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Basal pore pressure under various conditions in laboratory debris flows over a rigid bed

Norifumi Hotta

Graduate School of Agricultural and Life Sciences, The University of Tokyo, Department of Forest Sciences, Tokyo, Japan (hotta@fr.a.u-tokyo.ac.jp)

Constitutive equations for debris flows have been derived from simple modeling of the laminar motion of sediment particles, focusing on the stress structure of the particles and pore fluid. It is essential to first evaluate/validate the internal stresses of the debris flows to describe their motion precisely. This study measured the basal pore water pressure in debris flows over a rigid bed. Flume experiments were conducted under various conditions (particle size, flume inclination, and flow rate) to clarify the change in internal stress structure with the flow characteristics. Pore water pressure has been measured in actual debris flows in the field, but rarely measured in the laboratory since laboratory debris flows are generally shallow and a very sensitive pressure gauge is required to measure the pore water pressure. We succeeded in measuring the pore water pressure in the laboratory using differential gas pressure gauges. A silicon tube with an internal diameter of 4 mm was connected to the measuring part of the gauge, while aluminum tubing was connected to the opposite end of the silicon tube. A 0.03-mm-thick latex sheet was glued to the end of the aluminum tubing to act as the measurement surface. Based on a calibration with hydrostatic pressure, this sensor showed good linearity, but was easily affected by temperature changes. Therefore, the air and water temperatures were monitored during the tests and calibrated before and after each test. The results indicated that the basal pore water pressure was higher than the hydrostatic pressure. In experiments with large particles (3, 2, and 1 mm), the excess of the hydrostatic pressure corresponded to the theoretical value derived from the constitutive equations for debris flows. The excess pressure was higher with larger particles in these experiments. This is thought to account for the increase in Reynolds stress with increasing mixing length in pore water where the strong shear of sediment particles induces turbulence. Conversely, the excess pressure did not correspond to the theoretical value in experiments with small particles (0.7 and 0.2 mm). For 0.2-mm particles, the excess pressure was much greater than the theoretical value. The pore water pressure in these experiments was nearly equal to the total pressure containing the weight of the particles. It is possible that the flow phase transited from laminar to turbulent in the debris flows with small particles, resulting in the release of internal particle stresses, such as particle-to-particle collisions and friction between the particle surfaces.