A FIBER OPTIC PROBE FOR INDEXING SNOWPACK PROPERTIES

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ABSTRACT

Snowpack observations are made for the purposes of avalanche forecasting and control. In general, snow depth, density, relative hardness of individual layers, snow temperature, grain type and bonding between and within the layers are important to the forecaster in predicting the potential for an avalanche to occur at a specific slope. This method of forecasting is difficult, time consuming and sometimes dangerous.

A fiber optic snowpack probe is developed to simplify this task. The instrument uses reflected LED light intensity to index the void sizes between snow crystals. Results indicate that, with further improvements on the probe, snowpack properties can be indexed with less effort and time. Results from the experiments corralated with the manually obtained data. Different snow layers in the snowpack were detected with the fiber optic probe.

INTRODUCTION

An avalanche is a rapid movement of a large mass of snow. The essential elements for avalanches are deep snow and steep slopes. Although thousands occur each winter, the majority are unnoticed. Data from avalanche accidents show that avalanche activity occures in one-third of the United States and is a significant hazard in the West, where avalanche fatalities are rising to record leveles once again after a five year break. Avalanche hazard causes economic loss to residents, businesses, transportation systems and government agencies. Hence, disturbing the local economy (Snow Avalanche Hazards and Mitigation in the U S, Utah Avalanche Forecast Center Annual Report).

Snow is one of the most complex materials found in nature and it is highly variable. At a single location the snow cover varies from top to bottom, resulting in a complex layered structure. In general the thicker layers represent consistant conditions during a storm. The thiner layers, sometimes only millimeters in thickness, represent conditions between storms. These layers are very fragile and low in strength.

One other property of snow which we can observe and is known to be a major contributer to avalanche formation is the type of snow crystals. At first the snow crystals have intricate shapes. A typical layer of new snow is composed 85-90 percent of empty air spaces "Figure 1". However, depending on the weight of the snow above and the temperature, they settle, become rounded in shape and form a denser snow layer. As a rule of thumb, an increase in density corralates with an increase in strength.

A temperature gradient, that is a temperature difference between the warm ground and cold air, is also a large factor in determining the type of snow crystals within the snowpack. Under the influence of a strong temperature gradient (larger than 10 degrees/m) snow crystals within the pack will metamorphose into a shape that is a stable ice structure for these thermodynamic conditions. These TG or kinetic growth form crystals are typically larger than unmetamorphosed snow crystals. As a consequence of their morphologies and lack of intergranular icebond, these loosely bonded crystals form the weak layer of the snowpack "figure 2". (Armstrong and Williams, 1986)

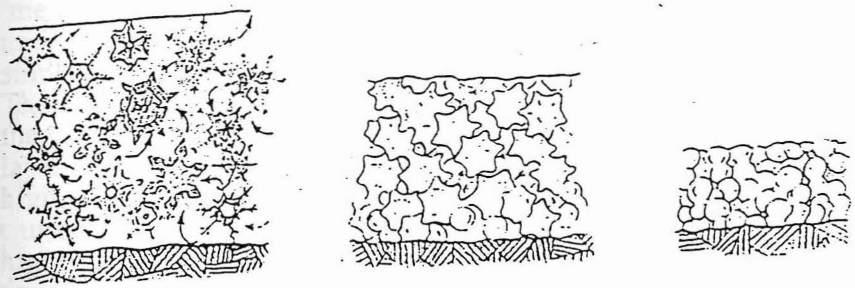

FIGURE 1. As the crystal shapes become more rounded, they can pack more closely together and the layer settles or shrinks in thickness. (The Avalanche Book)

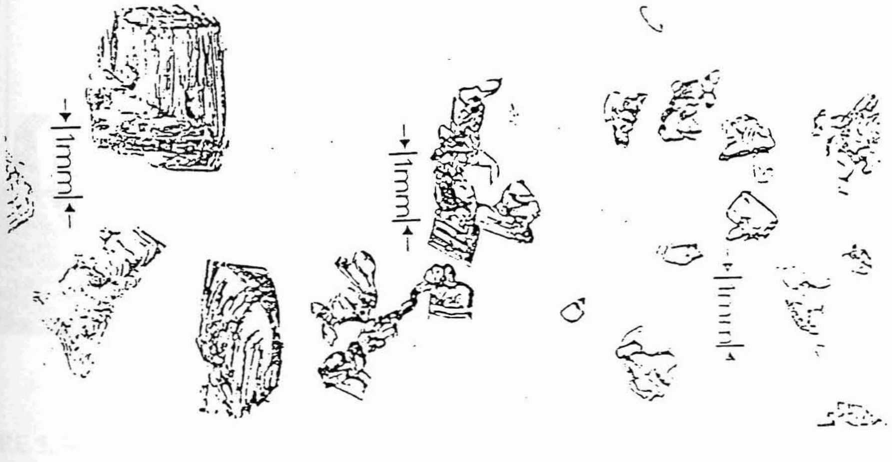

FIGURE 2. In the presensce of strong temperature gradients, the crystals grow in size and become large, coarse grains with facets and sharp angles. Bonds between the crystals are weak (R. Armstrong Photo, The Avalanche Book)

