A FIELD DETERMINATION OF FREE WATER CONTENT IN WET SNOW

by
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Summary

A field method of determining the free water content of snow by measuring the density to which wet snow can be compacted was investigated. Experimental tests show that there is a good relationship between free water content and compacted density especially for settled and coarse spring snow and for water contents above 5 percent. It is considered that the main value of taking compacted densities will be to give information on the physical structure of wet snow during tests.

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The free water content in wet snow is an important property that must be determined in any realistic classification of snow. It is a property that should be recorded during any tests under wet snow conditions. Unless this basic factor is known, such tests cannot be compared or their results properly analyzed. In addition a knowledge of the free water content and water holding capacity of wet snow has long been of great interest to hydrologists.

The method most commonly used to determine free water content is the calorimetric method described in detail by Halliday (1). In this method a quantity of wet snow is placed in a calorimeter containing hot water. The weight of snow, the weight of hot water, and the initial and final temperatures of the water are measured. Then by using a simple heat balance equation it is possible to calculate the percentage of free water in the sample. Halliday finds quite a range in the accuracy claimed by several different observers using this method.

Even if reasonable accuracy can be obtained the calorimeter method is not readily satisfactory for field use. For good results accurate temperature and weight readings are necessary. As free water content varies appreciably with time in a single day, with snow depth, and with position a suitable field method should permit the taking of several representative samples over the area where the snow is being tested. In the calorimeter method the number of samples that can be handled is limited by the number of calorimeters available. The whole procedure is time-consuming and not suitable for field use, especially in isolated areas.

Other non-calorimetric methods have been suggested by Bader (2). Gerdel (3) has developed a meter which measures the percentage of free water by measuring the dielectric content of snow. Aura and Kinesita (4) investigated the measurement of free water content in snow by centrifugal separation. These methods are promising but reports on their use are limited.

In soil mechanics, Proctor (5) found that the moisture content had an effect upon the density to which soil could be compacted. By using this dependence he was able to measure the moisture content of a particular soil by the use of a plasticity needle. As the size variation of individual grains is less in snow than in soil and as the specific gravity of ice is constant, the possibility arises that the relationship Proctor established for soils might prove to be even more applicable to wet snow. It was therefore decided to investigate the compacted density of snow under various conditions to see if a dependence with free water content could be established.

Experimental Procedure

The first step was to devise a method of compacting snow samples that could be duplicated and could be relied upon to produce consistent results. Two methods of compacting wet snow samples were tried.

In the first method the wet snow samples were collected in a specially prepared cylinder of 100 cc., with perforated sides to facilitate the escape of air. The wet snow was inserted loosely into the sampling cylinder. A constant load of 1000 gm/cm^2 was quickly applied by hand using an N. R. C. snow hardness gauge. When using this method it was necessary to measure the height of the compressed sample and weigh it to find the final density. Also for consistent results it was necessary to insert the same weight of snow into the container for each compaction test.

In the second method the wet snow was inserted loosely in one-inch layers in a 250 cc. container. Each layer was tamped with four blows of a 1000 gram weight dropping 10 centimeters. This method, modeled after a means of obtaining relative density in soil mechanics (6), produced more consistent results. The final compacted density was obtained by adding the weights of four 250 cc. compressed samples.

Figure 1 shows typical curves showing the relationship between compacted snow density and the number of times a 1000 gram weight is dropped 10 cm. on a one-inch layer in the confined sample. The points where the curves intercept the Y axis were obtained by inserting the snow loosely in one-inch layers without tamping. Figure 1 shows that for dry snow the maximum density increases only gradually after four blows of the 1000 gram weight.

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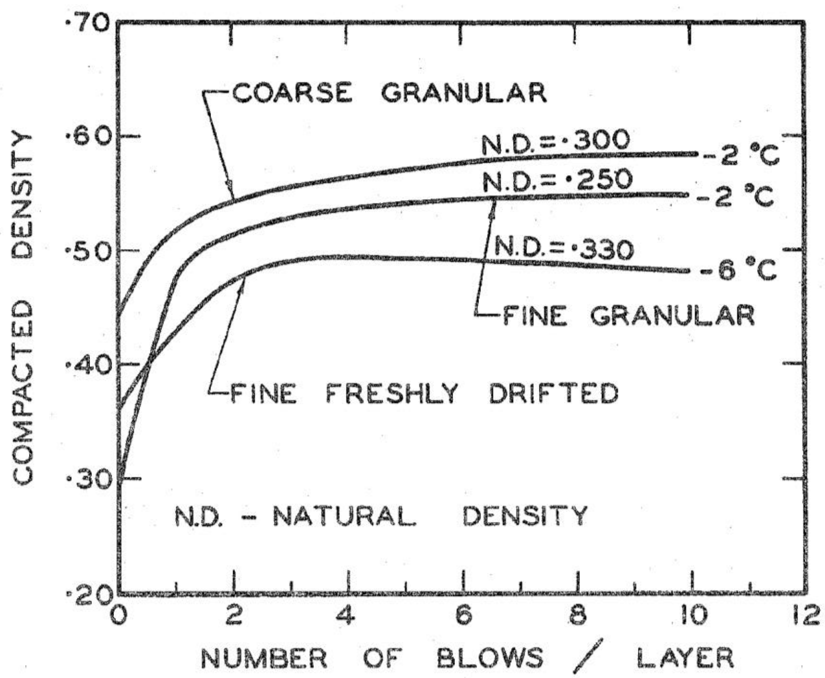


