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Compressional and Shear Wave Velocities of Soils at Low Pressures-- Theoretical Estimates, and Comparison of Laboratory and Field Data

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Thin soil layers control the amplitude and duration of seismic surface displacements because of large impedance contrasts with underlying bedrock. For example, site amplification occurs when energy is trapped in surface layers during strong motion. Values of P and S velocities and elastic moduli for materials such as silty sands and peat are more than an order of magnitude lower in the near-surface than at depth, and change rapidly in the top few meters. Effects of pressure and microgeometry on mechanical properties of unconsolidated materials can be explored using laboratory measurements under controlled conditions. At low pressures representative of the near-surface, however, P velocity data are scarce and reliable S velocities are extremely difficult to obtain because of high attenuation.

We developed a technique for simultaneous measurement of ultrasonic P and S velocities at low pressures for dry and saturated soil samples. We measured velocities for various mixtures of Ottawa sand, clays, and peat moss at pressures of about .01 to .1 MPa, representing depths of a few meters.

Our laboratory measurements of velocities in artificial soils compare reasonably well to literature values from the field at shallow depths, with P velocities between 150 and 400 m/s and S velocities about half as large. Our S wave amplitudes are highly sensitive to pressure and to clay content, and S velocity gradients are much steeper than P velocity gradients. We applied several effective medium theories to model measurements, and obtained useful velocity estimates when appropriate microstructure assumptions were made. Successful models can be used to extrapolate and generalize laboratory measurements. High-quality laboratory measurements can enhance interpretation of seismic data for applications to earthquake hazards reduction and environmental geophysics.

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