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Influence of obstacles on the dynamics of rapid granular chute flows

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We experimentally and numerically analyze the influence of obstacles on the dynamics of a rapid granular chute flow. A high-speed camera is used to capture the detailed flow processes and to extract the flow velocities, flow geometry and the interface between the solid- and fluid-type granular regimes through the flow depth. First, a short inclined plane that fits with the channel width is introduced with a relative angle of 45° to the down-slope direction. PVC and sand, with only a small difference in internal friction angles, are analyzed in detail. PVC (with smaller friction angle, $\phi = 33^\circ$) overflows the obstacle without depositing the material while flowing. Steady-state flow is quickly established for this material. However, as the sand (with a slightly larger internal friction angle, $\phi = 37^\circ$) encounters the obstacle, it begins to settle, and consequently shock waves develop until a steady state is reached where the flow occurs only in a relatively thin fluidized surface layer over the deposited material. This demonstrates that a small difference in the internal friction angle can lead to fundamental changes in the flow-obstacle interactions in rapid granular flows down slopes. This is a significant advance in our understanding. The second obstacle (which also covers the channel width) is a long wall erected perpendicular to the channel. We analyzed in detail the influence of the inflow velocity and height, and the inclination angle of the channel, on the deposition processes that includes strong shock wave generation and propagation.

We compare our experimental results with a new two-dimensional numerical channel flow simulation. A parametric analysis is performed for varying angles and lengths of the obstacle, the internal and bottom friction angles, inclination angles of the chute, and the inflow velocities and heights. In the vicinity of the flow obstacle interaction, large gradients in the flow fields (e.g., velocity and pressure) can develop in the direction of the flow depth. Because we can determine in detail the basic parameters and the dynamical quantities of the flow in these flow configurations, our physical model and numerical simulation method significantly improves on the typical depth averaged models. Our findings improve the understanding of rapid granular flows around obstacles, and thus helps in design and construction of more effective catching dams and for improved prediction of overtopping of existing dams.