Rheology of granular materials in slope flow

Jin Sun[1,*]

[1] School of Engineering, The University of Edinburgh, 3.07 Alexander Graham Bell, Edinburgh EH9 3JL, Scotland UK

[*] Corresponding author. Tel: +44-0131-651-9028; E-mail: J.Sun@ed.ac.uk

Abstract

Natural disasters, such as landslides and earthquakes, usually lead to large deformation and flow of the granular materials involved. Understanding such behaviour of granular materials is thus important for modelling and simulation of natural disaster events. The study of granular flows, i.e., rheology, has made significant progress in the past two decades, achieving fuller understanding of the steady flow behaviour. The unsteady flows, however, still pose many challenges for a universal model(s).

In this presentation, I will first introduce our findings of the rheology of dry granular flows, including the flow regimes for steady flows and rheological models for steady as well as unsteady flows. The flow regime analysis shows that master flow curves can be obtained by properly scaling stress and shear rate using the solid volume fractions, grouping the behaviour of flows at different volume fractions into the inertial, quasistatic and intermediate regimes. The unsteady flow model demonstrates the importance of incorporating microstructure in describing the evolution of the rheological properties.

I will then present the applications of the regime map and the rheological models in flow down slopes. For a particular case of steady vertical chute flow, it can be shown that a linear version of the inertial rheology, for which the bulk friction and steady solid volume fraction depend on the inertial number, predict a linear relation between the chute width and the size of the shear zones at the walls, in good agreement with the corresponding discrete element simulation results. This finding contrasts with previous works on purely quasi-static flow, which instead predict a roughly constant shear zone width.

For more complex flows, however, the rheology can deviate significantly from the steady state flow curves; whilst the flow regimes remain relevant to understanding the flow behaviour. I will show that in earthquake-induced landslides, the vibration modifies the inertial steady-state flow to an extent that its flow curves deviate from, but parallel the inertial master curve; in an erodible bed on a slope, the granular materials deep in the bed can display quasi-static behaviour, which again differs from the steady state. Such behaviour poses challenges for constructing rheological models for flow conditions relevant to natural disasters. Potential development in this regard will be discussed.