Fast shear behavior of granular materials in ring shear tests

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As part of a generic study of the granular-flow process in landsliding and fault rupture, which cause serious casualties and huge economic losses worldwide, we conducted preliminary investigations into the frictional response of dense granular materials to the presence of internally generated elastic body waves using four of the large ring-shear devices at DPRI. In a series of experiments, we measured the shear resistances and seismic outputs of granular materials at different overburden loads, strain rates, and with and without grains being broken. We used dry glass beads as grains in non-breaking flows, and dry rock salt in the breaking flows. In all experiments, a portable seismometer was mounted on the top of the apparatus to monitor seismic output.

Results and interpretation

Preliminary results from shearing 5-mm glass beads at a range of rates from 1 mm/s to 1000 mm/s under loads of 100 and 200 kPa showed a significant non-linear drop in apparent friction as the seismic output increased (Fig.1). This may in part be due to an increasing depth of flow as increasing numbers of beads became mobilized, which could be interpreted as a decreasing viscosity of the grain flow with increasing internal grain energy.

Results (Fig. 2) from shearing rock salt were more complex because shear became localized on shear planes as grains crushed. Apparent low-friction, stick-slip sliding developed and emitted a shrill squeal which was outside the recording range of the seismometer. Some puzzling results from the rock-salt experiments were found during subsequent SEM analysis (Fig. 3) and will be investigated in further experiments. It appears that although shear becomes localized, it may not remain fixed in position, but may shift rapidly to new locations. It is possible that the lifespan of a single shear plane is limited by the development of Riedel shears.

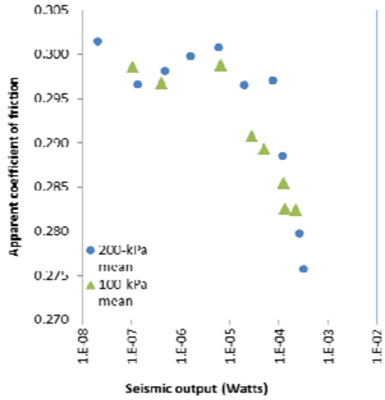

Fig. 1 Variation in frictional resistance of 5-mm glass beads with increasing shear-induced seismic output.

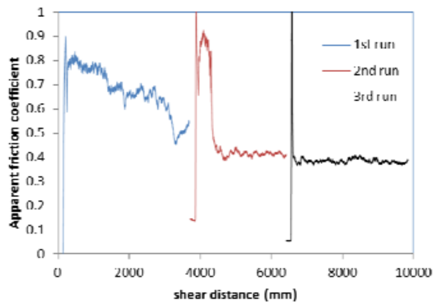

Fig. 2 Reduction in apparent friction coefficient in rock salt sheared at 400 kPa normal load. The three runs refer to stopping and restarting shear after about 4 and 6.5 m of travel distance.

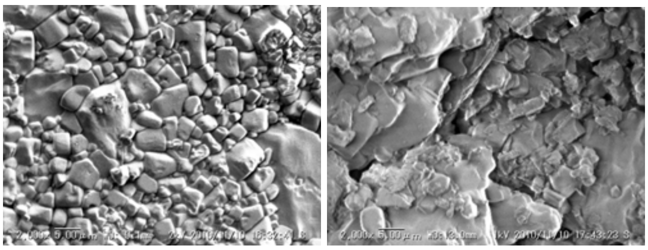

Fig. 3 SEM images of sheared rock salt. (Left) Image of tightly packed grains forming the surface of a shear plane. (Right) Image perpendicular to shear plane and parallel to slip direction. Note the loose packing with voids that appear to be a Riedel shear from lower left to upper right across the centre of the right image. Scale bar is 5 μm.