Effect of the Clay Type on the Behaviour of Dense Granular Suspension

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Field observations show that the role of clays in the dynamics of dense granular suspensions has been underestimated. This work aims at exploring to what extent the clay, and in particular the proportion of swelling clay, influences the macroscopic rheology of a simulated alpine debris flow of rock grains where the size spectrum extends over 6 orders of magnitude.

A model mixture was created from calibrated materials (see Figure 1) to produce a grain size distribution similar to that of a viscoplastic behaviour (Bardou et al., 2003). Four replicates were made with the same grading curve. The clay content of the samples was 3% dry weight only, and different 2:1 swelling clay to 1:1 clay ratios were investigated. The swelling clay ratio (SCR) was calculated as the percentage of 2:1 clay in the clay fraction of the bulk samples. The 1:1 clay was an industrial kaolinite and the 2:1 clay was a smectite derived from a natural soil. The smectite content in the bulk sample ranged from 0% to 2% dry weight, corresponding to an SCR ranging from 0 to 80%. The rheological behaviour of the four prepared samples was studied using the large-size apparatus (30kg lots) fully described in Tattersall and Banfill (1983). This apparatus is based on the computation of the torque necessary to rotate an impeller immersed in the sample at a given rate. The impeller is driven via a variable-speed hydraulic drive unit motor, and the torque is measured indirectly via the oil pressure. One sample can be tested at numerous speed values. The impeller has the form of an "H" and moves in a plane according to two parallel axes. The impeller system is driven by a gear box, which has an offset gear ratio that is not a whole integer, avoiding the creation of preferential paths.

The observed behaviours were very different. The sample with SCR=0 was relatively insensitive to changes in the solids concentration,at least for a certain range of solid concentration. This was in contrast to the three samples with SCR>0 where increasing the swelling clay fraction induced a dramatic change of the behaviour of the mixture which now showed a power law behaviour as solids concentration increased.

These tests carried out in the laboratory agree with observations made on natural debris flow material tested on a smaller rheometer. Although these results can’t be directly scaled-up to a quantitative assessment of the effects of changes in the SCR on alpine debris flow they have, however, several implications for rheological studies. The hydrodynamic effect of a matrix that contains a swelling clay seems to be more intense, that is more qable to sweep along sediment. Although representing a very small part of the total bulk material (0.5to 2%), the swelling clays cannot be neglected in the analysis of such mixtures. Moreover, colloid properties of these clays are very sensitive to factors such as electrolyte composition, clay surface chemistry and shaking(shear) energy. Therefore, the electrolyte used in test the materials, and contact time with between the electrolyte and solid phase for chemical equilibration, should be carefully selected with respect to field conditions.

References

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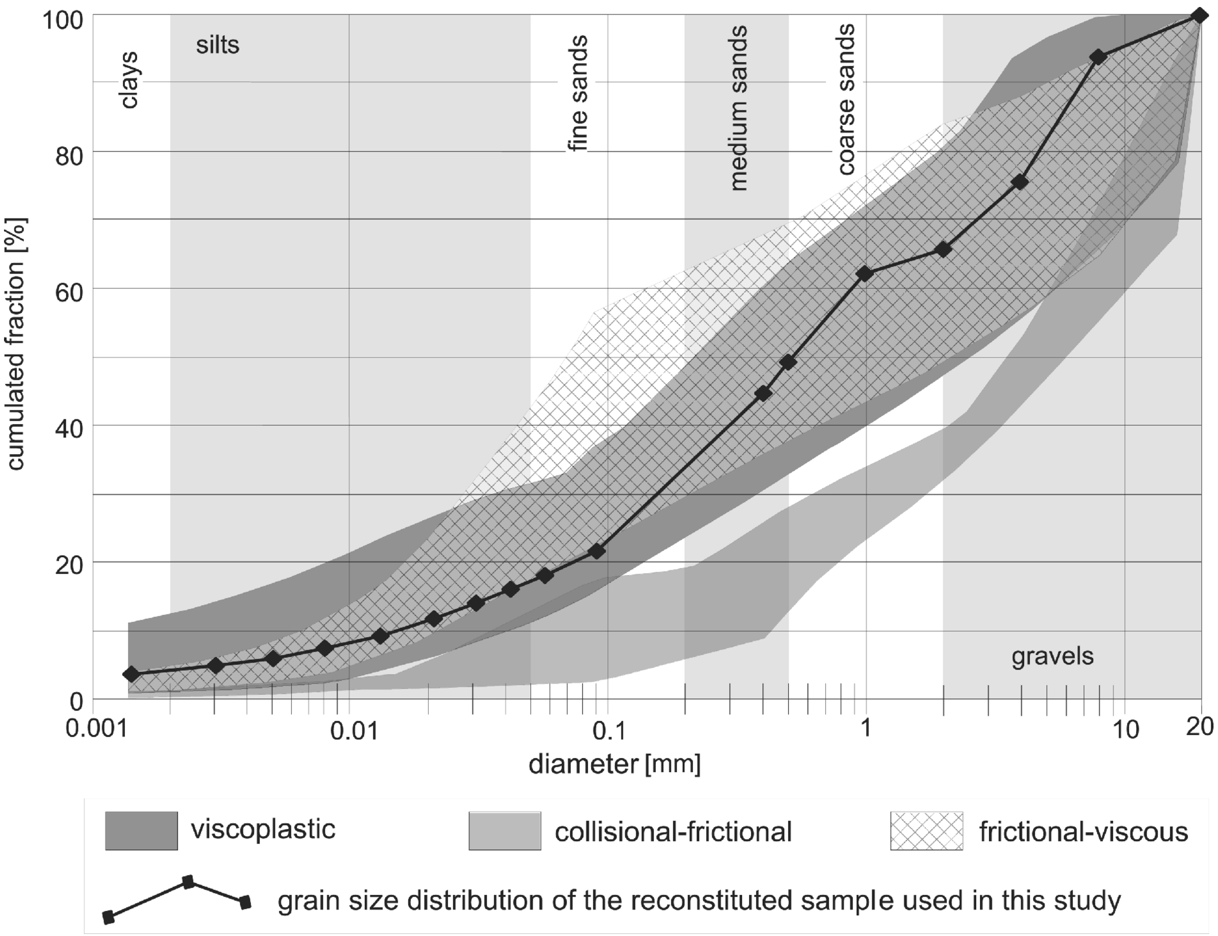

Figure 1: Grain size distribution of the model material on the basis of the mechanical domains determined for natural debris flow (adapted from Bardou et al., 2003).