Technical Report 68

JULY, 1960

Snow Stabilization using Dry Processing Methods

U. S. ARMY
SNOW ICE AND PERMAFROST
RESEARCH ESTABLISHMENT
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by Albert F. Wuori

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Wilmette, Illinois

PREFACE

This paper is an interim report for USA SIPRE Project 022.02.006, Snow road and runway construction. The purpose of this investigation was to determine the effectiveness of dry processing methods in compacting cold granular snow.

The work was performed in Greenland during the summer of 1958 by Mr. Wuori, project leader for CE Greenland Project 35, Snow runway construction. The work was done for the Snow and Ice Applied Research Branch, Dr. H. Bader, then acting chief. The author was assisted in the work by Mr. H. C. Brunke and Mr. E. R. Jackovich, Snow and Ice Applied Research Branch.

This report has been reviewed and approved for publication by the Office, Chief of Engineers.

W. L. NUNGESSER
Colonel, Corps of Engineers
Director

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SUMMARY

Experiments were made with several methods of dry processing and compacting snow on the Greenland Ice Cap. The Peter snow miller was used to process the snow initially, followed by compaction with vibratory compactors, rollers, and a D-8 tractor. The vibration frequency was found to have some effect on the degree of compaction with the vibratory compactors. Better results were obtained by precompacting with a roller before vibration. The best compaction was obtained using a D-8 tractor with low ground pressure tracks to compact the freshly processed Peter snow. Tests show that this method of processing may be adequate to produce a snow surface and base structure capable of supporting certain types of aircraft.

SNOW STABILIZATION USING DRY PROCESSING METHODS

by

Albert F. Wuori

INTRODUCTION

A study of methods of dry processing snow for the construction of snow runways has been conducted by USA SIPRE for the past two years at Houghton, Michigan. Part of this work is described in SIPRE Technical Report 53 (Wuori, 1959). Rotary snow plows were used for processing the snow for the base course, and rollers and vibratory compactors were used for compacting the surface. The experiments have shown that the vibratory compactors are more effective on cold, freshly processed snow, and rollers are more effective on comparatively warm snow.

The present experiments were conducted on the Greenland Ice Cap during the summer of 1958 to determine the effectiveness of the dry processing methods in compacting cold, granular snow. A Peter snow miller was used to process a 3-ft thick layer of snow to form the base and surface course of the test lanes. The Peter snow was then leveled, and various methods of surface processing were tested. Some of the test lanes were processed with the vibratory compactors and others with rollers.

The effectiveness of the processing methods was evaluated in terms of resulting density, final hardness, crushing strength, and bearing capacity of the processed snow.

Density and temperature profiles of the undisturbed snow and air temperatures during the period are shown in Figures 17 and 18.

TEST LANE CONSTRUCTION

Nine test lanes, each divided into several test sections, were constructed near Camp Fistclench in the no-melt zone of the Greenland Ice Cap.

The Peter snow miller was used to disaggregate and lay the base course snow. A cut 9 ft wide and 5 ft deep was made, and the snow was thrown back into the trench behind the plow by casting chutes (Fig. 1). This resulted in a layer of dense, processed snow approximately 3 ft thick on the bottom of the 5 ft deep trench. Two cuts or passes were necessary to make the test lanes 18 ft wide. For most of the lanes the plow was operated at a normal forward speed of 25 ft/min with a milling drum speed of 300 rpm.

The processed snow was deposited very unevenly by the Peter plow casting chutes and was difficult to level. The Adams towed-type grader was not effective because of difficulty in controlling the blade with the manual controls and because of the large volume of snow which had to be moved. Leveling with the tractor blade was more effective, although a level surface was still difficult to produce. One forward blading pass and one backblading pass with the tractor blade were made on each lane. The resulting surface was level enough for testing, but not level enough for landing aircraft.

After leveling, each test lane was divided into several 100-ft sections, and each section was given a different type of surface processing.

The vibratory compactors were used on some lanes, the vibration frequency being varied on each section. The compactors were towed by a D-8 tractor at a forward speed of 100 ft/min, the lowest speed possible with the D-8.

The sheepsfoot roller (Fig. 2) was used on some test lanes and the corrugated snow roller on others. On several test sections a roller and the vibratory compactors were used in combination.

