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

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INTRODUCTION

The flow-slides could often cause large economic and social damages. 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 kinematic is mainly related to the rheology of the involved materials that in turn depends on the mutual concentration of the component phases. For understanding the composition effects on the kinematic of flow-slides 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 simulations obtained with a particle-based SPH code (Brezzi et al., 2015). This procedure should permit to fine-tune the constitutive parameters determined in laboratory and individuate the most suitable values for describing the observed propagation. The analysis is still in progress, so here we comment only some preliminary results.

EXPERIMENTAL TESTS

A $10 dm^3$ prismatic container that discharges the material inside a channel 2m long and 0.16m wide composes the experimental apparatus. The chute base, 21.5° dip on the horizon, is roughened with glued sand. A smooth horizontal plane is located at the end of the channel for the mass arresting. The mass collapse is triggered by rapidly pulling forward a bulkhead; the same mechanical system starts the data acquisition of 3 ultrasonic flow meters recording of the flow height with time along the channel. Moreover, a camera captured the run-out behavior of the moving mass.

Mixtures of water with kaolin (WK), sand (WS) or both (WKS) were used: 16 tests were totally performed, changing the sand and kaolin contents and consequently the mixture densities.

PROPAGATION MODEL AND FITTING PROCESS

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 flow-slides. The material is studied as an equivalent fluid governed by a Bingham rheological law (O'Brien and Julien, 1988), which is characterized by the yielding stress τ and the viscosity μ. 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 the numerical model with data collected from the real phenomena, to produce a corrected posterior estimate (Baù, 2013). The fitting procedure follows a two-step forecast-update process: the forecast process is obtained using a Monte Carlo simulation of the system state applied in the SPH 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 SPH model makes it possible to have precise information about the most suitable parameters.

RESULTS AND FINAL REMARKS

As predictable, from the 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 data assimilation process results. In Fig. 1 the soil heights measured in the control sections with the WK24 test (24% of kaolin above the total volume) are compared to the simulated ones obtained adopting the parameters from the viscosity test, i.e. τ=23.5Pa, μ=0.05Pa·s. In this case, the mean absolute error (MAE) is 3.48mm, indicating a good likeness of the model to

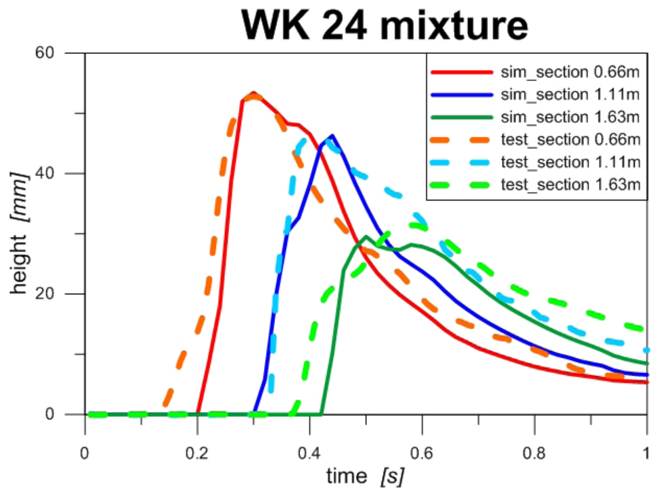

Figure 1. Graphs of the heights of the material versus time for the WK24 mixture.

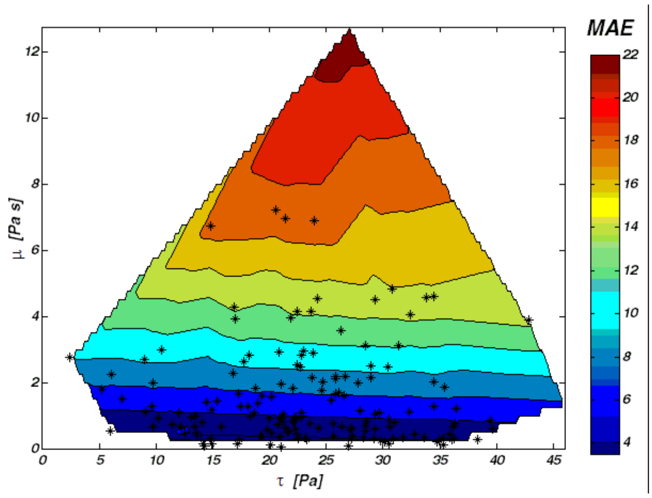

Figure 2. MAE behavior in depending of the parameters set chosen.

the test. After the application of the ES algorithm, the updated parameters become τ=6.5Pa, μ=0.15Pa·s, with a MAE of 3.26mm. In the WK19 test (kaolin content = 19%), the simulation performed with parameters from viscometer (τ=5.54Pa, μ=0.016Pa·s) has a MAE of 3.05mm and the ES algorithm application indicated as the best set τ=58.89Pa, 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, temporarily we cannot arrive to definitive conclusions. The ES algorithm probably needs more accurately and informative data for a good convergence and stability. Looking at the dependence of MAE from the -μ values (Fig. 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 sloping part of the canal, where the velocities are high, but none about the deposition area and this fact, probably, prevents to have a clearly calibration of τ, which is more important in quasi-static conditions.

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KEYWORDS

mud-flows; laboratory tests; data assimilation; calibration; back analysis

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