FIELD APPLICABILITY OF MASW DATA

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Abstract

One-dimensional multi-spectral analyses of surface waves (MASW) are used to predict subsurface shear-wave interval velocities. Shear wave velocities can also extract additional velocity-related information such as mechanical properties of soils and rocks. In general, MASW data compare favorably to other geophysical methods for predicting interval velocities. Furthermore, comparisons to vertical seismic profiles correlate well with MASW predicted shear-wave interval velocities.

Over 100 one-dimensional MASW records and 30 vertical seismic profiles in 5 states were collected and compared. Surface waves saturate the geophones (5-foot spread with 5-foot hammer offset) on bedrock and dispersion curves are difficult to evaluate. Consequently, MASW-derived shear-wave velocities are elevated above those derived from down-hole vertical seismic profile methods (VSP). MASW-derived shear-wave velocities collected in areas with a veneer to thick sequences of unconsolidated soil have predicted MASW shear-wave interval velocities that compare favorably to those derived from VSP data.

Introduction

Shear-wave interval velocities derived from the MASW method has been favorably compared to vertical down-hole seismic (VSPs) data for the prediction of subsurface shear-wave interval velocities (Xia, et al., 2002). VSP data are considered to be an industry standard for the prediction of shear-wave interval velocities. Unfortunately, VSP data are affected by borehole/casing effects; from poor interpretations due to overlapping compressional (p)-waves on shear (s)-wave refraction data; difficult field deployment and other problems that create difficulties with the determination of the first arrival time.

Consequently, the MASW method has been developed as a faster and easier method to predict s-wave interval velocities (Park et al., 1999). Several papers describe and defend the MASW method as a good predictor of s-wave interval velocities (Miller, et al., 1999; Park et al., 1999a; Park et al., 1999b, Xia, et al., 2000; Turesson, 2006; and Luke and Calderon-Macias, 2007).

The purpose of this paper is to determine when the 1-dimensional MASW method fails to provide s-wave interval velocities that agree with VSP data. Thirty borehole and cased-well VSP interval velocity shear-wave records from 5 states (Texas, Wyoming, North Dakota, Pennsylvania, and Vermont) are compared to interval velocities from 30 MASW-processed data collected from boreholes and cased wells (Figure 1).

