STUDY OF SURFACE WAVE METHODS FOR DEEP SHEAR WAVE VELOCITY PROFILING APPLIED IN THE UPPER MISSISSIPPI EMBAYMENT

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ABSTRACT

Surface wave methods have become an important tool for non-intrusively and inexpensively determining shear wave velocity (V_s) profiles for many geotechnical earthquake engineering applications. The primary objectives of this study are to (1) compare active-source and passive (ambient vibration) surface wave methods for developing V_s profiles to depths of 200 to 300 m at deep soil sites, and (2) identify the primary factors affecting the reliability and consistency of surface wave methods. This comparative study became possible with the advent of a unique low-frequency field vibrator developed as part of the National Science Foundation's (NSF) Network for Earthquake Engineering Simulation (NEES) program. This vibrator is able to actively excite surface wave energy down to frequencies of less than 1 Hz. Four surface wave methods (two active-source methods and two passive-source methods) were applied in this study, namely: (1) the Spectral-Analysis-of-Surface-Waves (SASW) method, (2) the active-source frequency-wavenumber (*f*-*k*) method, (3) the passive-source frequency-wavenumber (*f*-*k*) method and (4) the refraction microtremor (ReMi) method. The focus of this study is on two critical aspects of surface wave methods: (1) development of a reliable surface wave dispersion curve from field measurements, and (2) compatibility between the experimental dispersion curve and the theoretical model used in the inversion procedure to develop the final V_s profile. Measurements were performed at eleven sites distributed over a distance of about 180 km in the upper

Mississippi Embayment in the central United States, where soil deposits are hundreds of meters deep.

Limitations associated with each of the four methods were identified in this study. With respect to the SASW method it was found that potential phase unwrapping problems could cause an erroneous estimate of the dispersion curve. These errors were found to be associated with an abrupt mode transition caused by a strong velocity contrast at a shallow depth. With respect to the active-source *f-k* approach, it was demonstrated that near-field effects caused by a short near-source offset produced an underprediction of the surface wave dispersion curve at long wavelengths. Recommendations for acceptable source offset distances were developed based on the results from this study. The performance of the passive approaches (passive *f-k* method and ReMi method) was shown to be strongly dependent on the local ambient wavefield characteristics. Results from a study of the ambient wavefield characteristics at the 11 sites showed high ambient vibration levels at all sites in the frequency range of 1 to 4 Hz. Passive measurements using a circular array provided good comparisons with the active-source methods out to wavelengths of 500 m (2.5 times the array aperture) in most cases. Poor performance at one site was shown to be due to a multi-source wavefield at low frequencies. An improved comparison at this site was achieved by applying high-resolution processing methods. The ReMi method was found to provide good results down to frequencies of 3 to 4 Hz (wavelengths of 100 to 150 m) but very poor performance at lower frequencies (< 3 Hz). The wavefield characteristics at low frequencies were identified as the primary factor affecting the performance of the ReMi method.

Lastly, deep V_s profiles developed from active-source *f-k* dispersion curves using a fundamental mode inversion were compared with V_s profiles developed from SASW dispersion curves using an “effective-velocity” inversion. Good agreement between two inversion approaches was shown at most sites, however, large inconsistencies at depth were observed at one site. This inconsistency was shown to be due to incompatibility between the experimental dispersion curve and the fundamental mode model used in the inversion. The local site conditions, specifically the shallow depth of the Memphis Sand formation at this site was identified as the cause of the model incompatibility. Base on the findings from this study, recommendations for procedures to perform deep V_s profiling using surface waves are presented.