THE DAM BREAK PROBLEM FOR A HYPERCONCENTRATED SUSPENSION

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ABSTRACT
A rheological approach of muddy debris flows is presented for environmental engineering and risk assessment purposes. The debris flow is viewed as a hyperconcentrated suspension of non brownian solid particles. Experimental and theoretical studies are presented versus the concentration. The experimental work generally consists in generating the flow of well characterized suspensions by a dam break. Then, the time evolution of the front as well as that of the stage at given position are accurately determined. On the theoretical framework, the viscous equations of motion of the suspension are written with the shallow water approximation, and the asymptotic solution in a non dimensional form is derived. Finally, the experimental and the theoretical results are successfully compared and the limits of this rheological approach is fixed.

Zusammenfassung
In dieser Arbeit wird eine rheologische Methode zur Untersuchung von Schlamm- und Geröllströmungen mit Hinblick auf Umweltaspekte und Risikoabschätzung vorgestellt. Die Schlamm- und Geröllströmung wird als eine hyperkonzentrierte Suspension aus nicht-Brownschen, festen Partikeln betrachtet. Experimentelle und theoretische Untersuchungen zu Fliesseigenschaften in Abhängigkeit von der Konzentration werden vorgestellt. Die experimentelle Arbeit besteht im Allgemeinen darin, eine Strömung einer gut charakterisierten Suspension mittels eines Dammbruches zu erzeugen. Hier wird die Zeitentwicklung der Front sowie ihr Verhalten an bestimmten Positionen genau untersucht. Im theoretischen Rahmen werden die viskosen Bewegungsgleichungen für die Suspension mit der "shallow water"-Approximation beschrieben und eine asymptotische Lösung in dimensionsloser Form hergeleitet. Zusammenfassend werden die experimentellen und theoretischen Ergebnisse erfolgreich verglichen und die Einschränkungen für diese rheologische Untersuchungsmethode herausgearbeitet.

Résumé
Une approche rhéologique des laves torrentielles boueuses est présentée pour le génie de l'environnement et la prévision des risques. Les laves torrentielles sont modelisées par des suspensions hyperconcentrées de particules sphériques non browniennes. Généralement, sur le plan expérimental, l'écoulement de suspensions bien caractérisées est généré par une rupture de barrage et l'évolution temporelle du front de même que celle de la profondeur de fluide en une position donnée sont déterminées avec précision. Sur le plan théorique, les équations du mouvement de la suspension sont écrites en régime visqueux avec l'approximation des eaux peu profondes, et la solution asymptotique est établie sous forme adimensionnelle. Enfin, les résultats obtenus par la théorie et par l'expérience sont comparés avec succès et la limite de validité de la présente approche rhéologique est fixée.

Key words: Dam-break flow, hyperconcentrated suspension, wave-front evolution, image analysis, ultrasounds

1 INTRODUCTION

After long rains in mountainous regions, debris flows can occur. They consist in large quantities of muddy water transporting many kinds of debris and they are able to move rocks and boulders upon very long distances. Along this trip, they generally cause many destructions and they erode the soils. A classification of these mass movements has been undertaken by some authors (e.g. [1-3]). None of these classifications can be completely satisfactory, due to the different points of view among engineers, rheologists, geologists, mechanicians, geomorphologists among others.

Apart the phenomenological description of a debris flow (made of a front, a body and a tail), a common characteristic to all these approaches concerns the physical composition of a debris flow. It consists in a hyperconcentrated mixture of solid particles of various natures and sizes and a given liquid, transporting much larger divided solids. Thus, a rigorous laboratory study of a debris flow should first consider the basic features of the debris flow, in its initiation phase, i.e. without the boulders, and later, the transportation features. In this way, a debris flow is viewed here as a hyperconcentrated suspension of identical fine particles and, following

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5 CONCLUSION

An experimental and theoretical analysis of the dam break problem for a hyperconcentrated suspension was presented. The solid particles (plastic or glass beads) are sieved and their density is accurately measured. Then the suspending phase of the suspension is chosen. It is a transparent Newtonian liquid (e.g. solutions of glucose syrup or glycerol in water) with the same density as the solid particles. The suspension is characterized using rheometers as well as a vane-test or a channel-test. The suspension is Newtonian when the concentration is less than a certain critical value and its viscosity is determined versus the particle concentration. The dam break experiment is carried out with these suspensions in a completely transparent rectangular channel. The flow is one dimensional and some specific precautions are generally taken in order to ensure the stability of the suspension structure. The time evolution of the wave front can be determined using image analysis facilities and that of the stage at given position can be measured using either an ultrasonic system or also image analysis facilities. Thus, the effect of the presence of the solid particles on the flow can be quantified through the suspension viscosity. On the theoretical framework the equations of motion for the viscous flow are written and made non dimensional with the shallow water approximation. An asymptotic solution agreeing qualitatively with the experimental results is found. This rheological approach of the dam break problem for a suspension is stated valid in the range of particle concentration corresponding to its Newtonian behavior. Indeed, beyond this limit the suspension structure is unstable when undergoing a flow generated by a dam break.

EDITORIAL COMMENT:
The reviewed studies have been actually performed at the Laboratoire de Rheologie, 38041 Grenoble cedex 9 (France) under the auspices of the Directeur du Lab. de Rheologie, Prof. Jean-Michel Piau, and in collaboration with two of his students.
This contribution is to be regarded as a review, and Applied Rheology does not own the copyright for the presented (although original) material.

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