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Force from granular flows on a wall-like obstacle: contribution to snow avalanche dam design

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Dense avalanches of granular snow can lead to huge damages on structures: buildings, protection dams, etc. Understanding the influence of obstacles on flows of granular fluids and the force that granular fluids can exert on the obstacle is therefore of crucial interest. Our study deals with both steady and avalanche granular flows down an incline, and overflowing a wall-like obstacle. Small-scale discrete numerical simulations were carried out in various incident flow regimes from a slow dense regime to a rapid dilute regime. In the rapid dilute regime, the mean force is mainly driven by the kinetic energy of the flow. It scales as the velocity square similarly to the inertial regime for newtonian fluids such as water and air. In the slow dense regime, the property of granular materials to behave as a solid leads to the formation of a large stagnant zone upstream of the wall-like obstacle. The length of the stagnant zone diverges when the slope decreases toward a critical slope determined by the frictional properties of the granular medium. The resulting weight, balanced by basal friction, largely contributes to the total force on the wall. This latter can reach a value several times greater than the typical hydrostatic force of the undisturbed incident flow. This transition is well described by a hydrodynamic continuum model derived from the Euler theorem both in steady and unsteady states. Because of experimental evidence of similar behaviors between snow and granular flows, the continuum model is a good candidate to derive the mean force from major dense snow avalanches likely to overflow protection dams built in avalanche prone areas.