Testing different concepts of the equation of motion, describing run-out time and distance of slow-moving gravitational slides and flows.

INTRODUCTION

Despite the fact that many authors include inertial terms in the equation of motion for slow moving mass movements, it remains to be seen whether these terms are necessary to describe properly slow moving debris flows or landslides with velocities ranging from 1 to 2 m mm$^{-1}$ until 30 mm y$^{-1}$.

Objective

Compare the performances of two versions of the equation of motion with and without inertial terms for slow debris (mud) flows and landslides.

Model description

Landslides and debris (mud) flows have often been modeled as visco-plastic materials with a laminar flow regime, i.e. as Bingham fluids with constant yield strength and viscosity. The AC Model is a currently used model with the governing equations of the MassMeso model (Bégueria et al. 2009), which follows the form of the Saint Venant shallow water equations. It has been applied previously to mass movement modeling by a number of authors.

\[
\frac{\partial h}{\partial t} = 0
\]

(1)

\[
\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} = \frac{1}{\rho g h} \left( \tau_{xz} + \tau_{xy} \right)
\]

(2)

\[
S_i = \cos^2 \alpha \cdot \tan \phi' \cdot \left( \frac{1}{\rho g h} + \frac{1}{\rho g} \right)
\]

(3)

Eq. (1) is the mass balance with vertical height h (see figure 1) and velocity u. Eq. (2) is the momentum balance in terms of acceleration with on the left side respectively the the local or time acceleration, and the convective acceleration. These terms are also used to describe velocity patterns in slow moving landslides. The question arises whether we can delete these terms making it a steady state model (NA model). Eq. (4):

\[
\gamma a \cos \alpha + \frac{1}{\rho g} \left( \tau_{xz} + \tau_{xy} \right) = 0
\]

The models were calibrated on the observed run-out distance (110 m) and time (90 min) AC=85 kPa; NA=12 kPa and on a hypothetical scenario (110 m in 25 min) AC=0.2 kPa; NA=24 kPa sec. Fig. 6 shows the different displacement rates between the models. The faster the displacement the larger the differences.

Conclusions

For slow moving landslides there are only slight differences in the performance between the AC-model (equation of motion with inertial terms) and the NA-model (steady state model). Significant differences in run-out time with distance can be observed with relatively rapid moving debris (mud) flows in the order of meters per minute and higher. The NA-model however proved to be a simple, flexible and robust model but should not be used in case of these relative rapid or fast gravitational flows.

A comparison between the AC- and NA-model tested on the Monestier-du-Percy landslide

The two models were applied to the Monestier-du-Percy landslide, which developed in varved clays in the French Alps. Along the investigated profile (A-B) in the S-W part (see Figure 2) the slip surface is located at -16 m below the main houses and at -9 m nearby the road. Inclometer measurements in the nineties showed a mean velocity of about 30 mm y$^{-1}$

Figure 1: 

Figure 2: 

Figure 3: 

Figure 4: 

Figure 5: 

Figure 6: 

Figure 7: 

Slow moving mud flows on top of the Super Sauze mudslide

Figure 5 shows a relatively slow mud/debris flow which failed suddenly from a secondary scarp of the Super Sauze mudslide (Southern French Alps). It flowed on the hill slope in the first 30 minutes with a relative low mean velocity of 2 m.min$^{-1}$ until a distance of 40 m from the source area, and then continued flowing at a slower mean velocity of 1 m min$^{-1}$.

Contact: Th.W.J. van Asch
Faculty of Geosciences, Utrecht University, Netherlands
Email: t.vanasch@geo.uu.nl