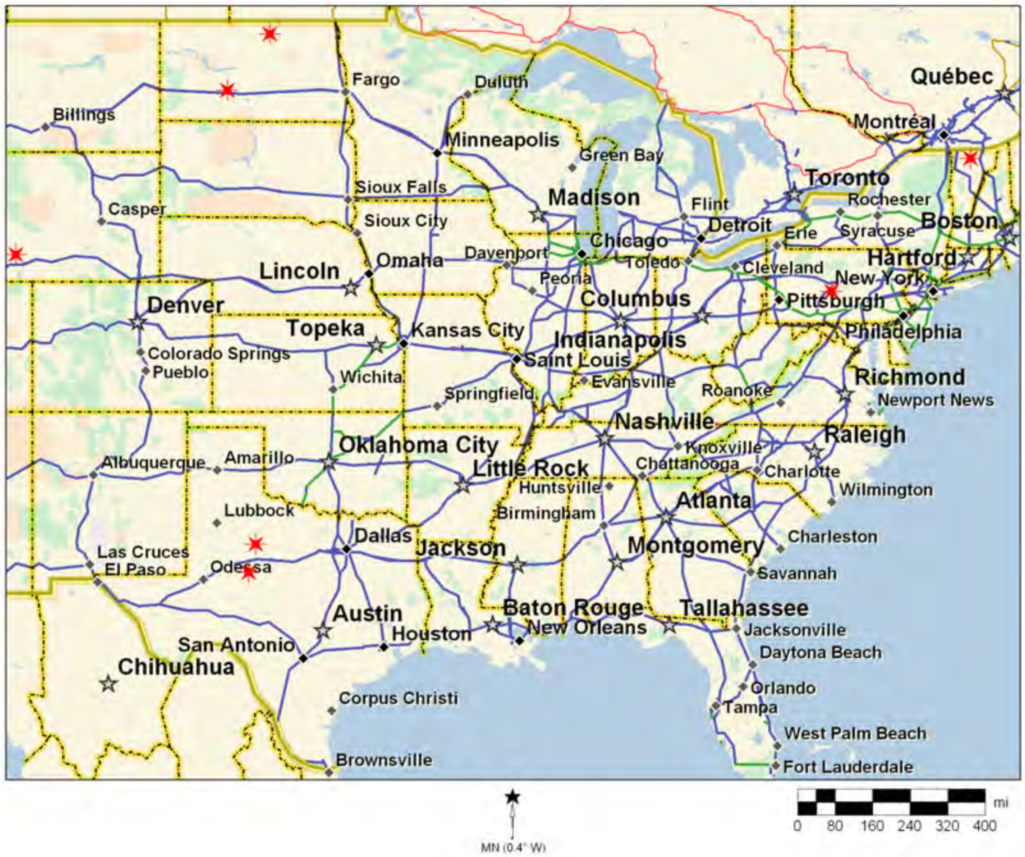

Figure 1: Location map of the central and eastern United States showing the sampling locations as red stars.

Methods

The 1-dimensional MASW method consists of a 24-channel array with a 5-foot spread using 4.5-Hz geophones and Geometrics 24-channel (Geode) seismograph. Using the impact of a 5-kg sledge on an alloy plate, 6 records were collected, stacked and stored into a PC. The data was interpreted using the SurfSeis 2.0 (Kansas Geological Survey, 2007) dispersion-inversion software.

VSP data were collected with a bow-spring-loaded pressure-case 3-component 8-Hz triaxial downhole sonde manufactured by Geostuff, Inc. (San Francisco, CA). Six records were collected and stacked at 1-meter intervals to total depth. Data was collected with a Geode seismograph and interpreted through Seistronix RS100 (Seistronix, 2005) program.

MASW data are used to extract interval velocities that can be used to model the mechanical properties of soils and rocks. Profiles of depth-to-velocity from the MASW-inverted analyses were compared to the VSP profiles (Figure 2). Data that do not compare well to real-world conditions will have an adverse effect on any design basis; consequently, any weakness with this method should be fully elucidated.

