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Slumping of a granular mass on an unconfined slope

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Dense granular flows generated by slumping of granular mass are often encountered in industrial processes where the transport and deposition of granular material such as seeds, cereals, and tablets are involved. They are also observed in geophysical systems, such as pyroclastic flows caused by collapse of a lava dome or volcanic explosions, snow avalanches, and landslides.

Constructing a numerical model to capture the major characteristics of spreading granular materials in the above situations is a significant challenge because the mechanics of the grains and their interactions are incompletely understood at a fundamental level. This study investigated the dynamics of dense granular materials, released from rest and allowed to flow down an unconfined slope, driven by gravitational forces. First laboratory experiments were performed to study granular slumping, in which a measured volume of materials were instantaneously released from a cylindrical tube and spread across an unconfined rigid plane inclined at angles less than the repose angle. On release from the source the particles initially spread radially. However up-slope motion is rapidly arrested and motion down the incline is promoted, leading to an approximately ellipsoidally-shaped deposit once the flow has been fully arrested. Secondly, the flows were modeled under the shallow layer approximation and integrated numerically to capture the motion from initiation to final arrest. In modelling, two types of Coulomb-type friction models were introduced. One has a constant friction coefficient, and another has a friction coefficient that depends upon the dimensionless inertial number of the motion. When the initial aspect ratio of a granular mass and the slope angle is low ($<$ 5 deg), the model with a constant friction coefficient can capture the deposit shape; but when the slope angle is increased, the inertial-number dependent friction model becomes more important. For high aspect ratio granular columns, the shallow water model fails to reproduce some aspects of the experimental observations. Finally an example of model application to geophysical systems is introduced.

Keywords: granular flow, slumping, pyroclastic flow, Coulomb friction law, shallow water theory