COMPRESSIONAL AND SHEAR WAVE VELOCITIES IN FINE-GRAINED POWDERS UNDER VACUUM AND LOW LOADS. R.M. Stesky and B. Renton, Erindale College, Univ. of Toronto, Mississauga, Ont. Canada, L5L 1C6.

The most extensive work on the elastic properties of dry powders has been done under hydrostatic pressure to 2 kilobars or under uniaxial strain at stresses up to 700 bars (4,5). These stresses far exceed the stresses expected in the lunar regolith (up to 3 bars at 100 m depth). Johnson and others (1) made a brief study of P-wave velocities at low axial stresses to 2 bars. However much remains to be done. In particular, the recent determination of the lunar shear velocity structure (2) highlights the importance of shear velocity measurements.

We are examining the elastic properties of dry powders under uniaxial strain at stresses to 5 bars, corresponding to a depth of 150 m on the moon. The experimental arrangement is similar to that used by Johnson and others (1). The soil sample (from 0.5 to 1 cm thick) was contained between two piezoelectric discs (1 MHz PZT for P-waves and 2 MHz AC-cut quartz for S-waves) within a 3.25 cm internal diameter brass container. The entire assembly was set in a vacuum chamber. Force was applied to the sample through a moveable piston mounted in a high-vacuum steel bellows and measured with a load cell. Piston displacement, and hence sample strain, was monitored with a displacement transducer. The preliminary work reported here was done under various degrees of vacuum from room pressure to 50 millitorr. We found little difference in elastic properties within this range of vacuum.

The sample was a relatively fresh olivine diabase, crushed to an average grain size of about 25 µm (sizes range from about 400 µm to less than 10 µm). A sample loading curve for a sample under atmospheric pressure is shown in Fig. 1. In this case the soil was precompacted with 2 bars axial stress to a density of 2.21 g/cc (porosity = 26%). The small loops in the curve correspond to cycles of unloading and reloading (5). Since the sample is under uniaxial strain, the slope of the dashed line is \( \rho V_p^2 \), assuming linear elasticity, where \( \rho \) is density and \( V_p \) is P-wave velocity. Thus we can estimate \( V_p \) at low frequencies and large strain amplitudes, shown in Fig. 3.

\( V_p \) at high frequencies was measured for a different sample (initial density 1.1 g/cc, compacting to 1.36 g/cc) during several compaction cycles. The data for the first and third cycles are shown in Fig. 2. In both cases, the \( V_p \) increases markedly with axial stress and is greater when the load is decreasing than when increasing. There is very little difference in the velocities for the two cycles; since most of the permanent compaction takes place when the first 0.5 bars is applied, this result is reasonable.

Preliminary measurements of ultrasonic \( V_p \) and \( V_S \) (shear velocity), in soil of density 1.55 g/cc at axial stresses between 1 and 5 bars, are shown in Fig. 3. The load was applied with a dead weight so no displacement data are available. Although the two velocities were measured with different samples, the consistency of \( V_p \) between the two acoustic experiments suggests the \( V_p \) and \( V_S \) may be combined to give a first order estimate of Poisson's ratio under these conditions. It lies between 0.40 and 0.43, with no consistent variation with stress between 1 and 5 bars. This high value, found for the top 10-20 meters only of the lunar surface (2), suggests that powder is present only to
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these depths on the moon, a conclusion reached from an analysis of electrical properties (3).

References

FIG. 1: Uniaxial strain compaction of powder (pre-compacted to 1.5 Bars) at atmospheric pressure.
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FIG. 2: P-Wave Velocity during two cycles of loading at 250 millitorr vacuum.

FIG. 3: P- and S-wave velocities to 5 Bars axial stress. Open symbol, loading; closed symbol, unloading.