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SOME PROPERTIES OF SAWDUST-SNOW-ICE MIXTURES

U.S. ARMY MATERIEL COMMAND
COLD REGIONS RESEARCH & ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE

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SOME PROPERTIES OF SAWDUST-SNOW-ICE MIXTURES

by

Gunars Abele

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PREFACE

Previous studies on the supporting capacity of snow pavements have indicated that heavy wheel loads, 40,000 lb, producing contact pressures up to 150 psi, can be supported on dry-processed, age-hardened snow pavements.

It may be desirable to expand this study further by developing methods for constructing snow pavements capable of supporting even higher wheel loads with higher contact pressures.

The use of additives in snow pavements to increase its strength has been considered. So far, however, the study of such additives has been limited to sawdust and wood chips. Preliminary results, obtained at the Keweenaw Field Station, Houghton, Michigan, in 1961, and in Greenland, 1962, have been very encouraging.

The work at the Keweenaw Field Station was done primarily for the study of wheel load supporting capacity of snow pavements, under the general supervision of Albert F. Wuori, Research Civil Engineer, Applied Research Branch.

Messrs. Frederick Scheuren and Earl Ollila, under the University of Denver contract, assisted in the field work in Greenland, 1962.

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INTRODUCTION

During World War II, Great Britain seriously considered the construction of a floating airfield composed of a mixture of wood pulp and ice. The discovery by Mark and Hohenstein, of Brooklyn Polytechnic Institute, that the inclusion of a small percentage of wood pulp greatly improved the mechanical properties of ice, stimulated considerable research in this field (Perutz, 1948).

Hanson (1958) made a limited study on the effect of sawdust in ice and snow-ice. His results also showed a significant improvement in the mechanical properties of ice to which sawdust had been added.

Preliminary studies on sawdust-snow mixtures were performed at the Keweenaw Field Station and in Greenland with a dual purpose:

(1) to determine the increase in the bearing capacity of a processed snow pavement to which sawdust had been added,

(2) to observe the skid reducing properties of a sawdust-snow pavement surface.

The work on sawdust-snow mixtures so far has been very limited in scope. The primary objective has been to determine methods and direction of such studies.

DESCRIPTION OF STUDIES AND DISCUSSION OF RESULTS

During 1943 and 1944 Great Britain and Canada performed a great amount of research on wood pulp-ice mixtures ("pykrete") in order to determine its mechanical properties.

Mechanically ground spruce or pine was mixed with water and allowed to freeze. The modulus of rupture of pykrete beams with various pulp contents (0 to 14%) was determined.

The results given by Perutz (1948) in a tabular form were plotted on a graph (Fig. 1). Since the general trend of the point distribution suggested a curve, the data were also plotted on a semi-logarithmic graph (see insert, Fig. 1). This plot gives an indication that the modulus of rupture in flexure of pykrete may be a function of the logarithm of the per cent of pulp in ice (in the range between 1% and 14% of wood pulp):

$$S_f \text{ (psi)} = 241.5 \log_e (\% \text{ pulp}) + 322.7$$

If this is true, Perutz's statement, ".... the strength increases rapidly up to a pulp content of 4%, after which the increase is comparatively small," is somewhat misleading.

The study on pykrete also showed the increase in ultimate compressive strength: 1100 psi for pykrete, compared to 620 psi for ice (mean values of a great number of tests, at -15C, with a 14% pulp content).

The principal effect of the wood pulp on the strength of ice may be explained by the fact that the wood fibers, embedded between ice crystals, act as reinforcement. In pure ice, cracks run through the ice crystal (Perutz, 1948). The wood fibers, having a considerably higher tensile strength than ice, would induce a crack to follow the path of least resistance around the wood particles, thus increasing the area of failure.

Hanson's data (1958) show some increase in ring tensile strength of ice with a 4% sawdust content, and a significant increase with a 12% sawdust content (Fig. 1). It should be pointed out, however, that the 3.5 to 4% sawdust content was mixed in water and snow, while the 12% sawdust content was mixed with water only.

