Geophysical Services

Environmental • Groundwater • Geotechnical

Downhole Seismic Surveys

Shear-wave and Compression-wave Analysis

Earthquake Response

Geotechnical Site Investigations

SHEAR-WAVE AND COMPRESSION-WAVE DOWNHOLE SEISMIC SURVEYS

Downhole seismic surveying is an important field method for determining key *in-situ* subsurface information for earthquake engineering and other geotechnical site investigations. Downhole surveys are undertaken to measure the vertical distribution of seismic velocity in the earth. Such surveys provide detailed information on stratigraphy and the engineering properties of subsurface soils and rock that is not available from surface seismic surveys. Shear-wave velocity profiles obtained from downhole surveys are routinely incorporated in site response modeling for earthquake hazard evaluation and structural design.

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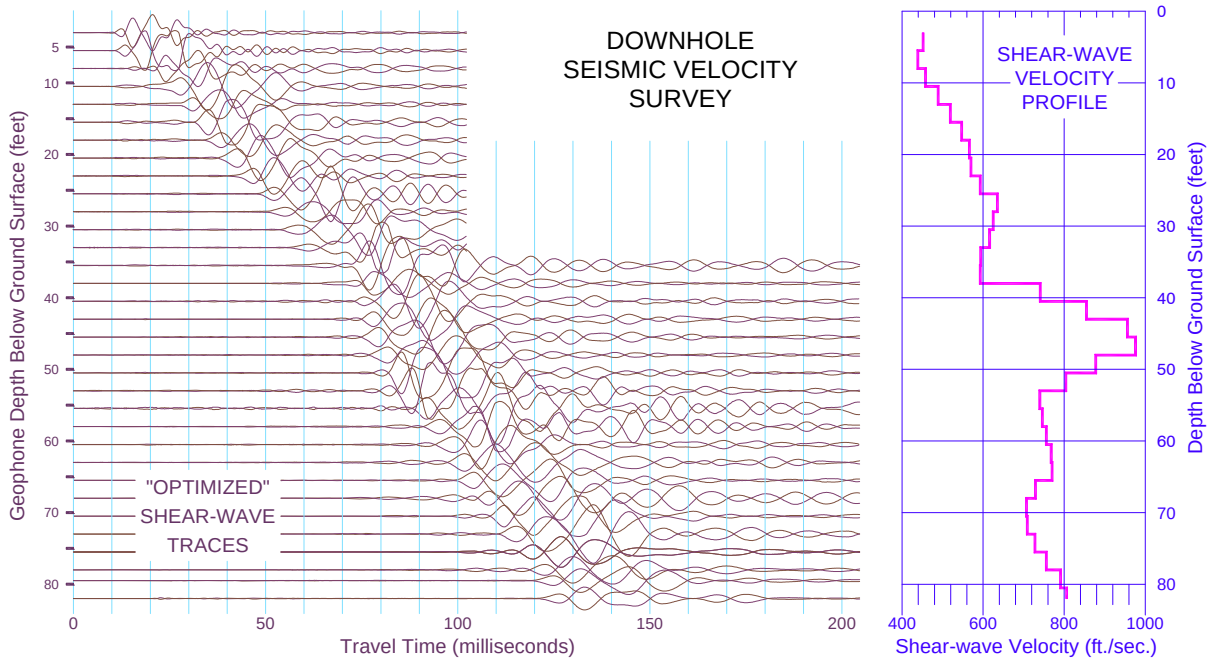

Northwest Geophysical Associates, Inc.

8366 SW Nimbus Avenue, Beaverton, OR 97008

(503) 992-6723 Fax: (503) 746-7094

www.nga.com · info@nga.com

Downhole Seismic Surveys

APPLICATIONS OF DOWNHOLE SEISMIC VELOCITY DATA

Downhole seismic velocity data are utilized in a variety of geotechnical site investigations, including earthquake site response modeling, foundation design for dynamic (vibratory) loads, and rock quality assessment. Downhole seismic data are also used for the enhancement and quality control of surface seismic interpretations.

FIELD PROCEDURES

A downhole seismic survey (also called a borehole velocity survey) is conducted by measuring the time for seismic waves generated by an impulsive source at the surface to travel to a sensor located at a sequence of depths in the borehole. The sensor consists of three geophones arranged in an X-Y-Z pattern. Two orthogonal horizontal geophones are used to detect shear-wave (S-wave) arrivals and a vertical geophone is used to detect compression-wave (P-wave) arrivals. At each measurement level, the sensor assembly is locked to the borehole wall using a clamping mechanism so that the geophones will couple with the seismic signals propagating in the earth.

BOREHOLE SENSOR

NGA utilizes a state-of-the-art BHG-2 three-component slimhole transducer manufactured by Geostuff Instruments. This transducer can be used in *boreholes as small as 2.2 inches in diameter*, thereby significantly reducing the costs of seismic borehole preparation. The BHG-2 employs a mechanical clamping “spring arm” to provide positive coupling of the geophone assembly with the borehole casing and the surrounding formation.

DATA PROCESSING

NGA has developed specialized software which aids in the identification and timing of shear-wave arrivals. This software computes the vector sum of the two orthogonal horizontal geophone signals and determines the orientation of maximum shear-wave particle motion. The software then mathematically rotates the signal into this orientation and plots the “optimized” shear-wave

trace at each measurement level. In general, this optimized or projected trace presents a more consistent waveform than either of the two horizontal geophones taken separately. In the field, a vertical stack of the optimized traces on a portable computer is used for preliminary analysis of the downhole data. This on-site analysis allows us to add supplemental data at intermediate levels where appropriate to refine the velocity profile.

QUALITY CONTROL

From our experience we have found there are several key factors in obtaining high quality downhole seismic data. These include:

- proper borehole preparation to assure good coupling between the geophone and the surrounding soils or rock formation;
- recognition and enhancement of the shear-wave and/or compression-wave arrival, and the suppression of spurious (e.g., tube-wave) arrivals;
- consistent timing of the wave-form arrivals;
- selection of a depth sampling interval appropriate for resolving the transitions of interest.

NGA personnel have been performing downhole and crosshole seismic surveys for over fifteen years. This experience enables us to recognize and anticipate difficulties which are inherent in data acquisition and data processing, and to provide detailed, high quality seismic velocity profiles which correlate well with other geological and geotechnical parameters.

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