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# GRANULAR MATERIAL AS A CONTINUUM: NONSMOOTH SIMULATIONS AGAINST EXPERIMENTS

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**Key Words:** Continuum Simulation, Experimental Granular Collapses, Frictional Hysteresis

In this study, simulated and experimental column collapses were obtained by releasing a granular mass down inclined loose beds. Accurate predictions of this transient flow configuration remain challenging since dilatancy, frictional hysteresis, as well as phase transitions may play active roles.

Numerical simulations were performed relying on the SAND6 code [1], which models granular matter as a continuum and resolves an *exact Drucker-Prager yield criterion* by leveraging nonsmooth optimisation tools formerly deployed for discrete contact dynamics approaches. By tracking solid fraction with the Material Point Method (MPM), the granular flow is able to traverse through its different phases – gas, fluid and solid. This strategy has been shown to perform efficiently in various flowing configurations [1], but requires additional experimental validation to assess its predictability. To this end, we have performed experimental granular collapses in a narrow flume (6-cm-wide) with slopes varying from 0° to 20° and two different materials respectively composed of monodisperse 0.5 mm beads or natural sifted 3.7 mm gravel. To locate the free surface, image sequences were recorded from the side with a high-speed camera. In addition, velocity fields were recorded using a tailored Particle Image Velocimetry (PIV) algorithm based on *optical flow* determination.

We demonstrate that nonsmooth three-dimensional simulations performed with friction coefficients measured independently can reproduce the experimental collapses with good accuracy. Side-wall effects are shown to be negligible in our configurations. A finer study also reveals the role played by the frictional hysteresis. To conduct this analysis, the  $\mu(I)$ -rheology was modified at low inertial regimes following [2] and in agreement with [3]:  $\mu(I)$  sharply decreases at low inertial numbers ( $I \ll 0.1$ ) and then increases for higher  $I$  ( $I \gg 0.1$ ). We observe that this ingredient allows for more accurate simulations of granular collapses and could consequently be appropriate to better forecast the behavior of the complex granular flows observed in natural or industrial processes like avalanches, levees, or retrogressive failures.

## REFERENCES

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