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Interaction of two-phase debris flow with obstacles

by

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Landslides, debris avalanches and debris flows are common geophysical events in mountainous countries, causing tremendous damages to people and infrastructures. Their dynamics are substantially affected and altered by the obstacles like trees, big boulders and civil structures on their way. Appropriately designed and optimally installed obstacles, including the breaking mounds, catching or deflecting dams, in the flow path can dramatically change the flow dynamics by deflecting, re-directing or arresting the debris mass. Properly engineered obstacles can tremendously reduce the momentum and kinetic energy of the flow so that the events may become much less devastating, or even harmless. So, the proper understanding of the flow-obstacle-interaction is required to construct desired defense structures for prevention and mitigation of such events.

Here, we simulate a two-phase debris flow as a mixture of solid particles and viscous fluid down an inclined plane with integrated obstacles (called Vindhyas) of different dimensions, shapes, sizes, numbers and spacing. This is achieved by employing a sophisticated and physically-based general two-phase mass flow model (Pudasaini, 2012) consisting of a set of highly non-linear and coupled partial differential equations representing mass and momentum conservations for both the solid- and fluid-phases. Simulations are performed with high-resolution and efficient numerical schemes capable of capturing rapid and detailed dynamics, including the strongly re-directed flow with multiple stream lines, mass arrest, strong shock waves and debris-vacuum generation and their pattern formations, as the rapidly cascading mass suddenly encounters the obstacles. Some novel simulation results are presented for the estimation of the impact pressures on the obstacles and the obstacle-induced reduction of kinetic energy with their physical significance. The solid and fluid phases show fundamentally different interactions with obstacles, flow spreading and dispersions, run-out dynamics and deposition morphology. These are novel results for two-phase debris flows past obstacles, their dynamics and depositions. These results are in line with natural debris flows and experimental results. Our understanding of the complex interactions of real two-phase mass flows with the multiple obstacles helps us to construct defense structures and constitute advanced and physics-based engineering solutions for the prevention and mitigation of natural hazards caused by different geophysical mass flows.

Keywords: Landslides, Debris flows, Two-phase mass flows, Flow-obstacle-interactions, High-resolution numerical simulations, Shock waves, Impact vacuum

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