

## **SEISMIC CROSS-HOLE METHOD**

The seismic cross-hole method consists of measuring the travel time of seismic waves propagating from a seismic energy source (downhole hammer) located in one borehole, to detectors (downhole geophones) placed at the same depth in adjacent boreholes. This procedure is repeated at numerous intervals throughout the depth range of the boreholes. Upward impacts with the downhole hammer produce vertically polarized shear (S-) waves that are detected by the downhole geophone. Downward impacts produce vertically polarized S-waves of the opposite polarity. By recording both directions of impact separately, we are able to superimpose the recorded wave traces and identify the S-wave arrival by the characteristic phase reversal.

Although the downhole hammer is designed primarily as an S-wave energy source, it does produce some compressional (P-) wave energy. We have found that the best way to measure P-wave travel times is by stacking (algebraically summing) the digitized signals (wave-forms) from numerous up and down impacts with the downhole hammer.

We produce seismic energy in borings using a downhole S-wave hammer manufactured by Soils Engineering and Geosciences (SEG) of Clinton, Mississippi. We detect the resulting P- and S-waves using downhole triaxial geophones coupled to the borehole walls; and a 24-channel Strataviewer seismograph manufactured by Geometrics, Inc. of San Jose, California.

Cross-hole surveys are conducted in 3" or 4" inch id PVC cased holes that are typically grouted in place to provide good coupling with the borehole walls. Normally 2 to 4 holes spaced 15 to 25 feet apart are used with the casings capped at the bottom and all water removed from the holes. As part of the cross-hole procedure borehole deviation logs are also run to accurately determine the attitudes of the boreholes in the suite. In this way the seismic wave travel path distances can be determined at every measurement depth.