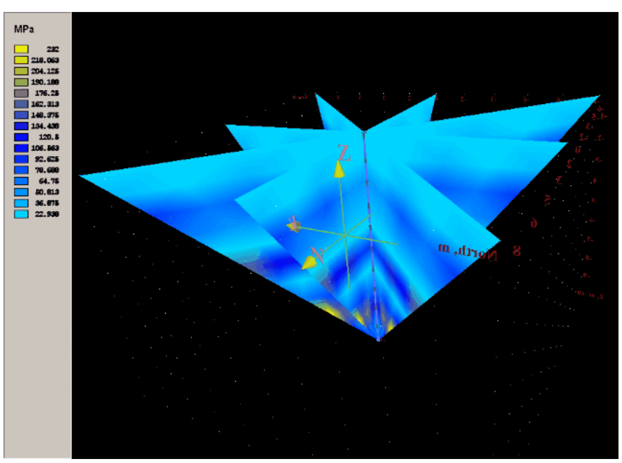
# Concepts in Downhole Seismic Testing

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*By publishing this manual we will hopefully provide a better understanding of downhole seismic testing and the role it can play in geotechnical investigations.*

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# Chapter 1 **Introduction**

There is considerable interest in methods of geotechnical *in-situ* engineering that provide accurate estimates of the shear and compression wave velocities ($V_S$ and $V_P$ respectively) and the associated absorption values ($\alpha_S$ and $\alpha_P$ respectively) in the ground, since these parameters form the core of mathematical theorems to describe the elasticity/plasticity of soils and they are used to predict the soil response (settlement, liquefaction or failure) to imposed loads (whether from foundations, heavy equipment, earthquakes or explosions [3], [22]). Moreover, accuracy in the estimation of shear and compression waves velocities is of paramount importance, because these values are squared during the calculation of various geotechnical parameters such as the Shear Modulus (G), Poisson's Ratio ( $\mu$ ) and Young's Modulus (E).

Applied seismology techniques such as the Downhole Seismic Test (DST) have gained extensive popularity in recent years since they allow the *in-situ* estimation of the shear and compression wave velocities and the associated absorption values. This technical document was developed to provide the reader with a theoretical and technical background in the application of DST for geotechnical *in-situ* site characterization.

Topics covered include the benefits of DST to the practicing geotechnical engineer when carrying out static and dynamic soil analysis and liquefaction assessment (Section 2). In Section 3 a detailed theoretical discussion is given which relates the stress-strain of a medium to the elastic constants of shear modulus, Poisson's ratio, Young's and bulk modulus, Lamé's constant and constrained modulus. A discussion on the derivation of the general wave equation, the P-wave equation and the S-wave equation is also given in this section. Next the important material properties of isotropy, anisotropy and transverse anisotropy are discussed along with the associated effect on the elastic constants and P-wave and S-wave equations, followed by an overview of Snell's law and seismic convolution. Afterwards the mechanism of absorption is discussed (with a summary of the governing equations) and finally the surface waves such as Rayleigh waves are outlined along with their utilization for geotechnical site characterization.

Section 4 delves into the details of DST with special attention given to seismic cone penetration testing (SCPT). Section 4.1 outlines important instrumentation considerations such as data acquisition, sensors types and their corresponding configuration, sources and testing procedure. Section 4.2 reviews DST post data processing and analysis methodologies. Some of the important data analysis topics covered include the application of digital zero phase frequency filters, cross-correlation analysis, polarization and hodogram analysis, iterative forward modeling, data inversion, blind seismic deconvolution and attenuation analysis.