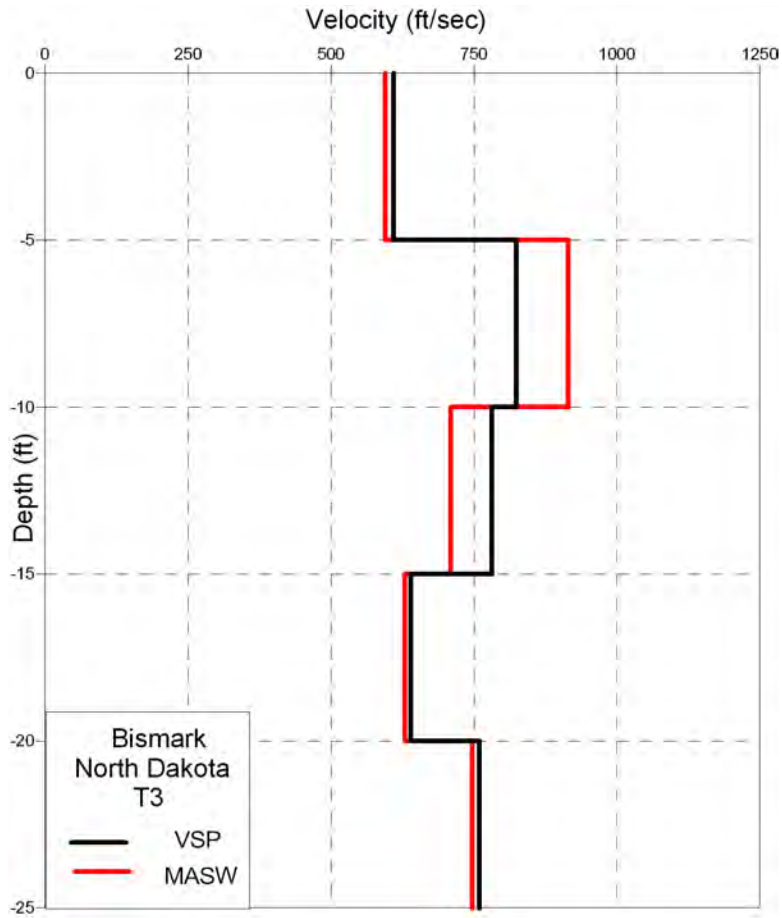

Figure 2: Shear-wave velocity-versus-depth curve for a glacial till showing VSP- and MASW-derived profiles.

Analysis

The MASW method is promoted over down-hole data collection methods due to its ease of deployment. The client does not need to provide for an open borehole and contractor need not worry about losing a sonde in the hole, collecting the data immediately after drilling, having the hole collapse prior to testing. MASW data from bedrock settings have dispersion patterns that are more difficult to interpret than those from soil settings (Figure 3). Soil dispersion patterns, however, appear reasonable and can be interpreted to produce a velocity profile equivalent to those generated through VSP methods (Figure 2).

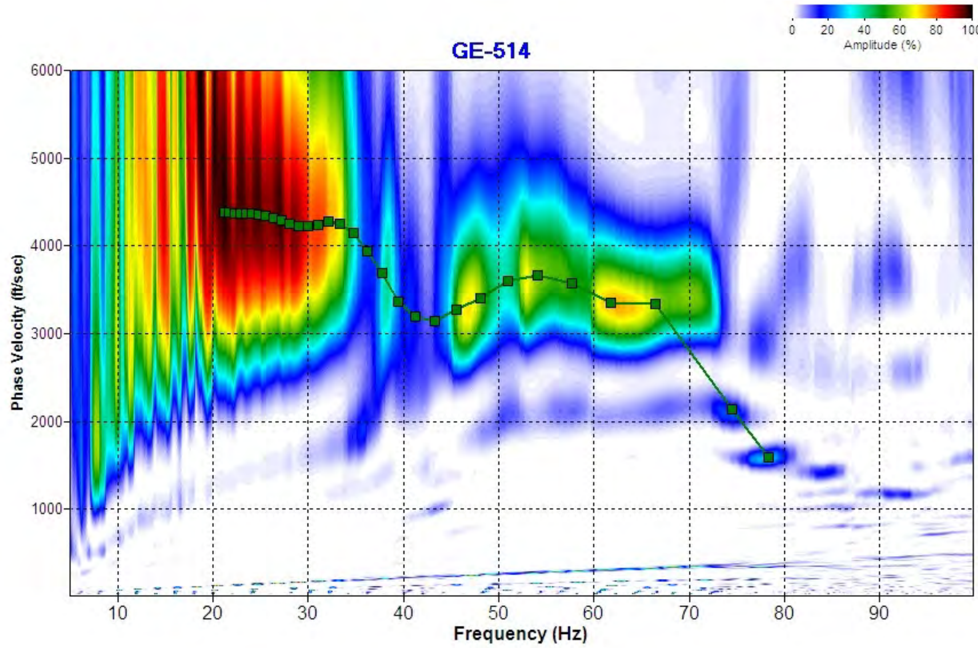

Figure 3: Dispersion pattern (phase velocity vs frequency) for a bedrock setting (i.e., rock at the surface); note the fundamental-dispersion curve is poorly developed and little useful data is present for the interpretation of the shallow portion of the rock record (i.e., higher frequencies).

