Dynamics and theoretical analysis of granular mass flows with high mobility

A granular material is a large collection of discrete solid particles, with fluids (water and air) filling the interstices between the particles. If the interstitial fluids play an insignificant role in the transportation of momentum, the flows of such materials may be considered as dispersed, single-phase flows. There are a lot of loosely deposited granular materials in Tibet due to glacier movements, and they can easily become instable due to intense rainfall and/or earthquakes and induce large-scale granular mass flows. Different from most of landslides which move like a rigid body, the granular mass flows in nature usually behave like liquids and have rheological properties. Usually, the granular mass is composed of loose solid particles with large diameters, and particles inside the mass have close contacts with each other and form contact structures, which play key roles on the flow dynamics (e.g., high speeds and long runout distances).

The continuum treatment of granular flows is an extension of fluid flows. Although some previous studies have concentrated on granular flow dynamics at the microscopic level, the continuum representation of granular materials in terms of the conservation of mass and momentum has remained a center of attention. Generally speaking, these studies use a depth-average "hydraulic" model with a Coulomb-type basal friction law or an empirical approach (e.g., the Voellmy model) to analyze granular flows. This method treats the granular system like a rigid block with no rheological properties. The frictional coefficient μ is a constant and remains unchanged during the entire flow process. Numerical models that apply the Coulomb-type basal friction law do not perform well in terms of prediction accuracy.

In this study, a new theoretical framework is developed by taking into account the contact friction, shear rate dependency, and effects of channel confinement on flow behavior. The new mathematical model considers the rheological properties of granular flows and the parameters representing different material properties have clear physical meanings.