These are some of the important properties of a snowpack that are known to contribute to the avalanche hazard. Over the years several conventional methods of measuring the strength have been proposed and used in operational avalanche forecasting programs. The first of these still widely used is the ram penetrometer (Fraser, 1966). this instrument is driven slowly into the snowpack by blows from a calibrated hammer. The resistance to penetration per blow increases substantially when the ram penetrometer passes through a strong layer. The ram gives the observer quick and convenient information about the relative strength of the snowpack from the surface. However, manually dug snowpits are still required to determine the snow crystal morphologies corralating with the weak layers.

A device which gives similar information is the snow resistograph, developed by C. Bradley (Bradley, 1966). It measures the relative force exerted by the snow on a pair of 60 degree cones attached to a spring. The force is recorded on a strip chart.

The next improvement came from T. Dowd and L. Brown, who developed the digital thermoresistograph. This instrument is a microprocessor based data acqusition system and it uses a semiconductor strain gage load cell with 60 degree cone in the end of a probe for strength measurements. The information is digitally recorded (Dowd and Brown, 1985).

In addition to the instruments mentioned above, several other tools and tests have been suggested. Most of them have not found their way into practice. A new tool, fiber optic snowpack probe, is developed with Japanese counterparts to equip the avalanche forecaster with a better, more reliable device (Abe, 1990) and (Abe, Ikarashi, Decker, Sensoy, Ream and Treper, 1992). Fiber optic snowpack probe is aimed at upgrading existing operational avalanche hazard forecasting tools and enhancing the safety of the forecaster in the field.

THE FIBER OPTIC SNOWPACK PROBE

The fiber optic snowpack probe, shown schematically in "figure 3" consists

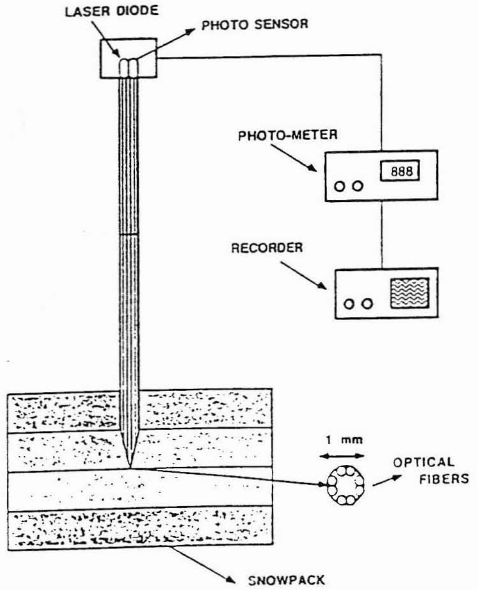

FIGURE 4. Schematic diagram of fiber optic probe

of a metal tube housing 8 filaments of optical fibers. Four of these fibers transmit the emitted light from an LED of power 10 mW and wavelength 630 nm. The other four are used as receivers to return the light reflected by the snow crystals. The intensity of the reflected light is a function of local void distribution and size in the immediate vicinity of the probe tip. This reflected light reaches a photometer through the receiving fibers. Relative differences in photointensity give information about the void size and hence, weaknesses in the snowpack.

The weak course grain layers, which are formed by crystals having relatively larger pore spaces, result in reflectivities much less than of those from fine grained crystals. The finer grained crystals are very closely bonded and the void sizes between them are much smaller. For this reason, fine grained snow tends to form stronger layers in the snowpack. This fine grained snow is detected by relatively greater intensity in the reflected light.

RESULTS AND DISCUSSION

Data have been analyzed and plotted in figures 4 and 5. The manually obtained ram numbers corralate well with the reflectivity data obtained by using the fiber optic probe. The probe gives a more detailed profile of the snowpack as it passes through different layers. However, when studied carefully, the similarities between the ram number and relative reflectivity can be easily seen. The only disagreement occures between the layers at about 110-125 cm above the ground, where intermidiate TG snow with ET changes is dominant. At this layer the ram number is relatively small however, the reflectivity is considerably high. This trend, which is contradictory to our primary conclusion, may be caused by ice lences immediately adjacent the thin layer of TG snow or by the highly faceted morphologies of the TG crystals themselves. In any case; the need to dig at least one calibtation snowpit, prior to extensive spatial probing with the fiber optic probe is underscored.

