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Sensitivity of numerical simulation models of debris flow to the rheological parameters and application in the engineering environment

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Debris flows represents serious hazards in mountainous regions. For engineers it is important to know the quantitative analysis of the flow in terms of volumes, velocities and front height, and it is significant to predict possible triggering and deposition areas. In order to predict flow and deposition behaviour, debris flows traditionally have been regarded as homogenous fluids and bulk flow behaviour that was considered to be controlled by the rheological properties of the matrix. Flow mixtures with a considerable fraction of fines particles typically show a viscoplastic flow behaviour but due to the high variability of the material composition, complex physical interactions on the particle scale and time dependent effects, no generally applicable models are at time capable to cover the full range of all possible flow types.

A first category of models, mostly of academic origin, uses a rigorous methodological approach, directed to describe to the phenomenon characterizing all the main parameters that regulate the origin and the propagation of the debris flow, with detail attention to rheology. A second category, which are referred mainly to the commercial environment, has as first objective the versatility and the simplicity of use, introducing theoretical simplifications in the definition of the rheology and in the propagation of the debris flow.

The physical variables connected to the rheology are often difficult to determine and involve complex procedures of calibration of the model or long and expensive campaigns of measure, whose application can turn out not suitable to the engineering environment. The rheological parameters of the debris are however to the base of the codes of calculation mainly used in commerce. The necessary data to the implementation of the model refer mainly to the dynamic viscosity, to the shear stress, to the volumetric mass and to the volumetric concentration, that are linked variables.

Through the application of various bidimensional and monodimensional commercial models for the simulation of debris flow, in particular because of the reconstruction of famous and expected events in the river basin of the Comboè torrent (Aosta Valley, Italy), it has been possible to reach careful consideration about the calibration of the rheological parameters and the sensitivity of simulation models, specifically about the variability of them.

The geomechanical and volumetric characteristics of the sediment at the bottom of the debris could produce uncertainties in model implementation, above all in not exclusively cinematic models, mostly influenced by the rheological parameters. The parameter that mainly influences the final result of the applied numerical models is the volumetric solid concentration that is variable in space and time during the debris flow propagation. In fact rheological parameters are described by a power equation of volumetric concentration.

The potentiality and the suitability of a numerical code in the engineering environmental application have to be consider not referring only to the quality and amount of results, but also to the sensibility regarding the parameters variability that are bases of the inner ruotines of the program. Therefore, a suitable model will have to be sensitive to the variability of parameters that the customer can calculate with greater precision. On the other side, it will have to be sufficiently stable to the variation of those parameters that the customer cannot define univocally, but only by range of variation.

One of the models utilized for the simulation of debris flow on the Comboè Torrent has been demonstrated as an heavy influenced example by small variation of rheological parameters. Consequently, in spite of the possibility to lead accurate procedures of back-analysis about a recent intense event, it has been found a difficulty in the calibration of the concentration for new expected events. That involved an extreme variability of the final results.

In order to achieve more accuracy in the numerical simulation, the rheological parameters were estimated by an implicit way, proceeding to their determination through the application of simple numerical iteration. In fact they can link the obtained values of velocity and hydraulic levels. Literature formulations were used in order to determine rheological parameters. The parameters μ and τ_{wo} were correlated to velocity and to empirical parameters that have small range of variability. This approach allows to produce a control of input parameters in the calculation models, comparing the obtained base result (velocity and water surface elevation).

The implementation of numerical models for engineering profession must be carried out in order that aleatory variables, that are difficult to determine, do not involve an extreme variability of the final result. However, it's a good manner to proceed to the determination of interested variables by means of empirical formulations and through the comparison between different simplified models, including in the analysis pure cinematic models.