Geophysical Research Abstracts
Vol. 12, EGU2010-14642, 2010
EGU General Assembly 2010

A distinct element approach to model the interaction between debris avalanches and embankments

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Protective measures against hazards associated with debris flows and debris avalanches, include a variety of barriers such as rock/boulder fences, deflection berms, gabions and earthfill barriers, which are placed along the potential flow path where the debris is transported and deposited or close to infrastructures potentially at risk. Recent progress in the field of numerical methods for the lagrangian analysis of discrete particulate systems provides an opportunity to develop a rational design strategy for earthfill barriers as well as other protection methods against debris avalanches. In this work, the Discrete Element Method (DEM) has been used to model the interaction between such natural phenomena and embankments. In the DEM approach, the motion of a granular mass subject to gravity is simulated by numerically solving Newton's equation of motion for each particle considered as an individual body.

A parametric study based on a case–history from a marginally stable rock slope near Assisi, in central Italy, has been conducted. The embankment has been simulated in two different ways. In the first case, the embankment acts as a rigid body. In this case, a series of DEM simulations has been conducted to investigate the effect of the influence of the geometry of the sliding mass, slope and barrier, and strength properties of the granular mass on the main design parameters for the barrier.

Results show that the barriers considered are all effective in retaining the debris mass; less than 6% of the initial rock mass passes the barrier. The predicted efficiency of the barriers is primarily affected by: i) barrier height; ii) run–out distance; iii) macroscopic friction angle of the debris; and, iv) size of the storage area left between the barrier and the slope base. For the limited range of values considered, the slope angle has only a minor impact on the computed results.

In the second case the embankment has been treated as a deformable body, which can slide at the base. This second analysis has permitted the assessment of the energy that is transmitted to the embankment by the debris flow at the impact. This has been compared to the initial value of the potential energy and allowed the total amount of dissipated energy to be calculated. In add, the safety factor against sliding of the barrier has been computed by means of the prediction of the forces exerted by the debris mass on the barrier, both during the transient dynamic stage following the impact and in the final equilibrium conditions.