Geophysical Research Abstracts, Vol. 9, 11270, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-11270

Rheological Modeling of the Open-channel Flow of Muddy Fluids

B. Nsom

Université de Bretagne Occidentale. LIME / IUT de Brest. BP 93169. Rue de Kergoat. 29231 BREST Cedex 3 – France (Blaise.Nsom@univ-brest.fr / Fax: +33 2 98 01 72 65)

Hydrogeological hazards generally mobilize large quantities of coarse grains suspended in a colloidal dispersion (clay-water mixture) called geological fluids. Mass movements generated by these materials often cause natural disasters in the form of debris flows or mudflows. They transport much energy and can indeed move rocks and boulders over very long distances.

It is difficult to distinguish a debris flow from a mudflow and the single term “debris flow” is commonly used for both these flows. After long and intense rains, a debris flow may occur in steep mountain torrents as steep front waves in which the largest boulders are transported, causing an abrupt increase of the stage in the torrent. This steep front is followed by a long tail, since the flow height is usually accompanied by a decrease in concentration, and the final portion of a debris flow wave generally appears as muddy water. Due to these characteristics, debris flow, and particularly the steep boulder front, can cause severe damage to villages, road systems and other structures built along its path. For example, such debris flow caused 100 deaths in Sarno, Italy, in May 1998, and 30,000 deaths in Vargas, Venezuela, in December 1999. The debris flow problem is dominated by uncertainty and, as a result, a strong prediction tool to cope with this destructive and dangerous phenomenon is missing. However, laboratory experiments, theoretical modeling and numerical simulation are all crucial steps in acquiring a better understanding about flow development and how to protect populations, goods and structures.

Since the flow is isochoric, it is governed by the conservation of mass and momentum equations, respectively, in the following form:

$$div\vec{u} = 0 \qquad (1)$$

$$\rho\frac{d\vec{u}}{dt} = \rho\vec{g} - \vec{\nabla}p + \overrightarrow{div}\left[2\eta D(\vec{u})\right] \quad (2)$$

where $\vec{u}$ is the velocity field, $p$the pressure field,ρ the fluid density, and $\vec{g}$ the gravity. We assume that a relationship exists between the stress and the strain rate. Nguyen and Boger (1983) showed that a debris flow conforms to a viscoplastic behavior scheme governed by the Herschel-Bulkley rheological equation which is writen as follows :

$\underline{\tau} = 2\eta.\underline{D(\vec{u})}$ if $-\tau_{II}^{>}\tau_0^2$ (3)

$\underline{D(\vec{u})} = \underline{0}$ if $-\tau_{II}^{\leq}\tau_0^2$ (4)

where $\underline{\tau}$ denotes the stress tensor, $\underline{D(\vec{u})}$ the strain-rate tensor, and η the apparent viscosity, defined as :

$$\eta = k\left(-4D_{II}\right)_{\left(\frac{n-1}{2}\right)} + \frac{\tau_0}{\left(-4D_{II}\right)_{1/2}} \quad (3)$$

where$k$ is the fluid consistency, $\tau_0$its yield stress and n the power-law index.

At this point, some assumptions can be made to simplify the equations. However, Piau (1996) formulated a more general approach, without resorting to such assumptions. In this paper, using similar reasoning and retaining the three rheological parameters (τ_0, k, n),we intend to go further and derive an operational equation of motion which refers to usual simplified models: Newtonian, power-law and Bingham for given values of the parameters. To completely describe the flow field, the initial and boundary conditions based on the specific configuration of the studied flow are to be taken into account, aiming at an exact solution.

So, a general model for the open-channel flow of muddy fluids in a long space domain is presented. The conservation equations of mass and momentum are written in a non dimensional form with a shallow-water approximation. Herschel-Bulkley rheological behavior is assumed without neglecting any component of the stress tensor. In addition, no *a priori* value is assigned to the rheological parameters. A strongly non linear partial differential equation is obtained and solved numerically for the specific case of a viscous (Newtonian) dam-break flow. The solution of this problem is obtained using a robust explicit finite difference method.