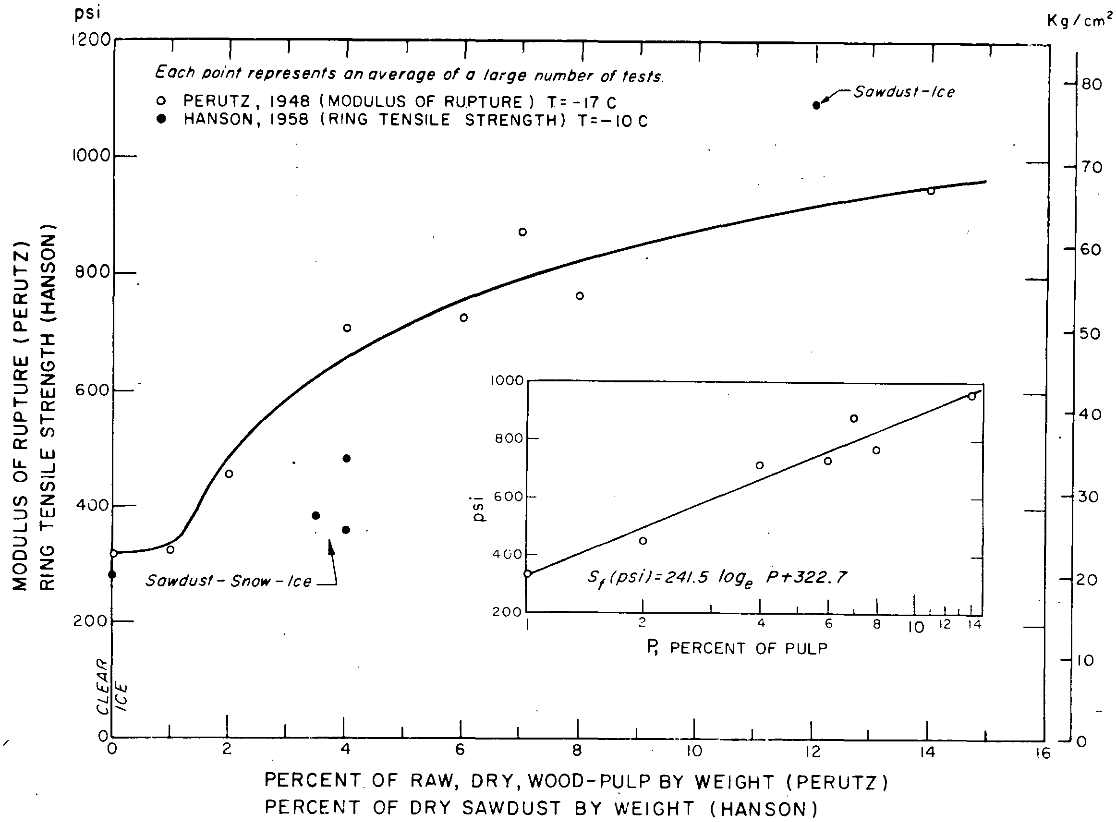

Figure 1. Percent of wood pulp in ice vs modulus of rupture and percent of sawdust in ice vs ring tensile strength.

Hanson's results were plotted on the same graph with Perutz's data for convenience only. Since ring tensile strength tests will give higher values than flexural strength (modulus of rupture) tests of ice (Butkovich, 1959), a true comparison of the two cannot be made. Besides, the temperatures differed.

It is interesting to note that Butkovich's data show the ring tensile strength values to be approximately 1.25 times the flexural strength of ice. Hanson's results at 12% sawdust content would then be very close to the curve drawn from Perutz's data.

The question now arises as to whether or not the addition of sawdust (or any other additive) would increase the bearing capacity of an age-hardened snow pavement in a similar manner.

