Data assimilation for the calibration of flume tests with different granular mixtures

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**Introduction**

The flowslides (mud-flow, debris-flow, etc.) often cause large economic and social damages. Besides the mechanisms that rule their triggering, the comprehension of their propagation represents an important aspect to be addressed, because it affects the reliability of different risk scenarios and the evaluation of mitigation strategies.

The flow-slide kinematics are mainly related to the rheology of the involved materials that in turn depends on the mutual concentration of the component phases: the water, the fine matrix and the coarse fraction.

In order to understand the composition effects on the kinematics of flowslides several flume tests were carried out using different kaolin-sand mixtures. On the base of the experimental results the constitutive parameters are now under determination using a data-assimilation numerical procedure applied to the test simulation obtained with a particle-based SPH code (Brezi et al., 2015). This procedure should permit to fine-tune the constitutive parameters determined in laboratory on the component and individuate the most suitable values for describing the observed propagation. The analysis is still in progress and here we comment only some preliminary results.

**The Experimental Apparatus**

A 10 dm3 prismatic container that discharges the material inside a channel 2 m long and 0.16 m wide composes the experimental apparatus. The chute base is roughened by glued sand and inclined with a 21.5° angle. A smooth horizontal plane is located at the end of the channel for the mass arresting. The mass collapse was triggered by rapidly pulling forward a bulkhead; the same mechanical system started the data acquisition of three ultrasonic flow meters recording of the flow height with time along the channel. Moreover, a camera captured the run-out behavior of the mass through the transparent walls of the chute.

Mixtures of water with kaolin (WK) or sand (WS) or both (WKS) were used in tests: Table 1 summarizes the performed test and the density of the mixtures in relation to kaolin and sand contents with respect to total volume. Finally, for each WK mixture, viscous properties were determined in a rotational viscometer (Zulpo, 2014).

**Numerical Propagation Model and Fitting Process**

The calibration procedure employs an Ensemble Smoother (ES) algorithm to provide improved estimations of rheological parameters. The ES is a Bayesian data assimilation method which, minimizing the variance of the estimation error, merges “prior” information from a numerical/theoretical model with data collected from the real phenomena, in order to produce a corrected “posterior” estimate (Bau D., 2013). The fitting procedure follows a two-step forecast-update process: the forecast process was obtained using a Monte Carlo simulation of the sys-tem state applied in a propagation model, while the update of the prior information takes place when available measures are assimilated by applying a specific filter to the forecast model results. The comparison between the heights recorded in laboratory and the ones obtained by the propagation model makes it possible to have precise information about the most suitable parameters.

The propagation model is a 2D depth-integrated model developed by Pastor et al. (2008), which takes advantage of the SPH particle-based approach to just follow large deformations like those expected in flowslides. The material was studied as an “equivalent fluid” governed by a Bingham rheological law (O’Brien & Julien, 1988), which is characterized by the yielding stress τ and the viscosity μ.

**Results and Final Remarks**

As it should be predictable, from flume tests it was derived that the run-out behavior is controlled by both kaolin and sand concentrations, but here, for lack of space, we comment only the results of data assimilation process. In Figure 1 the soil heights measured in the control sections in the WK24 test are compared to the simulated heights obtained adopting the parameters from the viscosity test, i.e. τ=23.5Pa and μ=0.05Pa s; in this case, the mean absolute error (MAE) is 3.48mm, indicating that the numerical model well describes the test. After the application of the ES algorithm, the updated parameters become τ=6.5Pa and μ=0.15Pa s, reaching a MAE of 3.26mm. In the test with WK19 mixture, the simulation performed with parameters from viscometer (τ=5.54Pa and μ=0.016Pa s) has a MAE of 3.05mm and the ES algorithm application indicated as the best set the τ=58.89Pa and μ=0.017Pa s with a MAE reduced to 2.78mm.

Since the algorithm deeply and alternatively modifies τ and μ values without equally reducing the MAE, in this moment we cannot arrive to definitive conclusions and other analysis must be performed. The ES algorithm probably needs more accurately and informative data for a good convergence and stability. Looking at the dependence of MAE from the τ-μ values (Figure 2) we observe that τ variations have a small influence on the performance of the model, while μ seems to have a fundamental role. On this aspect, it is important to notice that the measurements give information about the inclined part of the canal, where the velocities are high, but any information about the deposition area are available and this fact, probably, prevents to have a clearly calibration of τ, which is more important in quasi-static conditions.