The velocity of shear waves in rock is apparently too fast for generating a useful dispersion pattern; consequently, producing an interpretation consistent with VSP data is difficult. For example, the shear-wave velocity interpretation from the site in Figure 3 using MASW is well above the 2,500 ft/sec to 3,500 ft/sec derived from VSP first-arrival data (Figure 4)

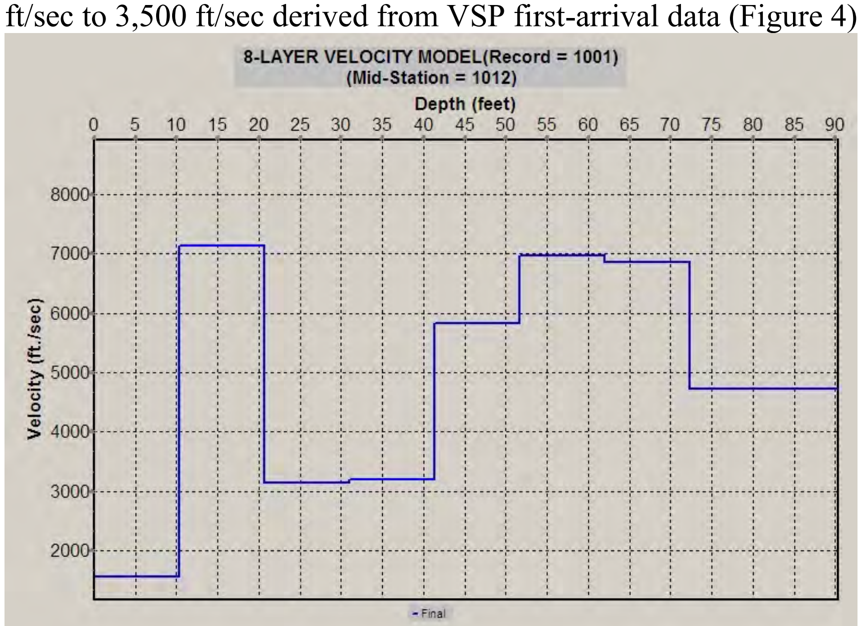

Figure 4: Shear-wave velocity profile generated through MASW methods for a rock site in Texas; note that interval velocities are well above those considered reasonable for this area and generated through VSP methods (i.e., derived from the first-arrival data).

Presumably, the propagation speed (i.e., phase velocity) in soil is slow enough that a defensible fundamental-mode dispersion curve can be generated and interpreted (Figure 5). In this example, glacial till is present to 65 feet below grade. The inversion of the fundamental–mode dispersion curve for this soil example produced a velocity-depth profile that compares very well with the VSP-derived shear-wave velocities (Figure 6).