During the 1961 winter test season at the Keweenaw Field Station two sawdust-snow tests sections were prepared. A test lane was first processed with a Peter plow to a depth of approximately 85 cm. After 1 day of age hardening, a 2.5 to 3 cm layer of sawdust (approximate density 0.25 g/cm^3) was spread on the snow surface. Using a pulvimixer, the sawdust was mixed into the processed snow to a depth of 30 cm for one section and to a depth of 15 cm for another section of the test lane; this gave approximately 8% and 15% of sawdust by volume for the two respective test sections. Another section of the processed lane was left without sawdust as a control section. All test sections were compacted with a vibratory compactor.

Part of the surface layer was cut off by subsequent removal of snow drifts from the test lane surface, leaving a sawdust-snow mixture depth of only 16 cm and 4 cm for the two sections.

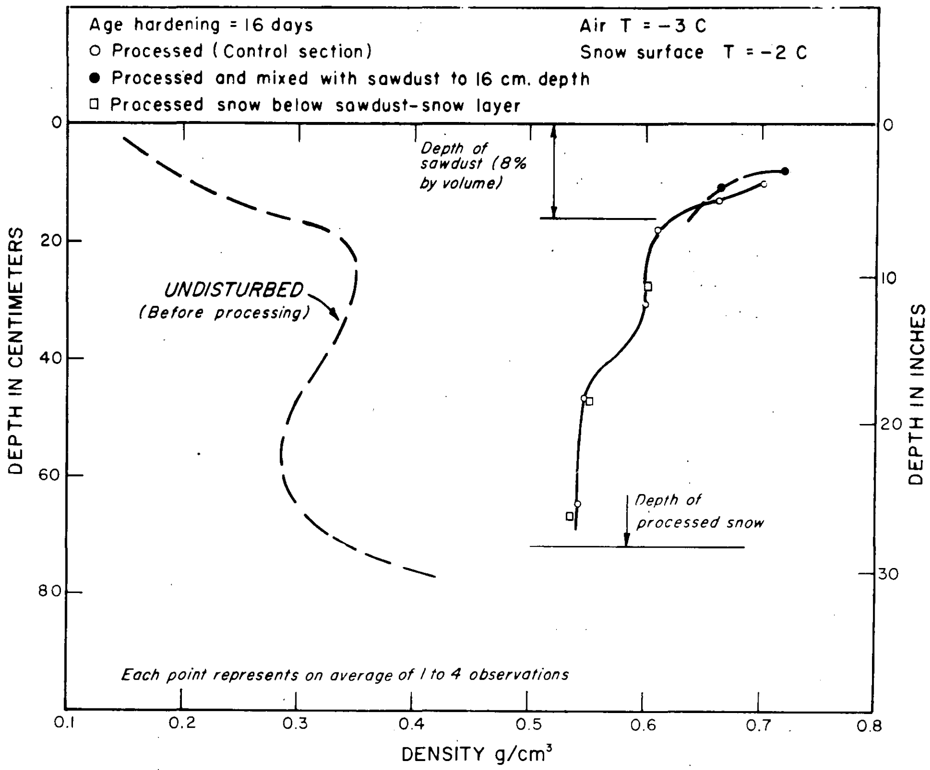

Figure 2. Density profiles of processed snow and sawdust-snow mixture.

Figure 2 shows the density profiles of the 8% sawdust section and the control section. No significant differences in density were apparent. Eventually the surface density of the sawdust sections increased. Because of the presence of sawdust, surface melting was accelerated during exposure to direct sunlight. This produced an increase in density for a depth of 0 to approximately 4 or 5 cm.

The ram hardness profiles for the same sections after 10 days of age hardening are shown in Figure 3. A slightly higher hardness was detected in the sawdust-snow layer as compared to the section having no sawdust. This may partly be attributed to the more extreme previous melting and subsequent refreezing of the sawdust-impregnated surface. (While the air temperature during the ram hardness tests was +3C, the snow surface temperature had not yet exceeded 0°C. The air temperature during the age hardening period up to 23 days is shown in Figure 5.)

