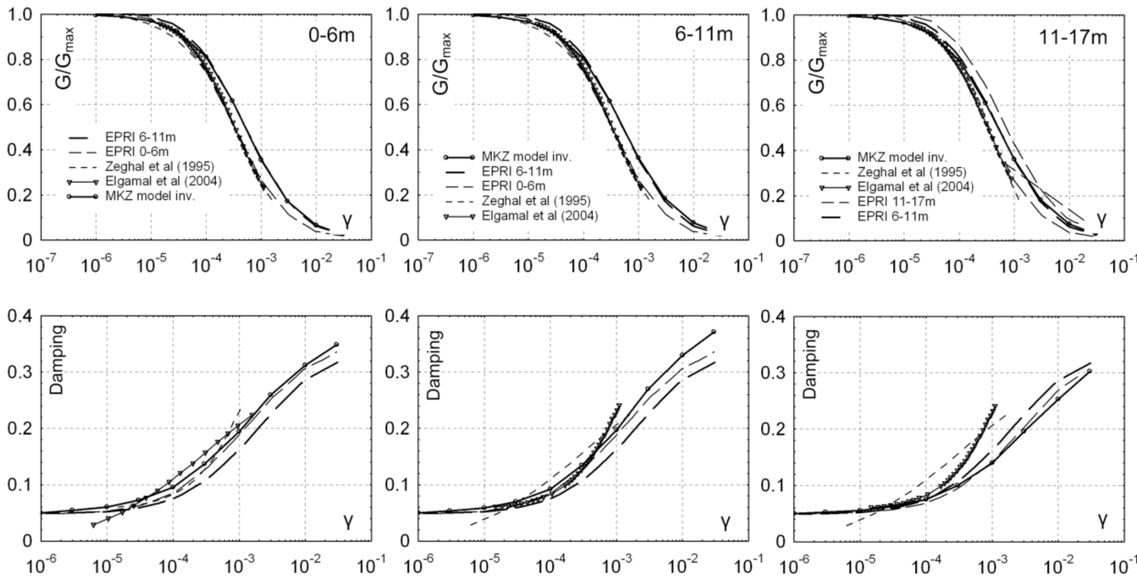
For the inversion we defined the objective function in the wavelet domain (to allow for equal weight across the frequency bands of the non-stationary signal) as the normalized maximum cross-correlation between observed data and synthetics on ground surface. We tested the inversion algorithm using synthetic site response data for homogeneous and layered inelastic soil profiles subjected to SH seismic motion. We investigated the robustness of the inversion scheme by introducing noise in the synthetic input and output and comparing the inversion results with their corresponding noise-free outcome.

Finally, we implemented the inversion algorithm to recordings obtained at the Lotung Large-Scale Seismic Test (LSST) site in northeastern Taiwan, where the Electric Power Research Institute in cooperation with the Taiwan Power Company has installed two downhole arrays of closely spaced triaxial strong-motion accelerometers (Tang, 1987). We selected this site because it is horizontally layered and seismically active. (Chang et al, 1991). The strong motion recordings at LSST have been repeatedly used in the past as input in numerous analysis techniques and ground response models developed to identify the soil dynamic parameters and evaluate the Lotung site seismic performance. We compared results with previous studies such as Glaser (1995), Glaser and Baise (2000), Ching and Glaser (2001), Elgamal et al. (1996a,b) and Zeghal et al. (1996) as well as experimental data for generic sandy and silty sites.



Downhole array instrumentation of Lotung LSST experiment site (modified from Anderson et al, 1993) (left) and shear wave velocity profile (V_s) at DHB location, adopted from Elgamal et al (2001).

Results shown below account for the time-variation of soil properties, namely the instantaneous adjustment to the level and strain and load path, which is a realistic approximation of the true inelastic response. As a result, they compare very well with generic soil properties by contrast to previous studies that were based on equivalent linear properties, while the constitutive nonlinear soil parameters estimated may be used for prediction of nonlinear site response at the site during future events.



Best-fit nonlinear cyclic soil response predicted at convergence of the proposed inversion at the midpoint between consecutive receivers of the DHB downhole array in Lotung (LSST): 0-6m, 6-11m and 11-17m. Comparison of results with previously obtained inversion data at the same site (Zeghal et al, 1996; Elgamal, 2004) and nonlinear dynamic soil properties proposed by EPRI (1993) for generic soils and similar confining pressure levels.

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