The tracks of the D-8, LGP tractor also compacted a part of each test lane. The two passes necessary for leveling, plus an additional pass for towing the compactors or rollers, made a total of at least three coverages of the tractor tracks. The tracks were

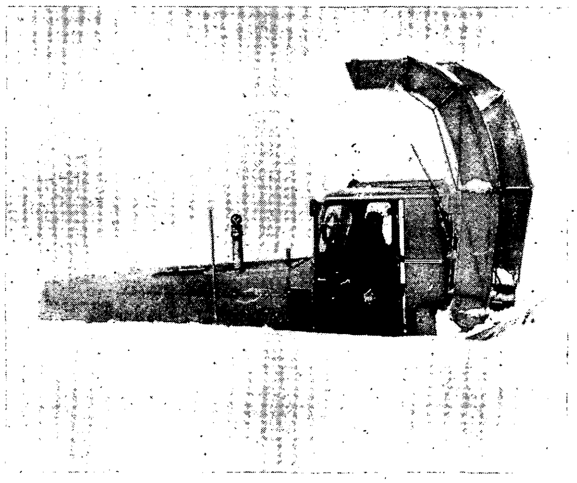


Figure 1. Peter snow miller laying base course snow.

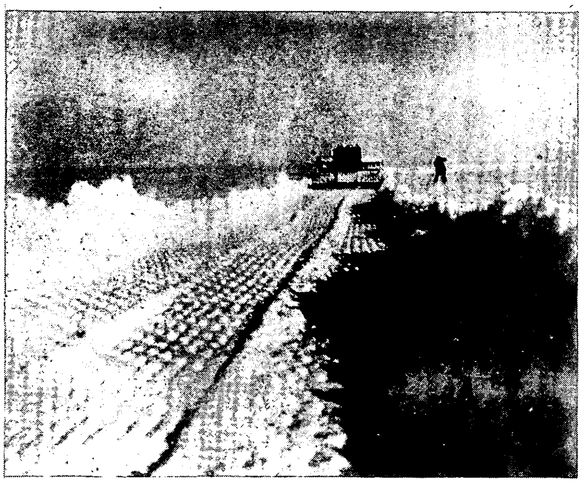


Figure 2. Rolling Peter snow with sheepsfoot roller.

54 in. wide and there was a 54 in. clearance between tracks. Therefore, all tests made in the center of each test lane represent only the compaction by either the rollers or vibratory compactors. The tests beneath the tractor tracks indicate additional compaction from the tractor tracks. The only exceptions are: section 4 of test lane A, section 4 of test lane B, and section 4 of test lane E, which received compaction from tractor tracks only.

Table I summarizes the methods of processing and the resulting density and hardness of each test lane. The hardness values, taken 20 to 30 days after processing, are comparable because there is little age hardening after the first 20 days (Fig. 3).

Test lanes A, B, and E were constructed to determine the effectiveness and optimum frequency of the vibratory compactors. Test lane C was compacted with both the corrugated and sheepsfoot rollers. Test lane D was given no surface processing. A 3-ft thick layer of snow was processed with the Peter plow using a different forward speed for each section and a constant milling drum speed to determine the optimum speed, if any, for processing snow. Test lanes F and G were constructed to determine the effectiveness of the sheepsfoot roller used before or after vibratory compaction. Test lane H was constructed to determine the effectiveness of using the corrugated roller to precompact the surface before vibration and to determine the effect of more than one pass with the vibratory compactors. Test lane I was constructed to determine the effect of weight of the vibratory compactors. The 80-lb counterweights were removed from 3 of the compactors which were mounted on the left side of the entire bank. The compactors were then used at different frequencies on each section. This resulted in the left half of each of the sections being compacted with the lighter compactors and the right half with the normal, heavier ones.

METHODS OF TESTING

Hardness testing, using the Rammsonde, was begun soon after each test lane was completed and continued through the period of age hardening. Two to three Rammsonde tests were made on each test section at daily intervals during the early stages of age hardening, and later at 3 to 4 day intervals.

