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Forecasting landslide motion by a dynamic elasto-visco-plastic model

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Forecasting landslide motion by a dynamic elasto-visco-plastic modelMany slopes are subjected to continuous movement and intermittent stages of slowing and accelerating motion. Various authors (Angeli et al., 1996; Butterfield, 2000, Corominas et al., 2005, Gottardi and Butterfield, 2001, Van Asch et al., 2007, Ranalli et al., 2010) used different approaches to study this problem and we propose a new model in this contribution. We presents a 1D elasto-visco-plastic model that assumes a frictional behaviour for an infinite slope: the sliding mass is assumed to move as a rigid body and the slope movements are concentrated within a narrow basal shear zone. The pre-existing surface is considered at residual strength conditions and includes a visco-plastic behaviour to take into account both dynamic-inertial and viscous effects. In order to reproduce this behaviour, a Newmark pseudo-static approach is adopted, starting from the Perzyna's visco-plasticity theory. This approach allows to take into account the "delayed plasticity due only to the evolution of the soil micro-structure after a load increment (e.g. water table oscillation). This type of plasticity is characterised by a different time-scale from consolidation induced plasticity. As the elastic response is assumed instantaneous, the plastic deformations are associated to a time-dependent evolution. The dynamic formulation of this approach is introduced by means of a simple equation that allows to take into account the landslide velocity. Thus, the slope is no longer characterised by a rigid and perfectly plastic behaviour but by a simple rigid-plastic one. Moreover, the shear resistance does not change during the evolution process of deformation and with the load increment velocity, so that hardening and softening behaviours are not taken into account. In order to describe the evolution of the visco-plastic deformations, three different viscous nucleus formulations have been adopted. A linear and rigid-plastic nucleus, in which irreversible deformations occur only if the plasticity surface is positive (and thus only if the acting force is higher than the resisting one). A second linear formulation, in which visco-plastic deformation always occurs. The third nucleus is an exponential and positive one which can take into account both high and small deformations increments. The viscosity of the proposed model is derived on the basis of a visco-plastic constitutive model. Other authors assumed more simple viscous fluids behaviours (Bingham type, Ledesma et al., 2009, Ranalli et al., 2009) or proposed theoretical power law models based on mathematical relationships relating the viscous forces to the system velocities (Ledesma et al., 2009).

To test the model with the different proposed formulations we used datasets from the literature (see above listed references) and a long term monitoring dataset from the Bindo-Cortenova landslide site (Italian Prealps, Lake of Como, Lombardy, Italy). This last site is characterized by a large and active slope failure located in the. Different landslides (June 1987, November 2000, May 2001) took place along the entire slope interested by large landslide (consisting of a permian conclomerate, immersed in a matrix of gravely sand). The toe of the slope underwent a catastrophic failure in december 2002 after a period of extremely heavy rainfall (1500-2000 mm/year, ca. 50To predict the landslide mechanical behaviour and define displacement thresholds caused by heavy rainfall, we adopted a constitutive modelling approach for the material involved. After calibration procedures, the computed evolution of deformations has been compared to ground displacement data given both by the on-site monitoring system and inSAR monitoring system.

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