



Granular effect on debris flow rheology

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Debris flow is characterized by the multi-disperse grain composition and intergranular collision and friction, but the granular effects on rheology are often reduced to the volumetric concentration of solid (C_v), almost ignoring the specific grain size distribution (GSD). In this study, small debris flows occurring in a tributary of Jiangjia Gully were taken as the material sources for rheology experiments. From the real flows we selected slurries with different C_v and maximum grain sizes (D_m) for rheological tests under shearing rate up to $40 \text{ (s}^{-1}\text{)}$, which is usually the real rate for debris flows in natural conditions. The results indicate that the flows follow the Herschel-Bulkley (HB) rheology, with randomly changing consistency coefficient and relatively constant exponent of 0.45 on average. Only at high shear rate will the flow exhibit Bingham behavior. The HB rheology also reveals shear thinning behavior in surge phenomena observed in the field. Shear-thinning behavior is revealed by the viscosity-shear rate relationship: $\eta_a = p\dot{\gamma}^q$, with the exponent (thinning index) dependent on shear rate. This greatly concerns the surge phenomena observed in field. Moreover, both the yield stress and the effective viscosity are found to be perfectly related to the scaling GSD parameters in power-law and exponential form, with nearly constant exponents independent of the shear rate (Figure 1). The rheology properties can be calculated from their relationships to GSD parameters (μ , D_c), which in turn can be used to infer the HB rheology for the concerned flows and then build the dynamical equations (Figure 2). This implies the presence of some interlock between the fine and coarse grains. Finally the rheology model (general in HB form) can be completely determined by the GSD parameters. This study has for the first time proposed quantitative formulas for rheology incorporating GSD parameters, which is helpful for more accurate dynamic analysis of debris flow.