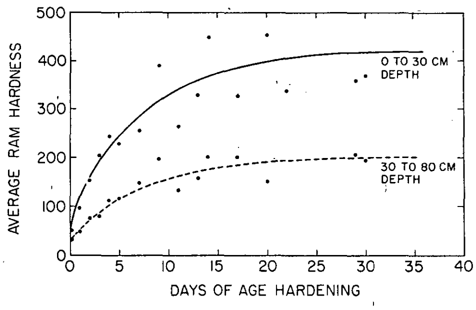


Figure 3. Typical age-hardening curves of a compacted Peter snow test section.

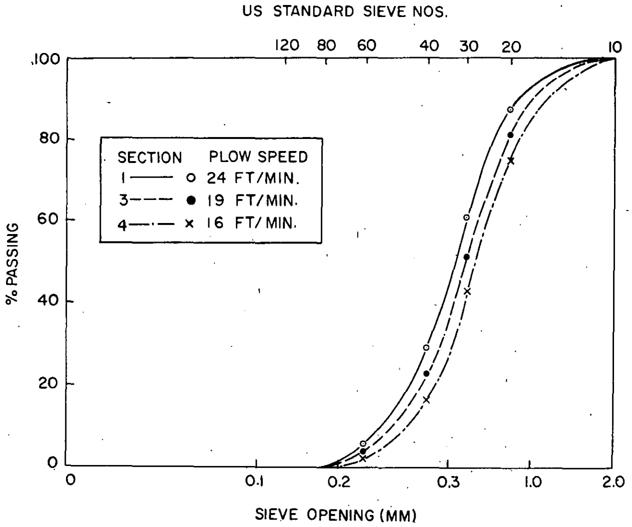


Figure 4. Sieve analyses of Peter snow processed at different speeds, test lane D. Age of snow 4 hr; sieve temp -9C; snow temp -9C; sample weight 50g.

A sieve analysis for particle size determination was made on the freshly processed Peter snow of most of the lanes (see Fig. 4). The Cenco-Meinzer vibratory sieve shaker was used, and the sieving was done in an undersnow laboratory which was kept at a constant temperature of approximately -10C.

A number of 3-in. diam samples were cored out of each test section with the 3-in. core auger. These samples were cut to 7.5 in. lengths and weighed. The densities were calculated and used for a density profile for each section. The samples were allowed to remain in the laboratory for 3 hr until they reached a temperature of -10C. An unconfined compression test was made on each sample. A motorized mechanical press was used for this test. The samples were tested to failure with an axial load applied at a rate of deformation of 0.2 in./min. This rate of deformation was chosen after a number of tests at various rates indicated that the crushing strength was relatively independent of the rate of deformation at 0.2 in./min or above.

California Bearing Ratio (CBR) tests were made on most of the test sections. Standard CBR field apparatus was used, and the tests were made at the standard rate of penetration of 0.05 in./min. Two complete CBR profiles were made on each section, each consisting of CBR tests on the surface, 6 in., 11 in., and 20 in. depths. A 5-lb surcharge was used on a few tests to determine if a surcharge weight was necessary to replace the weight of the removed material. There was apparently no difference in the tests due to surcharge. Therefore, all the remaining tests were made without surcharges.

Several large plate-bearing tests were made on some test lanes, using a 10 in. and 18 in. diam plate. Loads were applied with a hydraulic ram, using the D-8 tractor as a reaction. A Martin-Decker hydraulic load cell was used to indicate the load applied.

