

Numerical simulation of catastrophic debris flows

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Abstract

In this paper, we present a modeling technique named smoothed particle hydrodynamics (SPH) to simulate catastrophic debris flows. In the proposed SPH modeling technique, the Navier–Stokes equations are adopted as the governing equations and a Bingham model is adopted to analyze the relationship between material stress rates and particle motion velocity. Compared with the traditional numerical methods, the proposed SPH method has the following advantages to simulate the post-earthquake debris flows: a) Purely Lagrangian Description. Particles in SPH method carry field variables, such as mass, density, and stress tensor, and move with a material velocity, which can instantaneously track the movement of each particle, and accurately predict the velocity and long run-out distance of the debris flows; b) Mesh-free Method. The problem domain in the proposed SPH method is represented by a set of arbitrarily distributed particles, which could well perform the large deformation of such long run-out distance; c) Continuum Mechanics. The proposed SPH method is based on the continuum mechanics, so it is an efficient calculation method to simulate such large scale debris flows. First, a viscoplastic fluid was simulated and verified with the experimental results to evaluate the accuracy of the SPH model. Then, the propagation analyses of catastrophic debris flows are conducted by the application of SPH models. The results of the run-out and the pattern of deposition show good agreement with the limited field observation data. The proposed SPH numerical modeling herein can capture the fundamental dynamic behavior of post-earthquake debris flows and partly explain such complex phenomena. The SPH method could therefore provide preliminary estimates of the destructive impacts of catastrophic debris flows.

Keywords: Smoothed particle hydrodynamics, Debris flows, Long run-out, Hazard assessment