Geophysical Research Abstracts
Vol. 16, EGU2014-1561-1, 2014
EGU General Assembly 2014

Avalanche weak layer shear fracture parameters from the cohesive crack model

David McClung
University of British Columbia, Geography, Vancouver, B.C., Canada (mcclung@geog.ubc.ca, +1 604 822 6150)

Dry slab avalanches release by mode II shear fracture within thin weak layers under cohesive snow slabs. The important fracture parameters include: nominal shear strength, mode II fracture toughness and mode II fracture energy. Alpine snow is not an elastic material unless the rate of deformation is very high. For natural avalanche release, it would not be possible that the fracture parameters can be considered as from classical fracture mechanics from an elastic framework. The strong rate dependence of alpine snow implies that it is a quasi-brittle material (Bažant et al., 2003) with an important size effect on nominal shear strength. Further, the rate of deformation for release of an avalanche is unknown, so it is not possible to calculate the fracture parameters for avalanche release from any model which requires the effective elastic modulus.
The cohesive crack model does not require the modulus to be known to estimate the fracture energy. In this paper, the cohesive crack model was used to calculate the mode II fracture energy as a function of a brittleness number and nominal shear strength values calculated from slab avalanche fracture line data (60 with natural triggers; 191 with a mix of triggers). The brittleness number models the ratio of the approximate peak value of shear strength to nominal shear strength. A high brittleness number (> 10) represents large size relative to fracture process zone (FPZ) size and the implications of LEFM (Linear Elastic Fracture Mechanics). A low brittleness number (e.g. 0.1) represents small sample size and primarily plastic response. An intermediate value (e.g. 5) implies non-linear fracture mechanics with intermediate relative size. The calculations also implied effective values for the modulus and the critical shear fracture toughness as functions of the brittleness number. The results showed that the effective mode II fracture energy may vary by two orders of magnitude for alpine snow with median values ranging from 0.08 N/m (non-linear) to 0.18 N/m (LEFM) for median slab density around 200 kg/m3. Schulson and Duval (2009) estimated the fracture energy of solid ice (mode I) to be about 0.22-1 N/m which yields rough theoretical limits of about 0.05- 0.2 N/m for density 200 kg/m3 when the ice volume fraction is accounted for. Mode I results from lab tests (Sigrist, 2006) gave 0.1 N/m (200 kg/m3). The median effective mode II shear fracture toughness was calculated between 0.31 to 0.35 kPa(m)1/2 for the avalanche data.
All the fracture energy results are much lower than previously calculated from propagation saw tests (PST) results for a weak layer collapse model (1.3 N/m) (Schweizer et al., 2011). The differences are related to model assumptions and estimates of the effective slab modulus. The calculations in this paper apply to quasi-static deformation and mode II weak layer fracture whereas the weak layer collapse model is more appropriate for dynamic conditions which follow fracture initiation (McClung and Borstad, 2012).
References:
Bažant, Z.P. et al. (2003) Size effect law and fracture mechanics of the triggering of dry snow slab avalanches, J. Geophys. Res. 108(B2): 2119, doi:10.1029/2002JB))1884.2003.
McClung, D.M. and C.P. Borstad (2012) Deformation and energy of dry snow slabs prior to fracture propagation, J. Glaciol. 58(209), 2012 doi:10.3189/2012JoG11J009.
Schulson, E.M and P. Duval (2009) Creep and fracture of ice, Cambridge University Press, 401 pp.
Schweizer, J. et al. (2011) Measurements of weak layer fracture energy, Cold Reg. Sci. and Tech. 69: 139-144.
Sigrist, C. (2006) Measurement of fracture mechanical properties of snow and application to dry snow slab avalanche release, Ph.D thesis: 16736, ETH, Zuerich: 139 pp.