TWO-LAYER SHALLOW WATER MODELLING OF FAST GEOMORPHIC FLOWS AND EXPERIMENTAL VALIDATION ON IDEALISED LABORATORY DAM-BREAK WAVES

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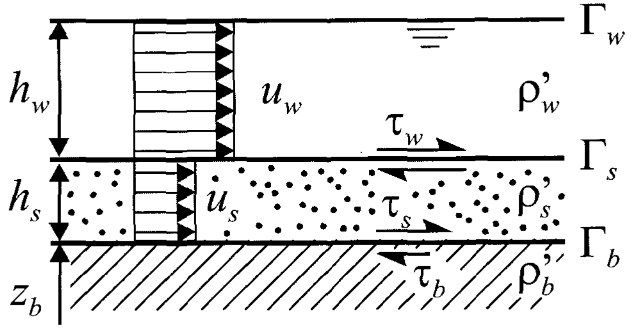
Fast geomorphic floods, as resulting from dam- or dike breaks and debris flows, may induce severe soil movements that in turn affect the wave dynamics in terms of arrival times and attained levels. A multi-phase approach is adopted to develop a set of governing equations that rely on a two-layer shallow water description. The proposed framework accounts for granular phase dilatation resulting from grain entrainment across the bed interface, and for the related mass and momentum exchanges induced between the flowing layers. The governing equations are solved in a finite volume numerical scheme, both in a 1D version on Cartesian grids and in a 2D version on unstructured triangular meshes. Numerical simulations are faced with results of idealised laboratory experiments of dam-break waves in two configurations: the 1D version is tested against experiments involving a bed profile with an initial discontinuity at the dam location; the 2D version is faced to a sudden valley enlargement in the downstream reach.

Catastrophic floods are often associated with the mobilisation of large amounts of sediments, in a variety of forms. Through friction, inertial effects and momentum exchanges, erosion of bed material may in turn significantly affect the dynamics of flood wave.

Our model relies on a vertical flow structure similar to that postulated by Capart and Young (2002), as sketched in the below figure.

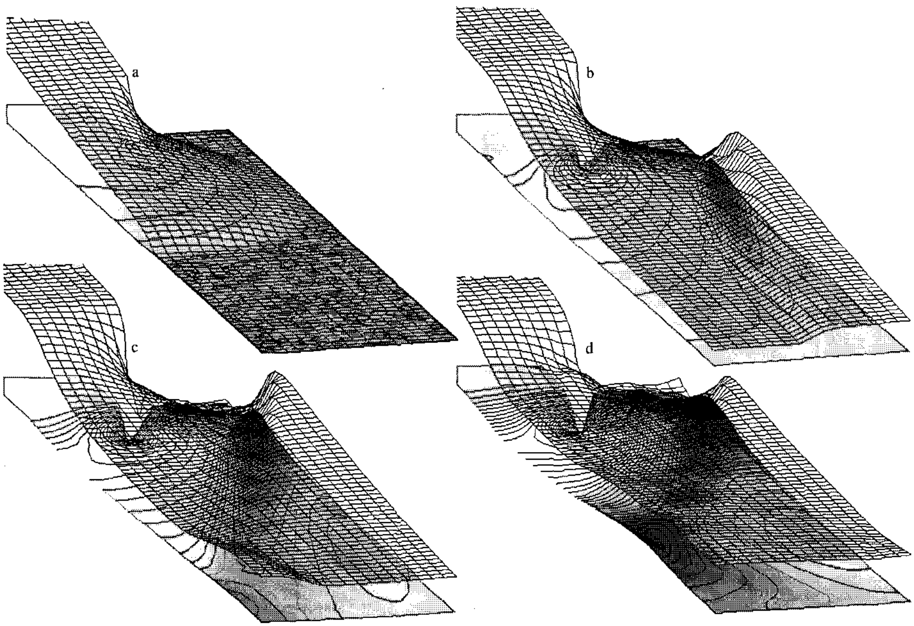


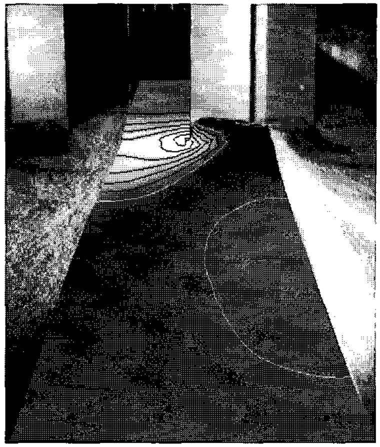
In contrast with previous formulations, the bed and transport layer are now also characterised by distinct granular concentrations C_b and C_s. The main motivation for this postulate comes from the fact that erosion, associated with entrainment of material through the bed interface, requires a dilatation of the granular matrix, hence a reduction of its granular packing, even for highly concentrated flows. This induces mass and momentum exchanges, explicitly accounted for in the equations. Their implications on the flow dynamics vanish for equilibrium situations, but they are believed to be substantial in case of highly transient flows with non-equilibrium sediment transport, as for dam-break waves or debris flows.

We describe the governing conservation equations, as well as the theoretical shock relation describing erosion and deposition as a response to different shear stresses experienced on both sides of the bed interface. The governing equations are solved using finite volume computations.

We then present two series of laboratory dam-break experiments used for the validation of the approach. The first configuration is one-dimensional, with a bed profile presenting a discontinuity across the dam. The higher bed levels in the upstream reach provide a rough analogue to reservoirs partially filled with sediments that are remobilised during the dam-break. The second configuration has a completely flat bed profile, but with a sudden channel enlargement to twice its width at some distance along the downstream reach. The objective was to investigate erosion and deposition patterns induced when a dam-break wave confined in a narrow valley invades a wider area. Comparison of numerical results with experimental observations show generally good agreement.

The below figures show selected numerical snapshots of the flow in the case of the enlargement, and a 3D impression of the simulated final bed topography, superimposed to a photograph taken after the test.





CAPART H., YOUNG D.L. (2002) Two-layer shallow water computations of torrential geomorphic flows. Proceedings of River Flow 2002, Louvain-la-Neuve, Belgium, September 2002.

Keywords: Dam-break; Movable bed; Two-layer shallow-water model; Laboratory experiments.