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Rheological characterization of large particle fluids

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Determining the rheological behavior of debris flows is a difficult task because they encompass a very wide range of particle sizes and flow conditions, whereas the rheological characterization of debris flows is limited by the size of particles involved in the experiments. Because of these limits the results achieved in the laboratory tests could be not representative of the whole material. The present work is an attempt to characterize the rheological behavior of a granular suspension by progressively changing the grain-size distribution. The aim was to determine the trend in the change of rheological properties and parameters (i.e. yield strength and viscosity) at changing the grain size distribution of the material.

Three samples have been analyzed at different solid concentration (from 38.0% to 54.2% by volume). The laboratory experiments have been initially performed on the fraction finer than 0.075 mm. Then fine sand (up to 0.425 mm in grain size) was progressively added at different percentages varying from 10% to 50%. A vane apparatus connected to a rheometer was used to perform the experiments in a control rate mode. The reproducibility of the results was within $\pm$12%.

The clay-finer fraction controls the viscoplastic behavior, while the silt and sand fractions act both at determining the frictional character of the flow and the magnitude of the viscosity and yield strength. This results in a non linear change of the rheological parameters with the increase of the coarse fraction content.

For a material mainly composed of fine sand, with a clay-finer content of 5-8%, (i) an increase of the particle dimensions results in a change from a shear-thinning to a shear-thickening behavior; (ii) the percentage of coarse (sand) particles affects the magnitude of the rheological parameters, and its effect is not straightforward; (iii); the increase of the yield-strength and the viscosity with solid content is more rapid for

more poorly sorted coarse material.

In the perspective of debris flow modeling this implies that (i) the rheological behavior is best described by the Herschel-Bulkley model, while the plastic viscosity, commonly used by the models which assume a Bingham behavior, underestimates the apparent viscosity; (ii) because of the different kinds of interactions prevailing at the different grain sizes, the extrapolation of the rheological parameters to a wider range of particle sizes could be misleading.