Figure 4 shows the ram hardness profiles of the same two sections after 16 days of age hardening. The saedust-snow layer (16 cm) appears to be somewhat harder than the section without sawdust.

A few California Bearing Ratio tests were taken on the sawdust-snow surfaces after 10 days of age-hardening. The results are shown in Figure 6. On the 16-cm deep sawdust-snow layer CBR tests were performed on the surface and at 15-cm depth (both sawdust), and at 20-cm depth (no sawdust).

A CBR test made on the 4-cm deep sawdust-snow layer (15% sawdust by volume) after 23 days of age hardening shows a considerably higher CBR value. It is not known how much of this was contributed by the increased sawdust content and how much by the longer age hardening or the lower temperature. It is unfortunate that a more extensive CBR testing was not possible at the time.

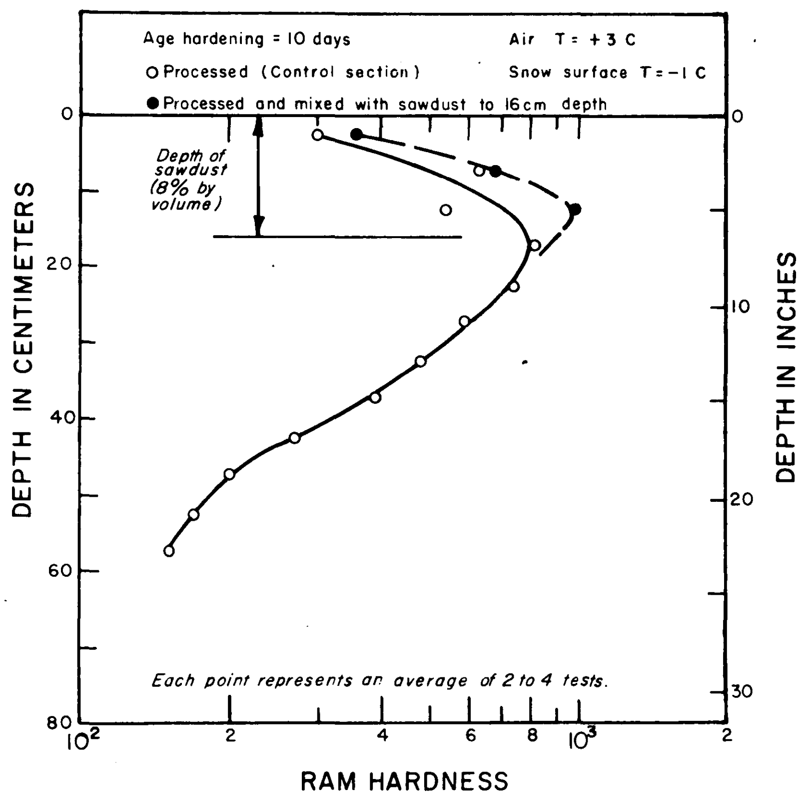

Figure 3. Ram hardness profiles of processed snow and sawdust-snow mixture after 10 days of age hardening.

