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Velocity estimation of high-concentrated flows: sensitivity analysis with main parameters included in the Bagnold equation

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1. Introduction

As it is known, the propagation of debris flow causes huge territorial changes and damages in short times. The motion of debris flow is determined by gravity and it especially occurs in steep mountainous areas.

Debris flow velocity is an important factor which influences the impact forces and runup. Due to the complexity of the phenomenon, it is difficult to define predictive methodologies. Numerical codes (among others FLO-2D by O'Brien J. S., 1986) have been developed to simulate the debris flow propagation but they still present limitations. In fact, they are generally based on simplifying hypothesis, neglecting the vertical variability of the particle concentration and of the rheology and requiring certain input parameters.

Among the existing theories allowing to relate the debris flow velocity to particle concentration the Bagnold's (1954) one is the most cited.

The Bagnold's (1954) equation can be written in the following form:

$$u = \frac{2}{2d_p}\left[\frac{g\cos\theta}{a_i\cos\alpha_i}C\left(1-\frac{\rho}{\sigma}\right)\right]^{1/2}\frac{1}{\lambda}\left[h^{\frac{3}{2}}-\left(h-z\right)^{\frac{3}{2}}\right] \quad (1)$$

with $\lambda = C^{1/3}/(c^{*1/3}-C^{1/3})$, u is the local mean velocity of flow toward x direction, d_p is the particle diameter, g is the acceleration due to gravity, θ is the channel bed or flow surface slope, C is the particle concentration in volume, h is the local mean depth of flow, z is the height measured perpendicular to the bottom, ρ is the fluid density, σ is the particle density, a_i end α_i are the shape coefficients end c^* is the maximum concentration.

Eq.1 is based on the assumption that the concentration particle C is constant along the vertical and the value of c^* is uniquely defined. But, as literature highlights (Iverson, 1997), the concentration varies along the vertical and assumes different values in time.

In this context, in the present work attention is restricted to Equation (1) with the specific aim to assess the impact of the aforementioned assumptions in flow velocity estimation.

2. Results and concluding remarks

With the aid of experimental data both specifically collected in a straight laboratory channel and found in literature (Lanzoni, 1993; Sanvitale et al, 2010; Sarno et al, 2013), the sensitivity analysis of the velocity estimated by Eq. (1) with the parameter a_i, C, c^* has been performed.

The analysis has shown that all these parameters significantly affect the velocity estimation. As an example, restricting the attention to the parameter C, Figure 1 shows the comparison between the estimated vertical velocity profile by assuming the concentration C constant and that obtained by assuming C variable along the vertical. In Figure 1 the experimental profile is also reported.

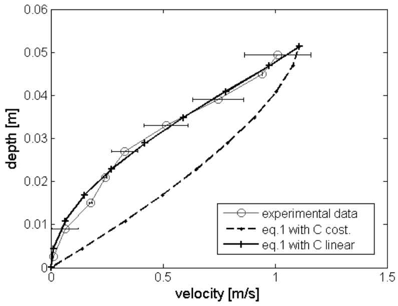

Figure 1. Comparison between an experimental profile (with the error bars) and the profiles obtained by Eq. 1 with *C*=constant and with *C*=linearly variable.

From Figure 1 it can be easily seen the remarkable difference between the *u*-values calculated by assuming C constant and those calculated by assuming C variable, demonstrating how the latter condition allows the best adaptation of the estimated velocity values to the experimental ones.

References

Bagnold, R. A. (1954). Experiments on a gravity-free dispersion of large solid spheres in a Newtonian fluid under shear. *Proc. R. Soc. London, A* 225: 49–63.

Iverson, R. M. (1997). The physics of debris flows. *Rev. Geophys.* 35 *pp.* 245–296.

Lanzoni S. (1993). Meccanica di miscugli solido-liquido in regime granulo-inerziale. *phD Thesis, Università degli Studi di Padova*.

O'Brien, J. S., (1986). Physical process, rheology and modeling of mudflows. *PhD thesis, Colorado State University, Fort Collins, Colorado, 172 pp., 1986.*

Sanvitale N., Bowman E. T., Genevois R. (2010). Experimental measurements of velocity through granular-liquid flows. *Italian Journal of Engineering Geology and Environment – Book Casa Editrice Università La Sapienza DOI: 10.4408/IJEGE.2011-03.B-043.*

Sarno L., Papa M. N., Tai Y. C., Caravetta A., Martino R. (2013). A reliable PIV approach for measuring velocity profiles of highly sheared granular flows. *Latest Trends in Engineering Mechanics, Structures, Engineering Geology ISBN: 978-960-474-376-6.*