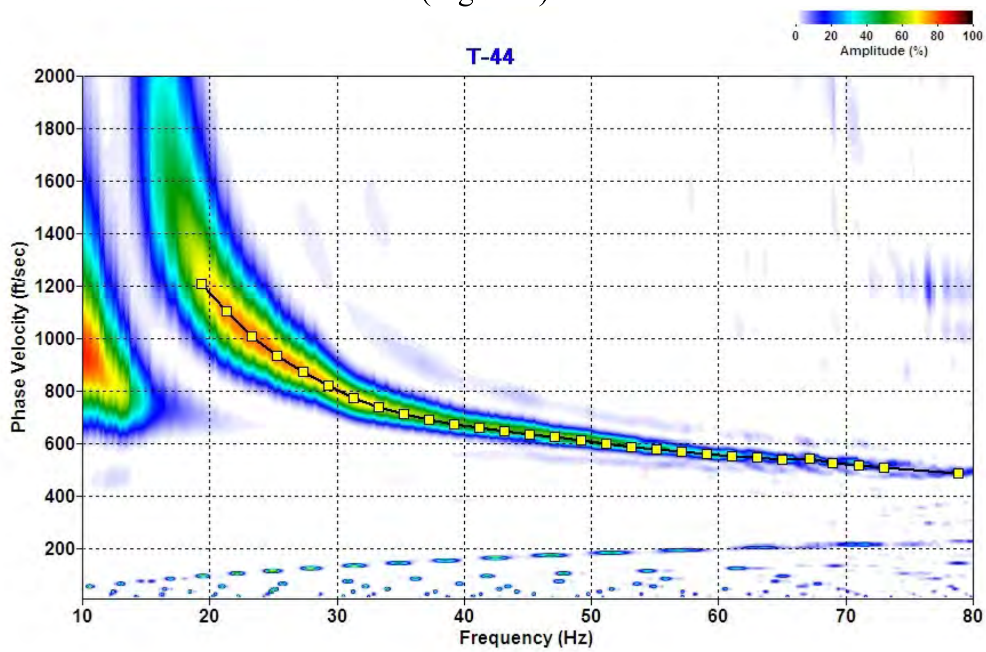

Figure 5: The fundamental–mode dispersion curve has been extracted from the dispersion overtone graph for this soil site in Wyoming. An inversion of the fundamental-mode dispersion curve produces a reasonable velocity profile that nearly matches the VSP-derived shear-velocity profile.

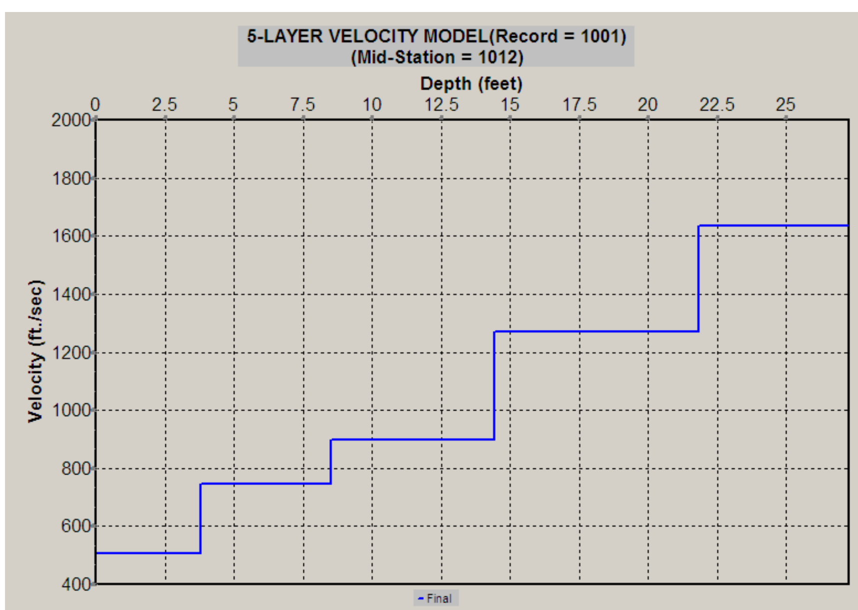

Figure 6: Velocity profile derived from the inversion of the MASW fundamental-mode dispersion curve using a simple 6-layer model.

Conclusion

The MASW method is a quick and effective tool for generating shear-wave interval velocities. Interval velocity data can be used to predict the mechanical properties of soil and rock. This method, however, generates shear-wave velocities that are greater than those observed from conventional, more established techniques for deriving shear-wave velocities in a bedrock environment (i.e., rock at or within 2 feet of the surface). This condition is probably caused by faster Rayleigh-waves in rock as compared to those in soil.

In a bedrock setting, the MASW method does not create an easily interpreted overtone image for picking the dispersion pattern. The inversion of the fundamental-mode dispersion curve from a surface-bedrock site is usually much greater than VSP-collected data. Further, the interval velocities generated through MASW methods in a bedrock setting are much greater than then expected.

The difficulty with the collection of MASW data from surface-bedrock can probably be ameliorated to some degree by increasing the geophone spread to 10 feet or more; however, the resolution would lower and near-surface shear-wave velocity prediction would suffer as a result.

References

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