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Numerical Modeling of Non-Newtonian Flows within a Newtonian Equation Framework

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Gravity driven flows such as debris, pyroclastic, avalanche, landslides etc. pose a great threat to life and property. In recent years rainfall combined with prior fire events have resulted in the generation of debris flows in the United States and elsewhere, landslides and mud flows are common occurrences in several regions of the world where monsoon rains cause soils to saturate, slump and then flow. In some regions these flows take the form of sand, boulders or other cohesionless material generated flows, and avalanches. These flows exhibit non-Newtonian flow characteristics, and provide a challenging engineering problem. These problems arise in the prediction of these flows as well as devising engineering solutions to alleviate danger these pose to the public. Since the advent of numerical modelling, engineers and scientists have used shallow-water equation based mathematical equations to simulate Newtonian flows. In the recent past researchers have attempted to use modifications to the stress terms in the shallow-water equations to account for non-Newtonian behaviour. However these modifications, in general, rely on just one or two of the non-Newtonian formulations to mathematically represent and then numerically simulate non-Newtonian flows. The non-Newtonian behaviour of flows is dynamic, and can change non-Newtonian states depending upon a variety of properties. These properties are inherent to the flows and depend upon the formative process, composition, as well as grain sizes of the debris. Therefore, the requirement is that of a mathematical and numerical description that accounts for these changing states. The Engineer Research and Development Centre (ERDC) of the U.S. Army Corps of Engineers (USACE) has developed a library of debris processes, DebrisLib. This, model agnostic, debris processes library can be linked to any shallow-water based hydrodynamic driver to enable the simulation of debris flows, and the changing non-Newtonian state of the debris flow. This presentation will demonstrate the mathematical development, and incorporation of DebrisLib into the USACE finite element and adaptive meshing software Adaptive Hydraulics (AdH). The implementation will be demonstrated using application to flume tests, avalanches as well as landslides.