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Flow law of ice-rock mixtures: Effects of particle size and shape

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Introduction:

In order to study the flow process of ice sheets on the Earth and Mars and the thermal evolution and the tectonics of icy satellites, it is crucial to understand the rheological properties of ice-rock mixtures constituting them. Particularly, the flow law, which shows the relationship between the stress and strain rate as a power law, is one of the most important physical property to apply the experimental results in the laboratory to a large-scale phenomena such as a flow of ice sheet on Mars. The authors examined the flow law of ice-rock mixtures and the dependencies of rock content, porosity, and temperature in detail and proposed a new flow law including these parameters. On the other hand, we should examine more physical parameters such as rock particle size to apply the results to the ice sheets and the icy satellites. In this study, we examined the flow law of ice-rock mixtures depending on the size and the shape of solid particles systematically.

Experimental methods:

We prepared the samples mixing ice grains having the diameter less than 710 micron with two kinds of solid particles, silica beads with a spherical shape and serpentine powder with a polygonal shape. The diameters of silica beads used were 1 mm and 1 micron, and that of serpentine powder was about 100 micron. We made the samples by two methods. One is a pressure-sintering sample (p.s.s.) that the mixtures of ice grains and solid particles were compressed at a pressure of about 50 MPa, and the another is a frozen sample (f.s.) that the mixtures of ice grains and rock particles, and the water at 0 ^{o}C were mixed in a mold. The mass fraction of solid particles was changed from 0 to 80 wt.%. The temperature was -10 ^{o}C. We made uniaxial compression tests under the constant strain rate at ILTS, Hokkaido Univ. The strain rate was from about 10^{-3} to 10^{-6} s^{-1}.

Results:

The strength of both the p.s.s. and the f.s. including 1 mm beads was almost similar to that of pure ice at the beads content lower than 50 wt.%, while it decreased as the beads content increased at the content higher than 50 wt.%. This result for 1 mm beads sample is noted to be quite different from the result for the f.s. including 1 micron beads: the strength for f.s. of 1 micron beads increased with the increase of the content. This could be caused by the difference of the internal structure: in the case of 1 mm beads sample, the ice grain size is almost the same as the bead size, and the beads distribute evenly in the sample. It is supposed that the stress concentration occurs around the beads in the ice grains, so the local deformation rate of the ice increases there. At the beads content lower than 50 wt.%, the distance among beads was enough long, so that the local high deformation rate around the beads does not affect the bulk deformation rate of the sample. At the content higher than 50 wt.%, the distance among beads was enough short, so that the local high deformation rate of ice grains caused by the stress concentration around the beads affected the bulk deformation of the sample. This mechanism causes the difference of the strength depending on the content. On the other hand, the strength of serpentine sample was almost same as that of 1 micron beads sample at the same content. That is, the effect of shape on the flow law was negligible small. Finally, the power law index n of flow law increased with the increase of solid particle content for all samples. This might be caused by the generation of micro-crack.

Keywords: ice-rock mixture, ice sheets on Mars, icy satellites, rheology, rock particle size, rock particle shape