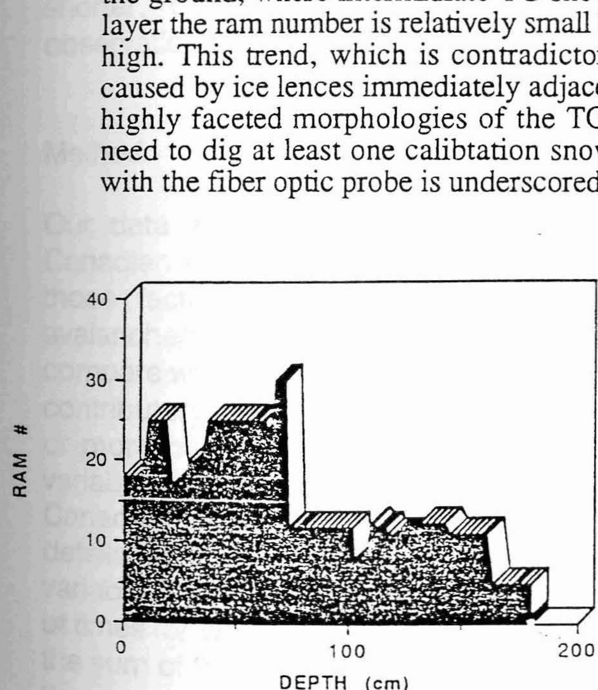

FIGURE 5. Ram number versus snow depth

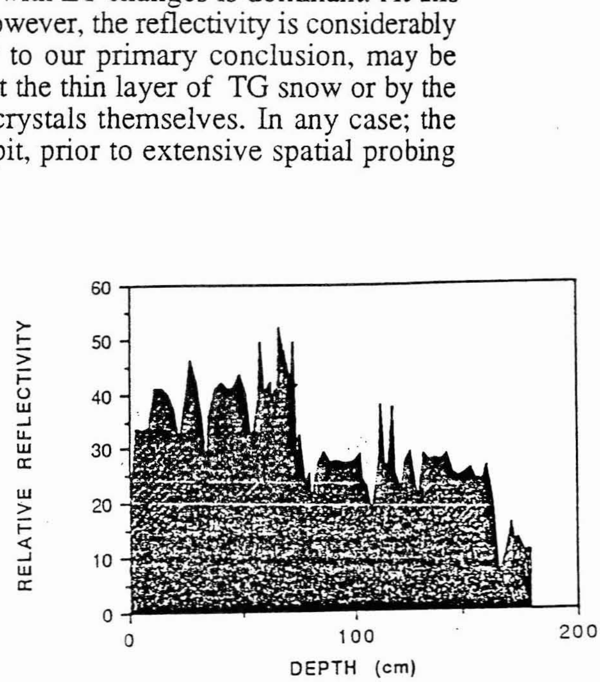

FIGURE 4. Relative reflectivity versus snow depth

SUMMARY

Due to the difficulties and inefficiencies in current methodologies, a fiber optic snowpack probe is designed to simplify the task of obtaining snowpack data for use by avalanche forecasters and technicians. Because of the size and morphological differences of the snow crystals occuring in the weak and strong layers of the pack, it is possible to index the layers of interest by processing the intensity of the reflected light at the probe tip within the snowpack.

REFERENCES

1. B. Armstrong and K. Williams, The Avalanche Book, p. 49-59, 1986
2. C. Bradley, The Snow Resistograph and Slab Avalanche Investigations, Publication No. 69 de I'Association Internationale d'Hydrologie Scientifique, 1966
3. C. Fraser, Avalanche and Snow Safety, p. 70-75, 1966
4. O. Abe, *J. of Japan Soc. Snow and Ice,* 53, 1b. Shinjo Branch of Snow and Ice Studies, Natural Research Institute for Earth Sciences and Disaster Privention, 1400, Takamachi, Shinjo-Shi Yamagata-Ken, 966 Japan
5. O. Abe, T. Ikarashi, R. Decker, B. Sensoy, D. Ream, B. Tremper, Snow Profile Observations for Avalanche Forecast by New Generation Ramsonde, *Annals of Glaciology,* Vol.18, 1992
6. Panel on Snow Avalanches, Snow Avalanche Hazards and Mitigation in the United States, National Academy Press, 1990
7. T. Dowd and L. Brown, A New Instrument For Determining Strength Profiles in Snow Cover, *J. Glaciology,* 32,111,1986
8. Utah Avalanche Forecast Center, Snow and Avalanches in Utah Annual Report 1991-1992