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SOME INDEX PROPERTIES OF THE MOUNTAIN SNOWPACK

by

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Statistical variation of *snow crystal shape and size, snow density, shear frame strength,* and *snow temperature* were studied at level study plots and at avalanche fracture lines located near Alta, Utah; Sunshine, Alberta, and Whistler, B.C. The objectives were to determine the statistical scatter intrinsic to the sampling techniques, how the indices of density and shear frame strength varied according to snow type, and the spatial variation of indices over distances typical of a slab area.

Snow crystal shape and size were determined from analysis of color microphotos obtained with polarized light. The samples were assigned into the following morphological categories depending on the shape of the majority of crystals in the sample: *newly-fallen crystals, initially metamorphosed crystals, rounded crystals, faceted crystals, melt-refrozen crystal clusters, crust crystals,* and *surface hoar.* It was possible to further stratify rounded and faceted crystals according to the projected area of the largest crystal in the sample. The size categories in mm^2 were: 1/8, 1/4, 1/2, 1, 2, 4, and 8. It was generally not possible to assign a size to the remaining 5 categories of crystal shape.

Initial studies indicated that the density of 20 mm thick layers could be measured using thin oval tubes which provided repeatable readings to within 1% accuracy as determined by adjacent sample pairs extracted at the same stratigraphic level in the pack. The 20 mm measurements were also within 1% accuracy of the standard Swiss tube (~ 50 mm dia) measurement as determined by averages of adjacent sample pairs. Measurements of 10 mm thick layers were attempted with thinner oval tubes, but repeatability decreased substantially ($>$ 2% errors) especially for layers which consisted of larger crystals ($> 1\ mm^2$ projected area). Unfortunately, many important layers in a snowpack have thickness $\leqslant$ 10 mm, and a 20 mm sample may greatly distort the density index.

Shear frames were used to index relative snow strengths. The index is sensitive to rate of pull, size of shear frame, mass of shear frame, number of vanes, normal pressure on shear surface, and other factors. A slow pull (failure induced in minutes) gives 25-35% higher values than a fast test (failure induced in seconds). The larger the frame area, the lower the strength index. However, it was not possible to establish with confidence a statistical correlation between index and size, despite $>10^3$ tests using frame areas varying by factors as high as 25x. If the frame mass is increased by 5x, the strength index increases by ~ 15%. If the number of vanes are increased from 3 to 6, the index decreases by ~ 15%. The index also depends critically on the normal pressure on the shear surface in the sense of a Coulomb-Mohr envelope. The repeatability of shear frame measurements averages to ~ 10% for a frame area $0.025\ m^2$.

The shear frame index varied from $< 10^2$ N/m^2 for newly-fallen crystals to $> 10^4$ N/m^2 for high-density rounded and faceted crystals. A comparison of shear frame indices versus density indices shows a very large scatter that is improved substantially if the samples are stratified according to crystal shape and size.

Spatial variation of index properties was studied in well-defined, buried surface hoar layer of initial thickness ~ 20 mm. Shear frame and density indices were obtained at 100 locations within a 10 m x 10 m area, and were fitted to a normal distribution. The ratios of standard deviation to mean were respectively 3%, 11%, and 20% for the 20 mm density index, shear frame index–0.025 m^2 area, and shear frame index–0.01^2 m area. Since a density variation of 3% correlates with a strength variation ~ 10% according to presently known strength-density relationships, it is possible to conclude with respect to ***statistical sampling*** of the snowpack that a shear frame area of 0.025 m^2 provides a self-consistent index at least with respect to the density index, and is to be preferred over the shear frame index obtained with a 0.01 m^2 area frame. Considering the difficulty of obtaining shear frame statistics, it is argued that the density index by itself provides a good measure of the spatial distribution.

The index properties of the surface hoar layer were also followed for an additional three month period until the layer could no longer be identified in the snowpack. It was therefore possible to obtain statistics on the time-variation of the shear frame index in what turned out to be an extremely critical and pervasive layer (causing numerous avalanche accidents and fatalities in Western Canada).

Normal distributions of shear frame indices obtained at the crown of avalanche fracture lines had standard deviation/mean ratios that were considerably higher than the ratios measured at level study plots. Much of the increased variance may be due to operator replication error caused by the severe conditions normally found at starting zones, and the increased difficulty of aligning the frame on an inclined plane.