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On the finite length-scale of compressible shock-waves formed in free-surface flows of dry granular materials down a slope

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The Rankine-Hugoniot jump conditions traditionally describe the theoretical relationship between the equilibrium state on both sides of a shock-wave. They are based on the crucial assumption that the length-scale needed to adjust the equilibrium state upstream of the shock to downstream of it is too small to be of significance to the problem. They are often used with success to describe the shock-waves in a number of applications found in both fluid and solid mechanics. However, the relations based on jump conditions at singular surfaces may fail to capture some features of the shock-waves formed in complex materials, such as granular matter. This study addresses the particular problem of compressible shock-waves formed in flows of dry granular materials down a slope. This problem is for instance relevant to full-scale geophysical granular flows in interaction with natural obstacles or man-made structures, such as topographical obstacles or mitigation dams respectively. Steady-state jumps formed in granular flows and travelling shock-waves produced at the impact of a granular avalanche-flow with a rigid wall are considered. For both situations, new analytical relations which do not consider that the granular shock-wave shrinks into a singular surface are derived, by using balance equations in their depth-averaged forms for mass and momentum. However, these relations need additional inputs that are closure relations for the size and the shape of the shock-wave, and a relevant constitutive friction law. Small-scale laboratory tests and numerical simulations based on the discrete element method are shortly presented and used to infer crucial information needed for the closure relations. This allows testing some predictive aspects of the simple analytical approach proposed for both steady-state and travelling shock-waves formed in free-surface flows of dry granular materials down a slope.