FLUID DYNAMIC TREATMENT OF THIXOTROPIC DEBRIS FLOWS AND AVALANCHES

HUBERT CHANSON[1] and PHILIPPE COUSSOT[2]

[1]Dept of Civil Engineering, The University of Queensland, Brisbane QLD 4072, Australia (Tel: +61-7-3365-4163, Fax: +61-7-3365 4599, e-mail: h.chanson@uq.edu.au)
[2]Laboratoire des Matériaux et Structures du Génie Civil, Unité Mixte de Recherche (LCPC-ENPC-CNRS), 2 allée Kepler, 77420 Champs-sur-Marne, France

Abstract

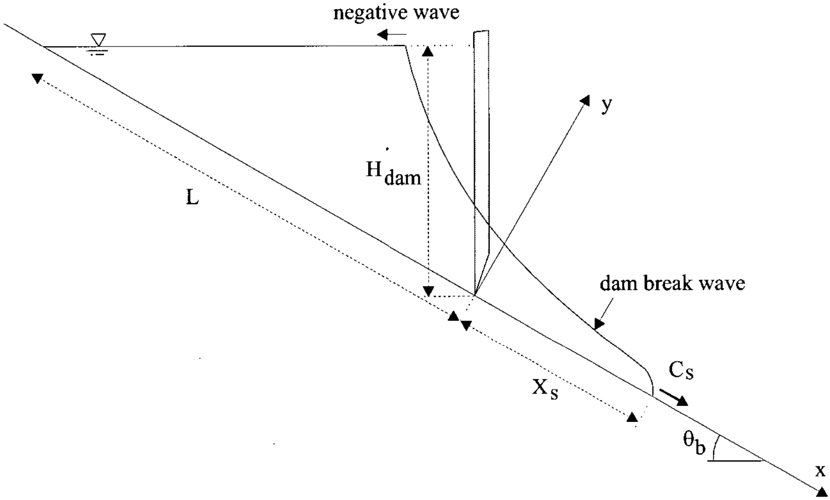
In natural mudflows, the interstitial fluid made of clay and water plays a major role in the rheological behaviour of the complete material. Since clay-water suspensions have often been considered as thixotropic yield stress fluids, it is likely that thixotropy plays a role in some cases of natural events. Thixotropy is the characteristic of a fluid to form a gelled structure over time when it is not subjected to shearing and to liquefy when agitated. A thixotropic fluid appears as a non-Newtonian fluid exhibiting an apparent yield stress and an apparent viscosity that are functions of both the shear intensity and the current state(s) of structure of the material. Under constant shear rate, the apparent viscosity of a thixotropic fluid changes with time until reaching equilibrium. To date, it is essentially the yielding character of non-Newtonian fluid behaviour which has been taken into account for modelling either steady, slow spreading and rapid transient free surface flows. There is a need to explore the interplay of the yielding and thixotropic characters of mud and debris flows.

This work describes a basic study of dam break wave with thixotropic fluid (Fig. 1). Such a highly unsteady flow motion has not been studied to date with thixotropic fluid, despite its practical applications : e.g., mudflow release, concrete tests including L-Box and J-Ring for self-consolidating concrete testing, preparation of industrial paints. Herein a theoretical analysis is developed. One-dimensional equations are developed yielding analytical solutions of the problem, and results are discussed. It is the purpose of this paper to fill a void in this field, to compare theoretical developments with physical modelling results, and to present new compelling conclusions regarding highly unsteady flow motion of thixotropic fluids.

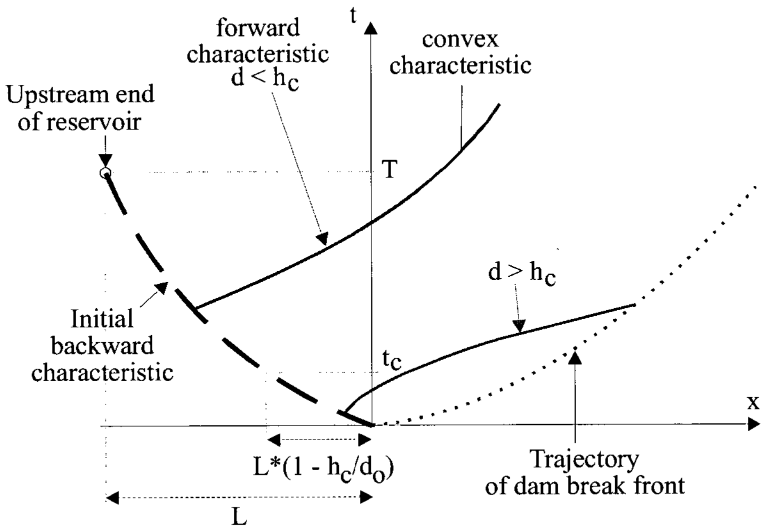
Theoretical considerations were developed based upon a kinematic wave approximation of the Saint-Venant equations down a prismatic sloping channel and combined with the thixotropic rheological model of COUSSOT et al. (2002). Theoretical results highlight three different flow regimes depedning upon the initial degree of fluid jamming λ_o and upon the ratio d_o/h_c. These flow regimes are: (1) a relatively-rapid flow stoppage for relatively small mass of fluid ($d_o/h_c < 1$) or large initial rest period T_o (i.e. large λ_o) (Cases A and B1), (2) a fast flow motion for large mass of fluid ($d_o/h_c >> 1$) (Case C), and (3) an intermediate motion initially rapid before final fluid stoppage for intermediate mass of fluid ($d_o/h_c > 1$) and intermediate initial rest period T_o (i.e. intermediate λ_o) (Cases B2 and B3). The qualitative agreement between the present theory and the experiments of CHANSON et al. (2004) suggests that the basic equations of this development (i.e. kinematic wave equation and rheology model) are likely to model correctly both fluid

behaviour and flow motion. The present work is the first theoretical analysis combining successfully the basic principles of unsteady flow motion with a thixotropic fluid model, which was verified with systematic laboratory experiments.

Keywords: Debris flow; Thixotropy; Dam break wave; Kinematic wave; Analytical solution



(A) Definition sketch



(B) Sketch of characteristic curves for a dam break wave of thixotropic fluid

Fig. 1 Dam break wave of thixotropic fluid