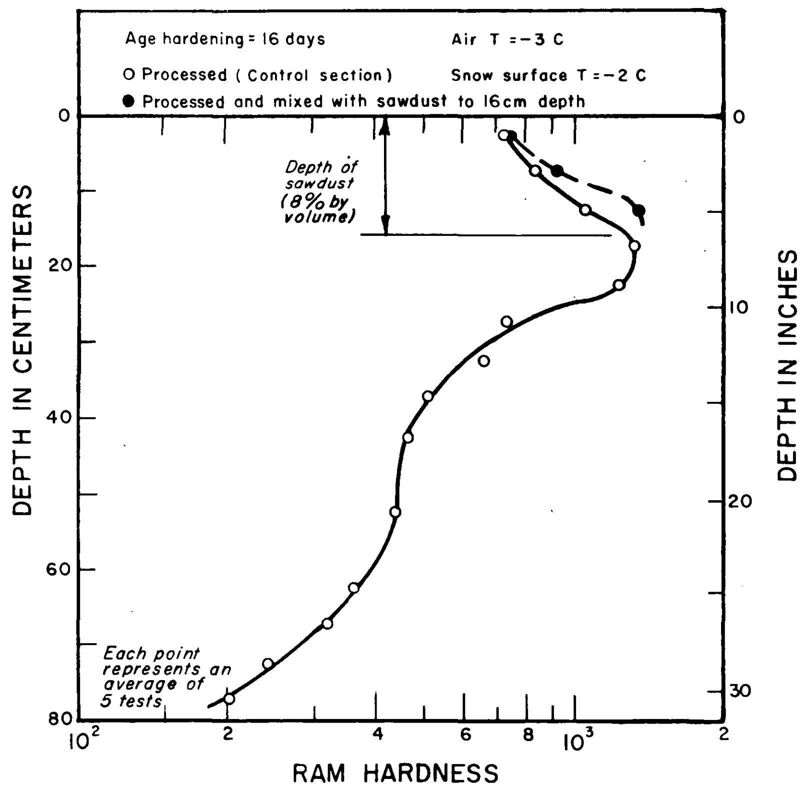

Figure 4. Ram hardness profiles of processed snow and sawdust-snow mixture after 16 days of age hardening.

