FRACTURE PROPAGATION IN WEAK SNOW LAYERS AND FAILURE OF OVERLYING SNOW SLAB

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Abstract

Fracture propagation in the weak snow layer and subsequent failure of the overlying slab, two essential processes of the slab avalanche formation, are studied in the present work. First, mechanical behavior of natural snow is characterized through uniaxial mechanical tests and density dependent power law expressions for snow properties are obtained. For simulation studies, a continuum isotropic elastic-plastic damaging material model with Drucker-Prager yield criterion and fracture energy-based softening is considered for the snow layers and model parameters are derived from the experimental data. In addition, a discrete ice column model for the surface hoar like weak snow layer is also conceptualized and used in numerical propagation saw tests (PST). The effective mechanical behaviour of ice column model is also determined through numerical tests and is found close to that of low-density snow.

Critical crack length (CCL) and fractured slab length (FSL) are studied in the standard field PST as well as in improvised saw test in natural snow cover. Improvised saw tests in natural snow cover suggest much higher critical crack size in comparison to the CCL in field PSTs. In numerical PST study natural snow cover is idealized as a three-layer snow cover with the ice column weak layer sandwiched between two homogeneous layers. CCL and fracture propagation speed (FPS) are determined from these simulations and the influence of slope angle, weak layer and overlying slab properties on CCL and FPS is presented. An analysis of the energy released and its distribution during dynamic fracture propagation in the weak snow layer is also discussed. A low-density continuum model of snow is also used as a weak layer in PST simulations and the results obtained are comparable to ice column weak layer model in terms of trends of variation. A study on crack tip stresses in the weak snow layer is also

presented. Crack tip stresses are estimated through static FE simulations in a slab-weak layer model with a pre-existing crack. The variation of crack tip stresses with slope angle is discussed and compared with results in the literature. CCL in PST is also estimated using energy approach. Effect of slope angle, slab properties and weak layer fracture energy on CCL is discussed and results are also compared with previous models. No major influence of the deformability of the weak snow layer on CCL variation with slope angle is observed though a lower CCL is obtained for compliant weak layer. A comparative study on critical crack size in idealized 3 D terrain and in field PST is also presented.

Above numerical model of PST with ice column weak layer is also used to study the failure of snow slab. The PST simulation results on the nature of slab failure, influence of top slab density, thickness, slope angles etc. on FSL are discussed and compared with field PST results. An analysis of stresses in the snow slab and their role on the snow slab failure is also discussed. The above continuum model of snow is also used to simulate the field PSTs and a comparison of simulation and field PST results is presented. The application of above continuum model of snow is also extended to simulations in idealized 2D and 3D terrains. FPS in weak snow layer and its variation with fracture propagation distance in upslope, downslope and across the slope (in 3 D only) directions is presented. Nature of snow slab failure in upslope and downslope directions and influence of slope angle, slab density and thickness on FSL in 2D terrain are discussed. In 3D terrain, failure in the snow slab is found to initiate in the upslope direction followed by downslope and flank failure.

Overall, the above studies provide a reasonably good insight into the fracture propagation process in the weak snow layer and failure of overlying slab. However, due the computational limitations, only limited understanding on snow slab failure in 3D terrain is generated.

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