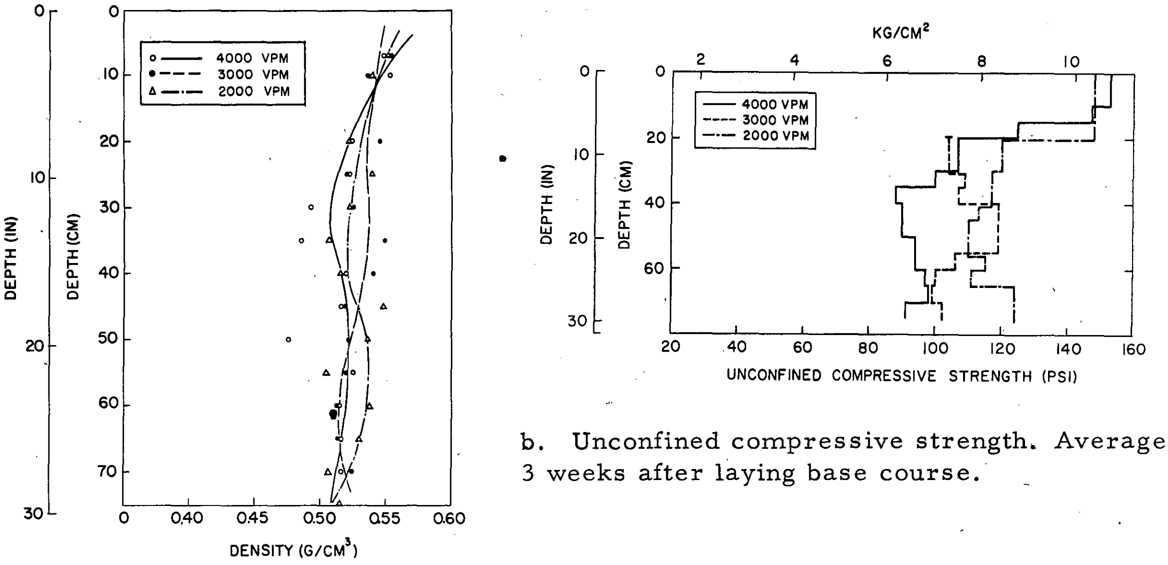
TEST RESULTS

Vibratory compaction

The data from test lanes A, B, and E, which were similarly processed, were combined to show comparative density and strength curves for snow processed with the vibratory compactors at different frequencies (Fig. 5). The average density curves (Fig. 5a) do not show any great difference in density resulting from the various vibration frequencies. The top 30 cm of the test sections which were vibrated at 3000 vpm show