FIGURE 1

TYPICAL CURVES SHOWING RELATIONSHIP BETWEEN COMPACTED SNOW DENSITY & NUMBER OF TIMES A 1000 GRAM WEIGHT IS DROPPED 10 CM ON ONE INCH SNOW LAYERS IN CONFINED SAMPLE

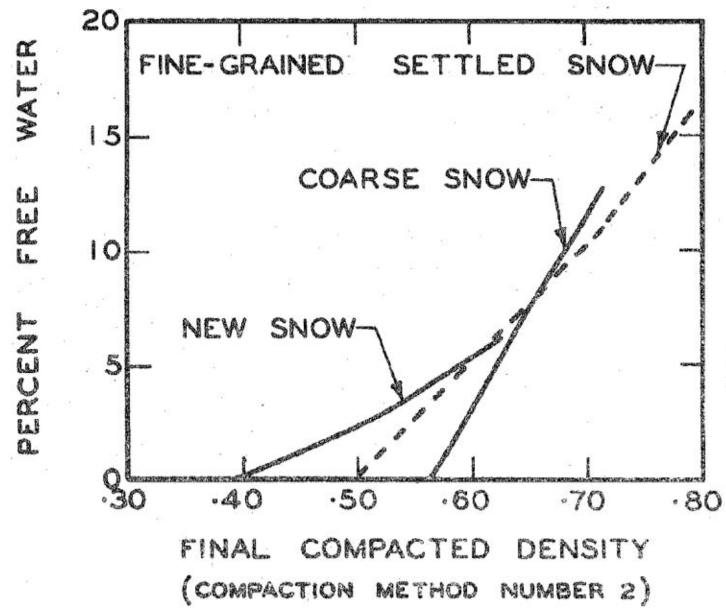
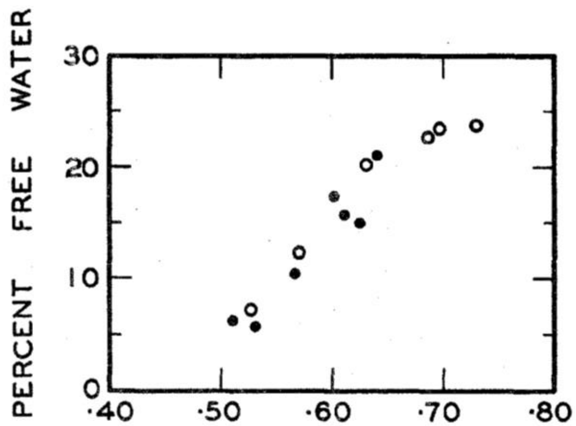


FIGURE 2

TYPICAL CURVES SHOWING FINAL DENSITY OF COMPACTED SAMPLE VS. PERCENT BY WEIGHT OF FREE WATER IN WET SNOW

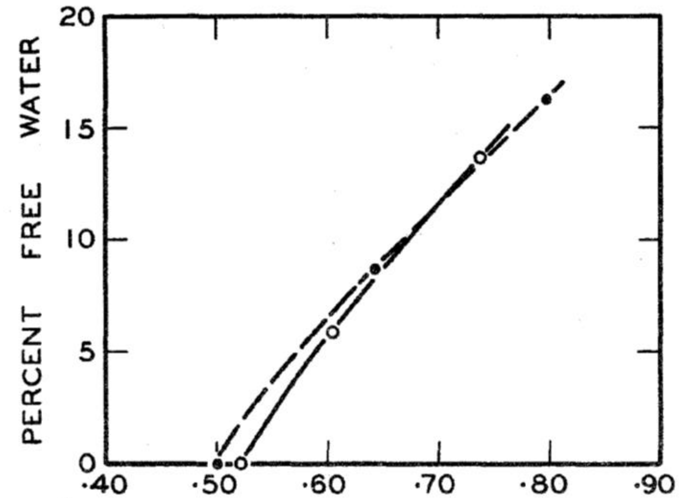


FINAL DENSITY OF COMPRESSED SAMPLE
(COMPACTION METHOD NUMBER 1)
LABORATORY RESULTS

LEGEND
- o FINE GRANULAR SNOW 1·19 MM. & LESS
- • COARSE " " 4·76 MM. TO 2·30 MM.

FIGURE 3

FINAL DENSITY OF COMPRESSED SNOW SAMPLE (LOAD = 1000 GM/CM²) VERSUS PERCENT BY WEIGHT OF FREE WATER IN WET SNOW



FINAL COMPACTED DENSITY
(COMPACTION METHOD NUMBER 2)

LEGEND
- •— — —• MARCH 2/56 NATURAL DENSITY=·320
- o———o MARCH 21/56 NATURAL DENSITY=·260

FIGURE 4

THE RELATIONSHIP BETWEEN COMPACTED DENSITY & PERCENT FREE WATER FOR TRIALS ON DIFFERENT DAYS

The free water content of wet snow was determined by the calorimetric method using essentially the procedure recommended by SIPRE (7). To keep errors to a minimum the results from tests in three thermos bottles were always averaged.