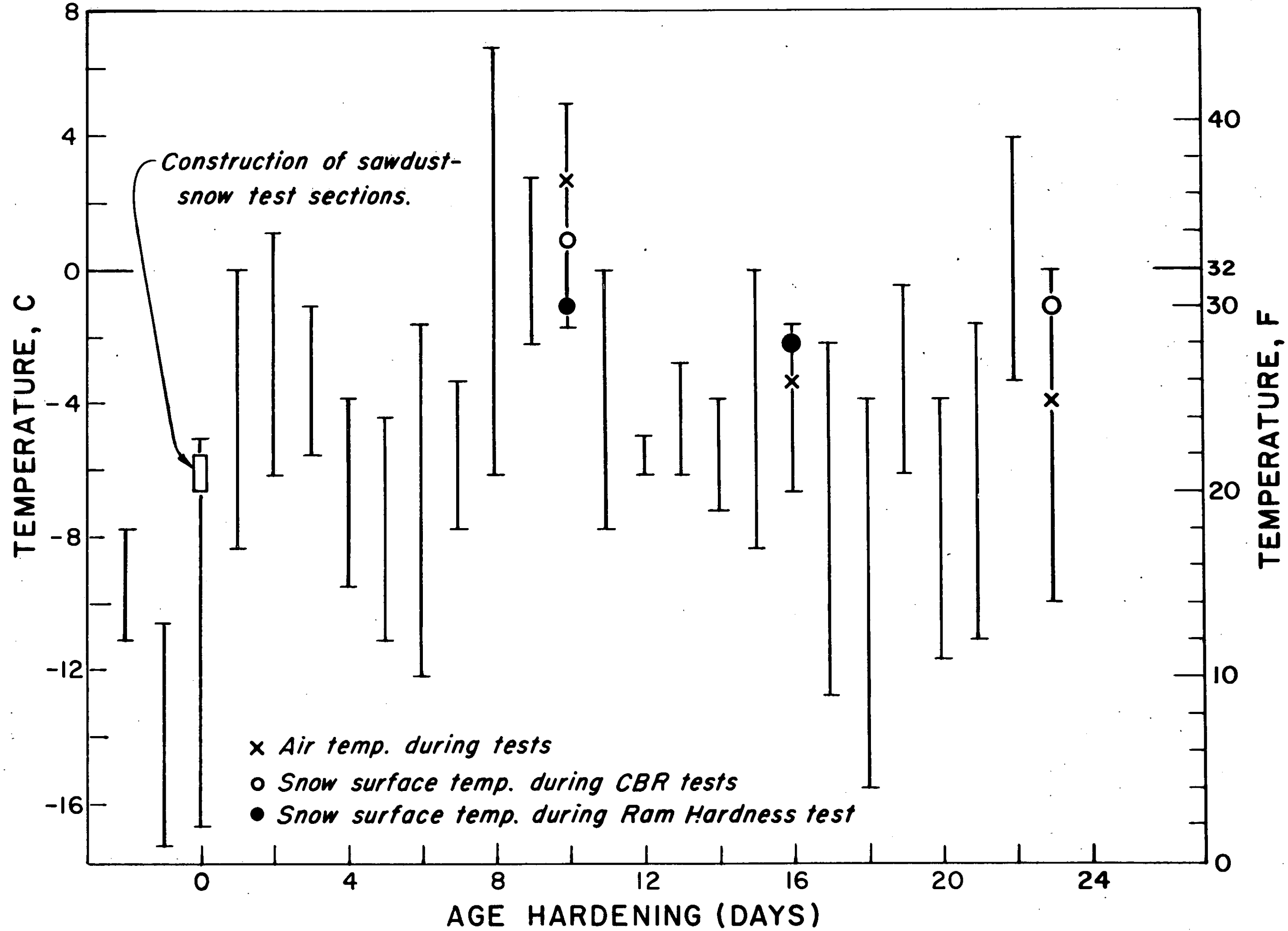

Figure 5. Temperature during age hardening of test sections, Keweenaw Field Station, 1961.

Since ram hardness is an indication of bearing capacity, it can be assumed that the presence of sawdust also somewhat increases the CBR value of the snow pavement (Wuori, 1962).

The unconfined compressive strength of the sawdust-snow layer after 16 days of age hardening was 153 psi, while the control section average was 128 psi.

A few preliminary tests with mixtures of wood chips (approximate density 0.2 g/cm³) and snow were performed in Greenland in 1962. (The additive consisted of wood particles ranging in size from sawdust to 5 x 4 x 2 mm chips.) Two mixtures were prepared: one containing 90% Peter plow processed snow and 10% wood chips and sawdust and the other 80% Peter snow, 10% wood chips and sawdust and 10% water (all percentages by volume). After 5 days of age hardening ram hardness tests and density observations were made. The results are shown in Figure 7.

