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Effect of friction properties on kinematics and internal deformation of granular slopes: insights from analogue modeling

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Collapses of granular materials frequently occur in nature in the form of, for example, rock avalanches, flow slides, debris avalanches and debris flow. It is of great importance to understand the kinematics and dynamics of this kind of rapid movement of granular materials. A series of analogue models are used to investigate the effect of friction properties of granular materials on the 3D internal structures during the collapse of slopes. Model results show that the collapse of slopes results in formation of different-generation normal faults in the rear of the failure mass and shortening structures in the front of the failure mass. The first-generation, steep normal faults (dipping about 60º) cut across the entire stratigraphy of the slope, and involve the bulk volume of the failure mass. In contrast, the later-generation normal faults (dipping about 40º) cut only across the shallow units, and involve less amount of the failure mass. Different-generation normal faults differ in amount of displacement they accommodate. Displacement along the same-generation normal faults decreases continuously from the middle section to sections on both sides of the slope. As such, some normal faults die out in sections on both sides of the slope. In other words, more normal faults generate within the middle section of the failure mass. Model results show that shortening structures, including round-hinged folds, tight isoclinal folds, overturned folds, and sheath folds, are also observed within the failure mass. Differential velocity within the failure mass results in the formation of round-hinged folds and sheath folds. With the advancement of granular flow, overturned folds generate due to the rotation of the axial plane in the flow direction. Progressive deformation of these overturned folds leads to the generation of tight isoclinal folds. Model results show also that friction properties have a significant influence on the internal deformation within the granular mass. Granular mass was displaced much further in the model with lower internal friction. More extensional faults were observed in the model with higher internal friction, whereas more shortening structures were observed in the model with lower internal friction. Displacement along the first-generation normal fault (i.e. the main failure surface) becomes larger in the model with lower internal friction.

Keywords: slumping structures; faults; folds; analogue models; granular flow