Whenever possible tests were run on days when air temperature were below freezing at night and above freezing during the day. During the morning the dry snow was compressed and the compacted density measured. As the water content increased, further compacted density measurements were made and the free water measured.

At first the snow in the test area was checked by the method outlined by Krumbein (8), to see if it was homogeneous over the area sampled. However experience under field conditions indicated that a few check samples of compacted density were sufficient to ensure that samples were being taken under essentially uniform conditions. Snow samples for compaction were taken from four points immediately adjacent to the points from which the three samples were taken for free water content determinations.

Experimental Results

Figure 2 is a plot of typical curves showing the relationship between final density of a compacted sample and the percent by weight of free water in wet snow. The effect of free water content on new snow is to increase the density to which it can be compacted. Fine-grained settled snow and coarse spring snow have a more gradual increase in compacted density with increasing free water content. At free water contents of 5 percent and greater the rate at which compacted density increases with increasing free water content seems to be comparable for different snow types.

To check the effect of crystal size on the density to which wet snow can be compacted, measurements on free water content and the compacted density were made on wet snow in the laboratory. The snow was screened into two different size ranges: 4.76 mm. to 2.30 mm. and 1.19 mm. and less. The snow was compacted by method No. 1. Figure 3, showing the results of these experiments, indicates that the final density of the compressed sample for any particular water content above 5 percent is about the same for both sets of laboratory samples. There is some tendency for the fine-grained type to compress to a higher density but the variation is not as great as might be expected.

Figure 4 shows how the experimental results can be duplicated. Observations on compacted density and free water content were made on two different types of snow on different days under field conditions. The dependence between compacted density and free water content is very nearly the same for both tests. Most of the variation is probably due to errors in measurement of free water content.

Discussion of Results

To estimate free water content from compacted density an observer would have to know the compacted density of the sample when dry and the compacted density vs. free water content curve for each snow type. For water contents above 5 percent, especially for settled and coarse spring snow, there is a close relationship between free water content and compacted density. Below 5 percent there is more variation in this relationship, especially for new snow.

One objection to this method is that it is sometimes difficult to standardize the compaction procedure. However tests by two different observers instructed in the second compaction method have shown that the final compaction densities can be duplicated satisfactorily. An observer using this method will have to be familiar with the different snow types and have had some experience with the technique of compacting snow samples.

It is considered that the main value of taking compacted densities will be to give information on the physical structure of wet snow during tests. For example if ski equipment is being tested under wet snow conditions, an observer could keep a record of compacted density during the experiment and thus would have a means of assessing the changes in amount of free water which have taken place during the experiment. Compacted density would be recorded in the same manner as undisturbed density; grain size and shape are recorded for tests of this kind.

Tests on the density to which wet snow can be compacted might be an objective way of classifying the physical structure of snow during the spring melt period. There has been considerable discussion about the term "ripeness" as applied to snow cover during the melting period (9). Church (10) has suggested that the relative density of the snow or a study of its crystal structure will indicate its capacity to hold melt water. As most studies on the water holding capacity of a snow pack deal with coarse settled snow with free water content above 5 percent, this method of determining free water content might be of value to hydrologists and give the general term of "ripeness" more meaning.

Acknowledgments

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THERMODYNAMICS OF TRANSPIRATION IN HEAVY FOREST DURING ACTIVE SNOW MELT

by
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1. Introduction. - Hydrologists have long recognized the importance of transpiration in their computations of loss in the basin water balance. With the various methods for estimating transpiration currently in use, it is possible to obtain a satisfactory degree of accuracy with seasonal totals. Thornthwaite's method (1), which uses a temperature index of heat supply, has been used for monthly estimates for the Willamette Basin Snow Laboratory (WBSL) and the North Santiam River, Oregon McClain (2), Miller (3). Since the source of transpiration heat supply is primarily solar radiation incident upon the forest, a temperature index alone cannot be expected to define potential transpiration completely. The method is popular because it is relatively simple and makes use of ordinarily available temperature data. However, Thornthwaite (4) recognizes the limitations of his method and suggests an energy balance approach for non-advective conditions.

2. Detailed analysis of the non-advective energy balance is particularly convenient for densely forested snow-covered areas during active spring melt. During the melting season, there is an abundant supply of water to plant roots, and transpiration can proceed at potential rate. If incident radiant energy is known, transpiration energy may be evaluated as a residual difference between input energy and the melt energy equivalent of measured runoff from the basin. This is possible because snow and forest canopy act almost as ideal black bodies for radiant energy in the long-wave spectrum and because transpiration is the principal operating loss mechanism during active spring melt. It is the purpose of this appendix to present an illustration of the thermodynamic relationships involved in forest transpiration during non-advective weather.

3. For illustrative purposes, a detailed energy balance has been worked out for WBSL with data from a non-advective period in the 1949 spring melt season. Starting with incident radiant energy at tree-top level,

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