A New instrument for determining strength and temperature profiles in snowpack

by Timothy Francis Dowd

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Engineering Mechanics
Montana State University

Abstract:
The purpose of this thesis project was the development of a new field instrument for determining strength and temperature profiles in snowpack. The standard tool now used for strength determination is the ram penetrometer, which is slow, cumbersome, inaccurate, and does not provide immediate results. Temperatures are generally taken with a dial stem thermometer in a snowpit wall, which is difficult to do accurately at specific intervals. The Digital Thermo-Resistograph was designed and built in an attempt to improve field snowpack data collection.

The Digital Thermo-Resistograph is a portable microprocessor-based data acquisition system for quick and accurate field collection of snowpack compressive strength and temperature data. This was accomplished by building a probe with a load cell and thermistor, a small snow platform for probe position information, and a Z-80 microprocessor-based data acquisition system. The system provides information in digital form for every sampled point. A 64 x 240 dot matrix LCD graphic display unit is used to show complete strength and temperature profiles in the field. Provision is made to transfer these profiles to paper via an ordinary X-Y recorder for a permanent record of field data. Sufficient memory for the storage of 25 profiles is provided.

The results of winter 1984 field tests are presented. The thermistor could not be made- to work accurately, and so was not integrated into the system. The Digital Thermo-Resistograph proved to be fast and reliable in collecting compressive snow strength information, which is measured from 0.0 to 2.55 kg/sq cm at five mm increments through the snowpack. Comparisons with the ram penetrometer are shown. Ideas for future developments are discussed.

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Master of Science

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MONTANA STATE UNIVERSITY
Bozeman, Montana

May 1984

APPROVAL

of a thesis submitted by

Timothy Francis Dowd

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

5/25/84 — Date

R L Brown — Chairperson, Graduate Committee

Approved for the Major Department

5/25/84 — Date

W A Hunt — Head, Major Department, Acting

Approved for the College of Graduate Studies

6/5/84 — Date

Henry L Parsons — Graduate Dean

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Signature Timothy L. Bond

Date May 25, 1984

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ABSTRACT

The purpose of this thesis project was the development of a new field instrument for determining strength and temperature profiles in snowpack. The standard tool now used for strength determination is the ram penetrometer, which is slow, cumbersome, inaccurate, and does not provide immediate results. Temperatures are generally taken with a dial stem thermometer in a snowpit wall, which is difficult to do accurately at specific intervals. The Digital Thermo-Resistograph was designed and built in an attempt to improve field snowpack data collection.

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Chapter I

Introduction

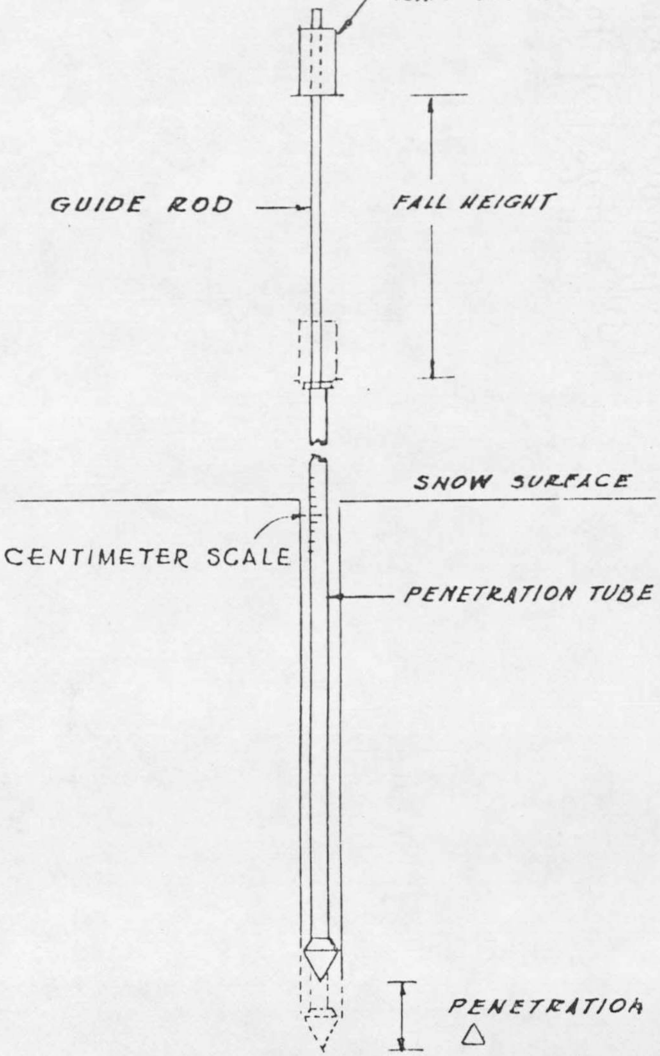
The mountain snowpack is of interest to ski areas, winter mountaineers, climbers, hydrologists, scientists, and others. From the first day that snow falls, the mountain snowpack is a dynamic ground cover that often presents a hazard in the form of avalanches. Naturally occurring snowpacks generally exhibit a complex stratigraphy composed of individual layers of snow with different properties (Perla, 1975). This layering is caused by changing weather and snowstorm conditions. For example, an ice layer or hard crust can result from wind action or sun-induced melt-freeze cycles. Surface hoar and graupel are examples of thin, weak layers which are caused by very different meteorological conditions. Additionally, once the snow is on the ground, it metamorphoses due to temperature gradient induced vapor transport in the snowpack itself.

