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Effects of grain size composition on the representative diameter of debris flows: Laboratory experiments with bidispersive granular materials

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Debris flows are solid-liquid phase flow which generally includes a wide range of grain sizes, from clay and silt to boulders. This leads segregation of coarser grains to the surface and front of the flow and liquefaction of finer sediment, which is involved with pore fluid and regarded as a liquid phase. Although the representative diameter of the grain size distribution should be considered when applying the constitutive equations of debris flows, the best way to determine the appropriate representative diameter that reflects the inherent characteristics of the debris flow remains unclear. This study investigated the effects of grain size composition on the representative diameter of debris flows via laboratory experiments with bidispersive granular materials. We used sediment particles of five different diameters with various grain sizes of the smaller particles: 2.9 mm for grains of larger particles and 1.3 mm, 0.84 mm, 0.23 mm, and 0.11 mm for grains of smaller particles. Focusing on the behavior of the smaller particles, two models for representative diameter determined simply by the material properties were considered to describe flow resistance of debris flows using constitutive equations. These models were (i) the average diameter of the larger and smaller particles (: Model 1) and (ii) the diameter of the larger particles with no contribution from the smaller particles to interparticle stress (: Model 2). To examine which model can describe the flow resistance better, we introduced a decoupling factor as contribution rate between these two models: the value of 0 and 1 for cases described completely by Model 1 and 2, respectively. Decoupling factors of mixtures of 1.3 mm and 0.84 mm grains had the value of almost 0, whereas decoupling factors of other mixtures exhibited intermediate values between 0 and 1. This indicates that the smaller particles do not necessarily behave as a completely solid or liquid phase, and the representative diameters are determined not only by the material properties but also by the kinematic conditions. When we consider turbulent conditions of pore fluid using the ratio of turbulence velocity to settling velocity, the decoupling factor values were positively correlated with the turbulent conditions, indicating that the behavior of the smaller particles is affected by the turbulence of the pore fluid. This leads to the conclusion that the smaller particles may behave as intermediate way between solid and liquid phase depending on the turbulent conditions of the pore fluid; therefore, the representative diameter should be determined considering such behavior of finer sediment.