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**The determination of the damping ratio as a key geotechnical parameter by multi-channel spectral analysis of seismic downhole data**

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Dynamic shear modulus and damping ratio of soil serve as indispensable basic data for the seismic design on important engineering projects. It is known that damping is one of the dynamic soil parameters describing the process of inelastic energy loss of a seismic wave traveling through a medium. However, damping is influenced by several mechanisms in soils that are not understood thoroughly to allow sufficient modeling.

At small strain levels the material damping is related to the frequency-independent hysteretic damping which appears as hysteresis loop in the stress-strain diagram. The energy dissipated in the material during one cycle of a harmonic oscillation can be calculated by the inside area of this hysteresis loop. Laboratory tests such as low-frequency torsional shear or cyclic triaxial tests make use of the stress-strain behavior and determine the damping ratio directly from this hysteresis loop. Established techniques to determine the material damping ratio are mostly based on the measurement of the spatial decay of surface waves caused by the dissipation of energy (material damping) and the spreading of the wavefronts over an increasing area (geometrical damping). The approach presented considers the fact that geometrical damping has no influence on the phase velocity of body waves and likewise the dispersion curve and therefore apply the multi-channel spectral analysis of seismic downhole data to determine the damping ratio.

This approach is based on the work of Meza-Fajardo and Lai, 2007 which showed the possibility of determining material damping ratio spectrum entirely from in situ phase velocity measurements of P- and S-waves. They proposed a model of energy dissipation in soils based on linear viscoelastic material behavior. A distinctive feature of this linear viscoelasticity theory is that the parameters phase velocity, the attenuation coefficient and damping ratio are functions of frequency.

The approach is demonstrated on a downhole data set of a test performed using a S-wave vibrator source generating seismic signals at the surface. Data were acquired by a digital borehole geophone clamped mechanically to the borehole wall and gathered in the time domain. Then, the data were transferred into the phase velocity - frequency domain by applying a discrete Fourier transform on the time axis and a discrete slant stack on the distance axis. The phase velocity - frequency spectra of the data was calculated and a dispersion curve was obtained by picking the maximum energy within a certain frequency range. Finally, a numerical fit of the theoretical dispersion relation to the experimental dispersion curve was carried out to calculate the damping ratio. The obtained results show a good agreement with damping ratios found in the literature for similar soils.

*K.C. Meza-Fajardo and C.G. Lai. Explicit causal relations between material damping ratio and phase velocity from exact solutions of the dispersion equations of linear viscoelasticity. Geophysical Journal International, 171(3):1247–1257, December 2007.*