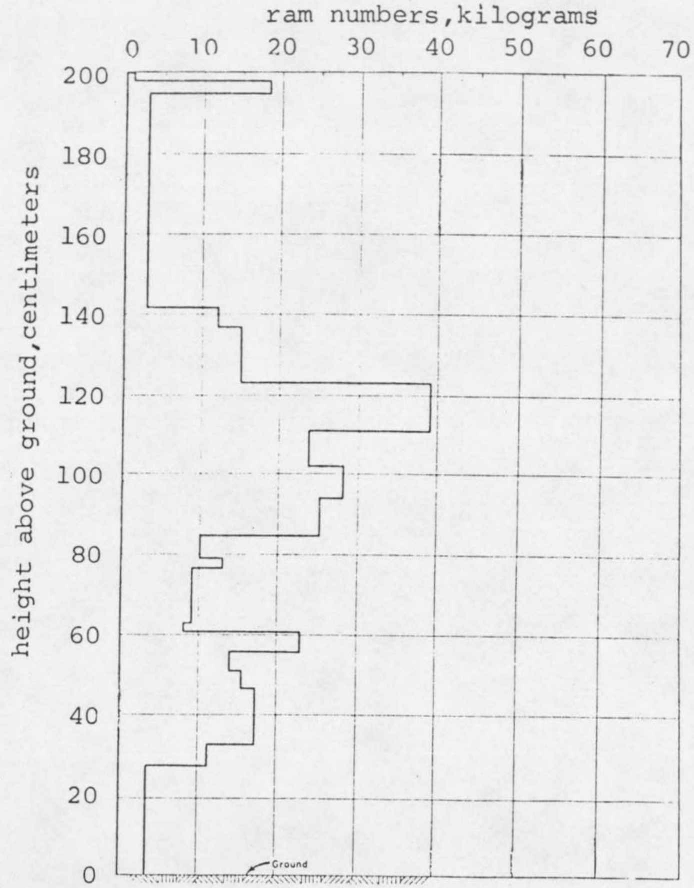
One snowpack property which is of considerable interest to scientists and avalanche personnel, and the subject of this thesis, is strength. The three types of strength that can be measured in snow, as in most materials, are compressive, tensile, and shear strength. There are several conventional methods of measuring the compressive strength of snow, which is of great interest. The standard instrument found in ski areas and research institutes worldwide is the Rammsonde, or ram penetrometer (Figure 1). This device consists of a tube with a 60 degree cone on the end, a centimeter scale down the shaft, and a ram weight on a guide rod used in a slide hammer fashion. The cone angle of 60 degrees is standard for use in compressive snow strength measurement. A relative strength index, or ram number, with the dimension of kilograms, is determined by the equation shown in the figure. The ram number is plotted on graph paper to illustrate the relative strength profile of the snowpack.

The problem with the ram penetrometer method of strength measurement is the high error content of information taken from the snowpack. This problem results largely from the tedious nature of the process, which can take fifteen minutes for a single profile. There is an ever-prevalent tendency to drop the ram weight from a greater height than necessary, resulting in deeper penetrations per drop and consequent lower resolution. Also, reproducibility of a ram penetrometer profile is low.

Another problem with using the ram penetrometer is the lack of provision for an immediate strength profile in the field. It must be drawn up later, after the operator has returned from the field, typically after several hours. It is generally considered that a ram penetrometer profile takes an hour from data collection to final graphic preparation. A faster method is needed in order to collect better, more useful data in the time available.

Dr. Charles Bradley, a geologist at Montana State University, developed a strictly mechanical device that produces strength profiles quickly in the field (Figure 2; Bradley,1966). It measures the reactive





$$\text{Ram number} = Q + R + \frac{N \times H \times R}{\Delta}$$

Q = weight of tube(s), KG
R = weight of ram, KG
N = number of blows
H = fall height of ram, CM
Δ = penetration in N blows, CM

Figure 1. The ram penetrometer, the ram number formula, and a sample ram profile.