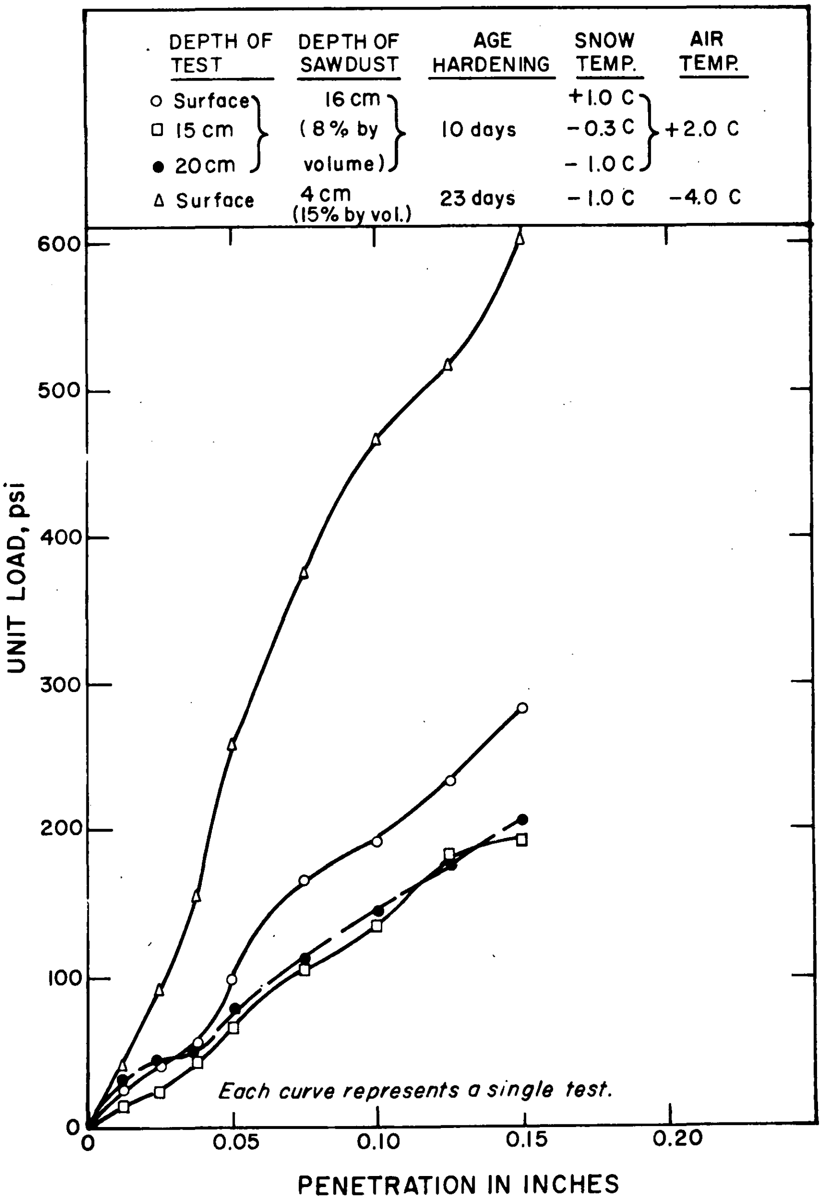

Figure 6. California Bearing Ratio tests on sawdust-snow mixtures.