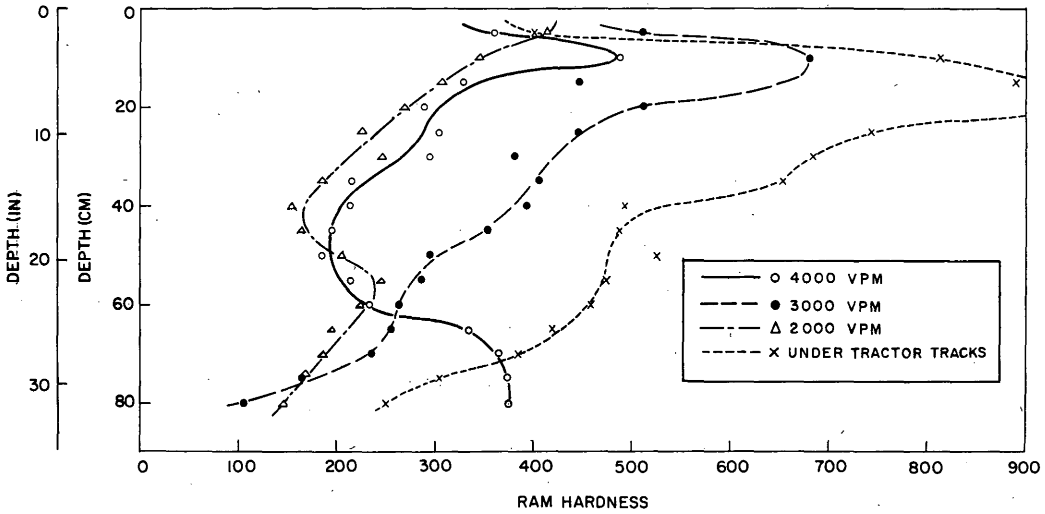
Table I. Test lane summary

Test lane	Processing	Base course			Surface layer			Avg ram hardness 20 to 30 days after processing (D-8 track coverages shown in parentheses)			
								Base course		Surface layer	
		Thick-ness (cm)	Density* (g/cm³)	Air temp (C)	Processing	Thick-ness (cm)	Density* (g/cm³)	Center	Beneath D-8 track	Center	Beneath D-8 track
A-1	Peter plow 25 ft/min	50	0.52	-1.5	Vibrated 4000vpm	30	0.54	180	450(3)	360	700(3)
2			0.52		Vibrated 3000vpm	30	0.54	400	450(3)	480	730(3)
3			0.53		Vibrated 2000vpm	30	0.56	230	400(3)	370	600(3)
4			0.51		Leveled only	30	0.53	220	300(3)	300	550(3)
B-1	Peter plow 33 ft/min	55	0.51	-1.5	Vibrated 4000vpm	25	0.54	300	600(3)	300	800(3)
2			0.52		Vibrated 3000vpm	25	0.53	180	440(3)	660	670(3)
3			0.53		Vibrated 2000vpm	25	0.54	230	330(3)	310	560(3)
4			0.53		Leveled only	25	0.55	210	430(3)	350	840(3)
C-1	Peter plow 25 ft/min	45	0.53	0.0	Sheepsfoot roller 1 pass Corrugated roller 1 pass	35	0.56	200	370(4)	390	540(4)
D-1	Peter 24 ft/min	50	0.55	-8.0	None	30	0.49	230	None	125	None
2	Peter 25 ft/min	50	0.55	-8.0	None	30	0.49	350	None	110	None
3	Peter 19 ft/min	50	0.54	-8.0	None	30	0.50	400	None	140	None
4	Peter 16 ft/min	50	0.49	-8.0	None	30	0.48	210	None	125	None
E-1	Peter plow 25 ft/min	50	0.50	-8.0	Vibrated 4000vpm	30	0.53	220	450(3)	370	840(3)
2			0.53		Vibrated 3000vpm	30	0.56	250	400(3)	470	880(3)
3			0.51		Vibrated 2000vpm	30	0.53	120	400(3)	250	680(3)
4			0.51		Leveled only	30	0.55	430	620(3)	550	800(3)
F-1	Peter plow 25 ft/min	45	0.50	-7.5	Vibrated 4000vpm Sheepsfoot roller 1 pass	35	0.54	330	460(4)	430	560(4)
2			0.49		Vibrated 2000vpm Sheepsfoot roller 1 pass	35	0.54	260	300(4)	330	660(4)
3			0.53		Sheepsfoot roller 1 pass	35	0.55	410	410(4)	500	600(4)
G-1	Peter plow 25 ft/min	50	0.50	-7.5	Sheepsfoot roller 1 pass Vibrated 4000vpm	30	0.56	340	530(4)	790	880(4)
2			0.52		Sheepsfoot roller 1 pass Vibrated 2000vpm	30	0.54	300	560(4)	660	840(4)
3			0.52		Sheepsfoot roller 1 pass	30	0.53	400	400(4)	640	900(4)
H-1	Peter plow 25 ft/min	40	0.53	-5.0	Corrugated roller 1 pass Vibrated 3000vpm 1 pass	30	0.57	130	130(4)	450	850(4)
2			0.50		Corrugated roller 1 pass Vibrated 3000vpm 2 passes	30	0.55	420	500(5)	650	820(5)
3			0.54		Corrugated roller 1 pass Vibrated 3000vpm 3 passes	30	0.56	200	690(6)	560	840(6)
4			0.54		Corrugated roller 1 pass	30	0.56	220	500(6)	310	770(6)
I-1a	Peter plow 25 ft/min	40	0.49	-5.0	Vibrated 4000vpm w/o counter weights	30	0.53	150	530(3)	250	800(3)
b			0.53		Vibrated 4000vpm w/counter weights	30	0.56	260	500(3)	340	1000(3)
2a			0.55		Vibrated 3000vpm w/o counter weights	30	0.57	360	220(3)	400	450(3)
b			0.53		Vibrated 3000vpm w/ counter weights	30	0.54	240	370(3)	300	650(3)
3a			0.53		Vibrated 2000vpm w/o counter weights	30	0.55	200	530(3)	400	820(3)
b			0.54		Vibrated 2000vpm w/ counter weights	30	0.55	320	530(3)	350	800(3)



a. Density

b. Unconfined compressive strength. Average, 3 weeks after laying base course.

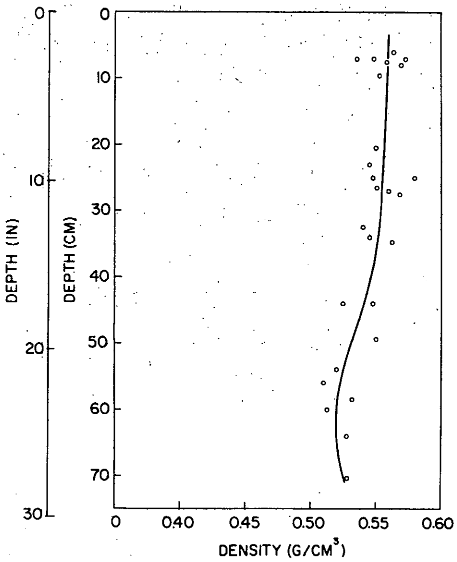


c. Ram hardness. Average, 3 weeks after laying base course.

