Geophysical Research Abstracts, Vol. 7, 10219, 2005
SRef-ID: 1607-7962/gra/EGU05-A-10219

Site-specific, nonlinear soil response using an active source

F. Pearce (1), P. Bodin (2), T. Brackman (2), Z. Lawrence (2), J. Gomberg (3), J. Steidl (4), F-Y. Menq (5), R. Guyer (6), K. Stokoe (5) and P. Johnson (1)

(1) Los Alamos National Laboratory, New Mexico, USA, (2) University of Memphis, Tennessee, USA, (3) United States Geological Survey, Memphis, Tennessee, USA, (4) University of California, Santa Barbara, USA, (5) University of Texas, Austin, USA, (6) University of Massachusetts, Amherst, USA

Next to the velocity structure, the most important site physical characteristic for prediction of Strong Ground Motion (SGM) is the material elastic nonlinear response: the modulus reduction and nonlinear dissipation. Site characterization is currently carried out by point measurements, most generally by laboratory analysis of core and/or using *in situ* borehole diagnostics (velocity and density logs, for instance). We are developing an alternative approach where the site linear and nonlinear elastic properties can be characterized *in situ*. The approach, known as Nonlinear Resonant Ultrasound Spectroscopy (NRUS) is used to interrogate the nonlinear characteristics of the medium by applying an active source. NRUS relies on monitoring a resonance mode frequency change as a function of drive level. The elastic nonlinear behavior is extracted from the change in resonant frequency and dissipation characteristics with drive level. This type of experimental approach is commonly applied in the laboratory to characterize sample nonlinear response (1).

In order to test the method, on August 18 2004 we performed a sequence of exploratory experiments using the Network for Earthquake Engineering Simulation (NEES) vibrator source T-Rex (2) at the Garner Valley experimental site, adjacent to the Garner Valley Downhole Array (GVDA) southeast of Los Angeles. In the experiment, the TRex source is step-swept in frequency encompassing the modal frequencies expected theoretically for the velocity structure at the GVDA, measured independently 10 m distant from the experimental site (3). We focus on several interfaces determined from that study, and therefore selected a frequency band of 5-30 Hz for the step-sweep.

An array of nine 3-component accelerometers located immediately adjacent to the vibration plate recorded motions generated by six progressively larger forces, ranging from 13-100 kN in shear and 27-240 kN in compression.

Our results show clear resonance modes in both compression and shear. Measured accelerations reached 2G (the instrument clip-level) at full force, corresponding to strain amplitudes of the order of 4.5x10^{-3}. The detected acceleration amplitudes span more than a decade, implying minimum strains are of the order of 10^{-5}-10^{-4}. The data in both compression and shear show dominant resonance modes that correspond to the uppermost sediment layer 3-m in thickness. We observe a decrease in the dominant shear and compression resonance frequency of approximately 20% and 15% respectively, corresponding to a modulus reduction of 40% and 30% respectively. Strong nonlinear attenuation is observed in laboratory and in actual SGM observations (4), increasing significantly with strain amplitude; however, the interpretation of this behavior from our results is unclear due to the complex behavior of the composite soil column in resonance conditions. We simulate our field experiment using a 1D staggered grid finite difference model of nonlinear wave propagation that describes the soil behavior using the generalized (2 parameter) Masing rule. Model results reproduce the nonlinear soil behavior observed in the field experiments. With these promising results in hand, we are planning a follow-on experiment at the University of Texas at Austin test site in March 2005.

1. Guyer, R. and P. A. Johnson, The astonishing case of mesoscopic elastic nonlinearity, *Physics Today*, 52, 30-35, (1999).

2. http://nees.utexas.edu/equipment/trix/triax.htm

3. Bonilla, F., J. Steidl, J.-C. Gariel and R. Archuleta, Borehole response studies at the Garner Valley Downhole Array, southern California, *Bull. Seism. Soc. Am.* 92, 3165-3179, (2002).

4. Field, E. H., P. A. Johnson, I. Beresnev, and Y. Zeng, Nonlinear ground-motion amplification be sediments during the 1994 Northridge earthquake, *Nature* 390, 599-602, (1997).