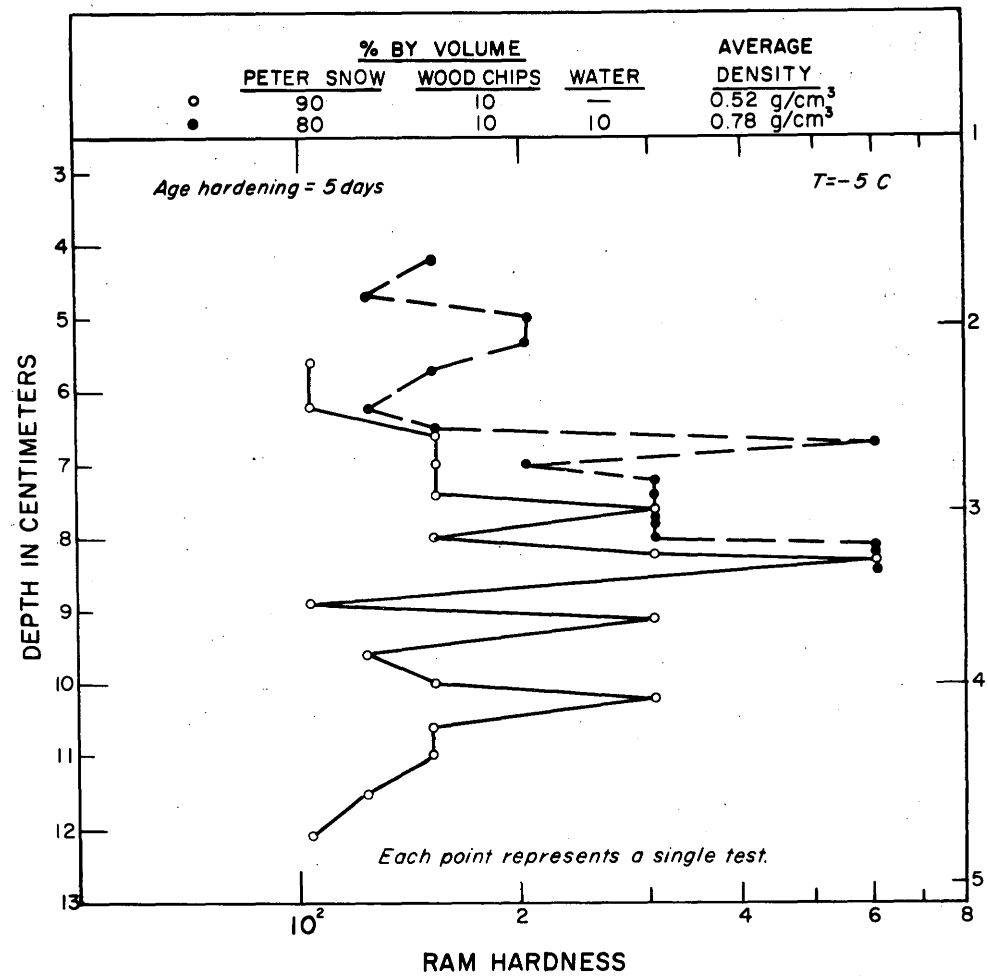

Figure 7. Ram hardness profiles of wood chip-snow mixtures.

No difficulties were experienced in performing field and laboratory tests on the previously discussed sawdust-snow mixtures. However, wood chips in the mixture made coring and shaping of the density samples difficult and possibly affected the reliability of the ram hardness tests.

The average density of the wood chip-snow samples was 0.52 g/cm³ and of the wood chip-snow-water (ice) samples 0.78 g/cm³.

The average ram hardness values of the two mixtures were 198 and 309, respectively.

A 25-ft x 4-ft x 4-in. (10-cm) deep test sidewalk was installed in Trench 12 at Camp Century in front of the CRREL office building. A 50% wood-chip, 50% Peter-snow mixture was used (percentages by volume). After several days very little age hardening was noticed. The mixture did not appear to age-harden at the natural rate. It was immediately assumed that the percentage of wood particles in the mixture was too high. To make the sidewalk suitable for walking, water was sprayed on the surface, the amount of water being approximately 10% of the total volume of the mixture. This produced a hard, non-skid surface.

The sidewalk experiment seemed to suggest that the presence of a high percent of wood chips or sawdust tends to retard the natural age-hardening process of disaggregated snow. However, a 3 to 5 cm thickness of Peter snow left over from the sidewalk installation, which was spread on the trench floor around the sidewalk 2 hours after processing, did not age-harden. The conditions in a closed trench (constant low temperatures, very little air circulation) are not the best for the age-hardening process. To what extent the closed trench conditions were responsible for the retardation of the age-hardening process in the wood chip-snow mixture, and how much of this effect was due to the high wood content, is not known.

SUMMARY

It can be assumed that there exists an optimum amount of sawdust that can be added to processed snow with favorable results. This optimum sawdust content has not been determined. The addition of some sawdust to processed snow increases the ultimate bearing capacity of snow. There are indications that if the amount of sawdust exceeds a certain percentage, the age-hardening process will be retarded. Foreign particles in processed snow will decrease the snow grain-to-grain contact which is necessary for age hardening to occur.

The optimum sawdust content for ice also apparently has not yet been determined. It is expected that the optimum additive content would be considerably higher for ice than for snow.

It would be desirable to perform a complete series of sawdust-snow mixture tests, with sawdust content as the only variable. Then similar series of tests could be performed with temperature as the variable. The most favorable sawdust particle size would also have to be determined. Standard sawdust appears to be superior to wood chips as an additive in processed snow.

Hanson (1958) indicates that softwood sawdust is superior to hardwood sawdust. The type of sawdust warrants further study.

Investigation of the use of sand or rock as additives may be desirable since rock is available on the edge of the Greenland Ice Cap.

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