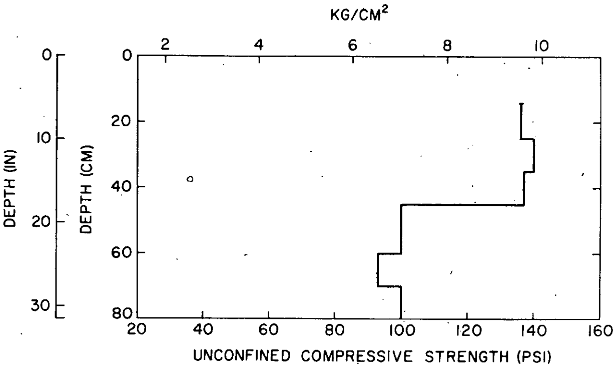
Figure 5. Density and strength of Peter snow vibrated at various frequencies, test lanes A, B and E.

a higher hardness value than those vibrated at either 4000 or 2000 vpm (Fig. 5c). The greatest hardness, however, was achieved in the snow compacted with the D-8 tractor.

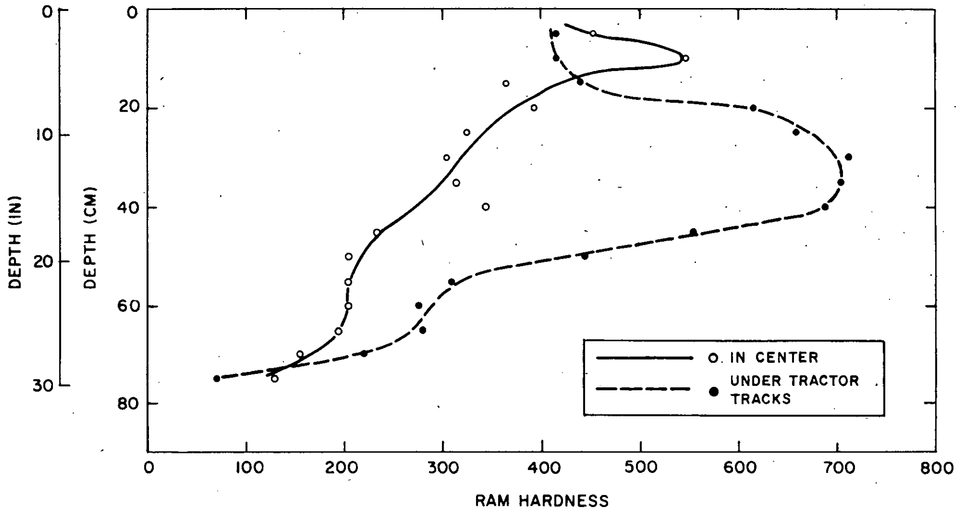
The length of the vibratory compactor base is 14 in. When towed forward at a speed of 100 ft/min, the compactor takes 0.7 sec to pass over any given point on the snow surface. During this 0.7-sec interval, 47 blows are delivered at a frequency of



a. Density



b. Unconfined compressive strength. Average, 15th day after laying base course.

