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The fluidity of boulder debris flows is affected by fine sediment in the pore water

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Basic equations for debris flows are frequently derived using the simple assumption of monogranular particles. However, actual debris flows include a great diversity of grain sizes, resulting in inherent features such as inverse grading, particle size segregation, and liquefaction of fine sediment. The liquefaction of fine sediment affects the fluidity of debris flows, although the behavior and influence of fine sediment in debris flows have not been examined sufficiently. This study used flume tests to detect the effect of fine sediment on the characteristics of laboratory debris flows consisting of particles with two diameters: one diameter was fixed at a large particle size, while the small diameters were varied with the experimental conditions. From the experiments, the greatest sediment concentration and flow depth were observed in the debris flows mixed with finer sediment, indicating increased flow resistance. Then, the experimental friction coefficient was compared with the theoretical friction coefficient derived by substituting the experimental values into the constitutive equations for debris flow. The theoretical friction coefficient was obtained from two models with different fine-sediment treatments: one assuming that all of the fine sediments were solid particles and the other that the particles consisted of a fluid phase involving pore water liquefaction. A discriminant index was introduced to clarify which contribution from the two models could better explain the experimental results. The comparison of the friction coefficients detected a fully liquefied state for the finest particle mixture with sediment. However, even with the same particle size, the debris flows could be regarded as a liquefied state, a solid state, or a partially liquefied transition state depending on the experimental conditions other than the sediment particle size. These results infer that the liquefaction of fine sediment in debris flows was induced not only by the geometric conditions that allowed small particles to be stored in the interstitial space of large particles but also by the flow conditions: i.e. "fine sediment" and "coarse grain" in the debris flows of mixed particle sizes can be defined according to the kinematic conditions.