Geophysical Research Abstracts,
Vol. 11, EGU2009-10525, 2009
EGU General Assembly 2009

Arrest of Avalanche Propagation by Discontinuities on Snow Cover

B. Frigo and B. Chiaia

Politecnico di Torino, Structural and Geotechnical Engineering, Torino, Italy (barbara.frigo@polito.it)

Abstract: Considering the spatial variability of the snow cover, the paper analyses, in the framework of Fracture Mechanics, the Mode II fracture propagation on snow cover that leads to large dry slab avalanches. Under the hypothesis of a perfectly brittle phenomenon, avalanche triggering is usually investigated numerically by means of Linear Elastic Fracture Mechanics (McClung, 1979; Chiaia et al., 2008). Since, however, the real phenomenon is intrinsically dynamical, another aspect to investigate is represented by dynamic fracture propagation. In this paper, we model dynamic crack propagation into a dry snow slab, to assess the possibility of crack arrest due to the presence of weak zones distributed along the snow slope. As a consequence of the first triggering mechanism (the Mode II fracture propagation on the weak plane), the secondary Mode I crack propagation in the crown is studied by means of numerical simulations based on Dynamic Elastic Fracture Mechanics and on the theory of crack arresters.

By taking into account kinetic energy and using the FEM software FRANC 2D (Wawrzynek and Ingraffea, 1993), several paths of crown fracture propagation and their stability have been investigated. The snowpack is considered as a linear–elastic plate (2D problem), whose physical and mechanical parameters are chosen according to classical literature values. To investigate the possible arrest of crown fracture, we apply the theory of crack arresters, usually adopted for pipelines and perforated steel sheets fracture problems. To study crack arrest, different crack paths are simulated, in discontinuous (equipped with different shapes and geometries of artificial voids) snowpacks. The simulations show the effectiveness of these weak zones, to reduce substantially the crack driving force of the propagating fracture. This means that, increasing spatial variability tends to stabilize the snow slope, eventually splitting a major avalanche event into smaller, independent avalanches.

Our results are supported also by other investigations, which suggested that increased spatial variability in the snow cover leads to a lower release probability of snow avalanches. The above studies are based on very different approaches, such as cellular automata (Kronholm and Birkeland, 2005) and statistical renormalization (Chiaia and Frigo, 2009) models, but come to the same conclusion, i.e. that the presence of randomly distributed weak zones increase the global robustness and toughness of the snow slope.

From a practical engineering viewpoint, results could be used towards a new idea of active avalanche protection, based on the presence of natural (e.g., trees) or artificial objects throughout the slope, able to create low deposition zones as discontinuities in the snow cover.

Key words: snow avalanche, fracture mechanics, crack arrester.

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