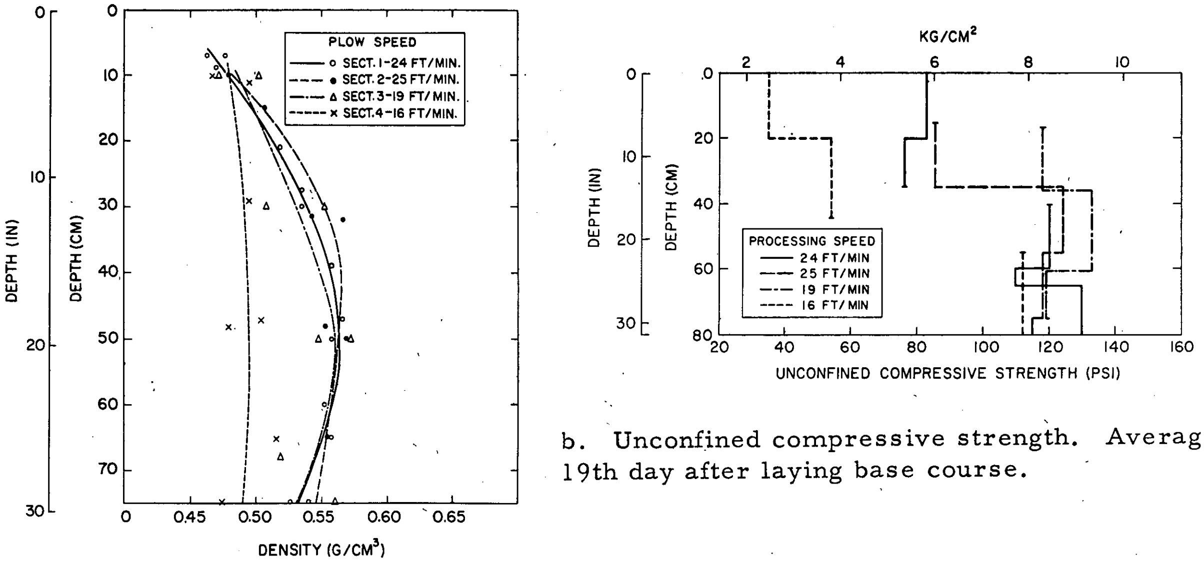


c. Ram hardness. Average, 24th day after laying base course.

Figure 6. Density and strength of Peter snow rolled with sheepsfoot and corrugated rollers (one pass with each), test lane C.

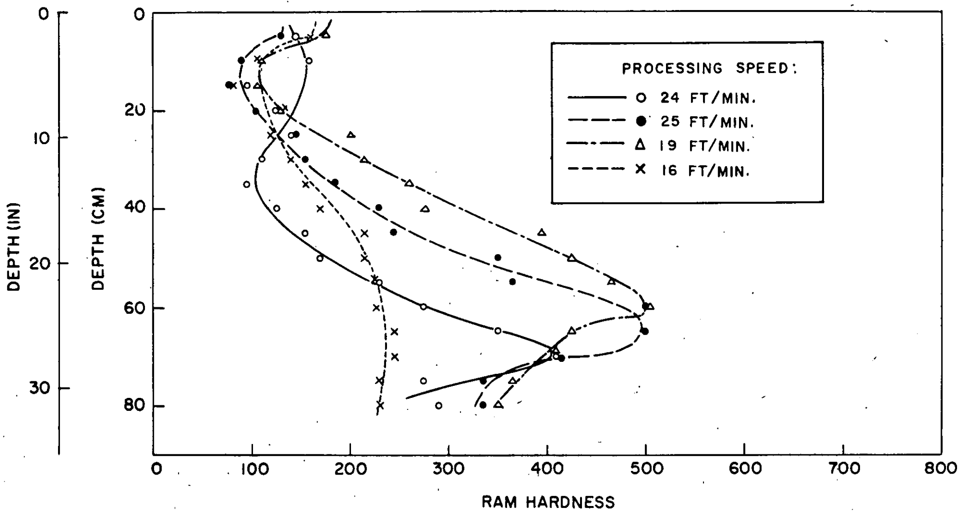
4000 vpm, 35 blows at 3000 vpm, and 23 blows at 2000 vpm. It would seem that the highest frequency would be the most desirable, since it results in the greatest number of blows. However, the rate at which these blows are applied is also important. The most effective vibration frequency probably depends on the resonant frequency of the snow. Frequencies much higher or much lower than this are likely to be relatively ineffective.

The tests did not show a great difference in compaction due to changing the vibration frequency. However, there were indications that a frequency of 3000 vpm is more effective than either 2000 or 4000 vpm.



a. Density.

b. Unconfined compressive strength. Average, 19th day after laying base course.



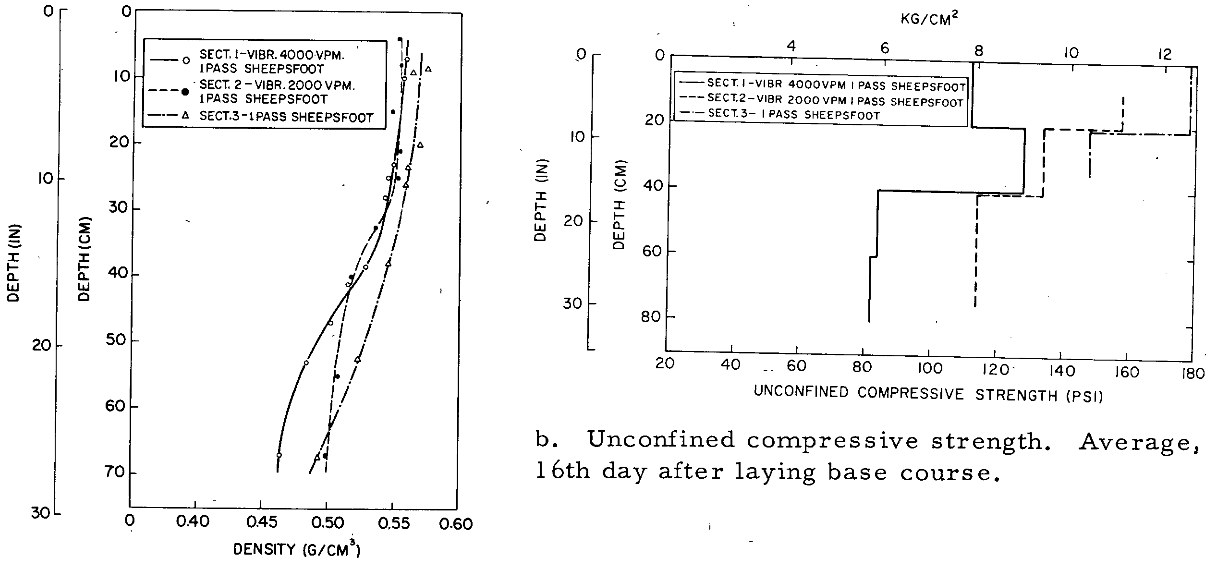
c. Ram hardness. Average, 19th day after laying base course.

Figure 7. Density and strength of uncompacted Peter snow, processed at varying speeds, test lane D.

The data for test lane I (Fig. 11) do not show any appreciable difference in density or hardness when the weight of the compactors was decreased by 20%. The data again show the great increase in density, hardness, and strength of the snow compacted by the tractor tracks.

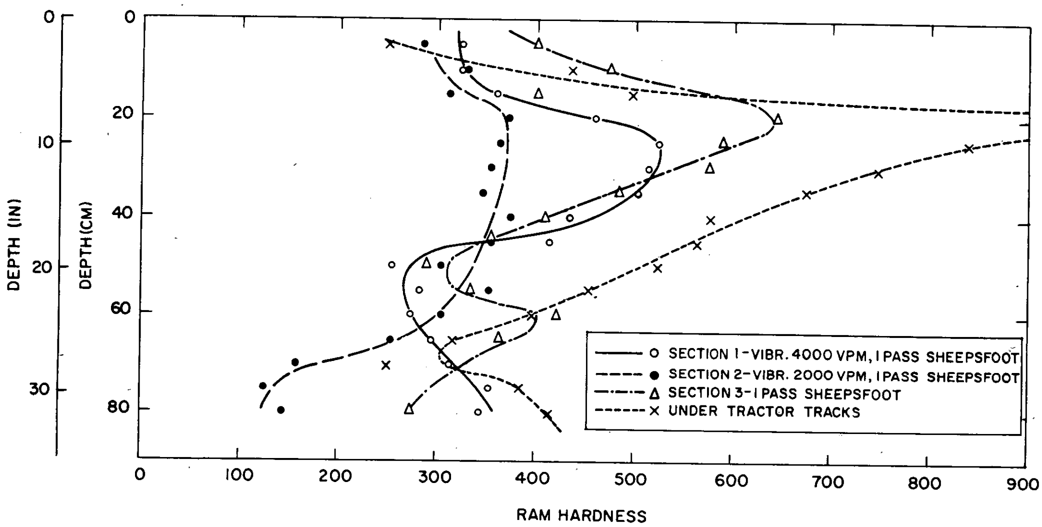
Rolling

Fairly good compaction was achieved on test lane C by using a sheepsfoot roller followed by a corrugated roller (Fig. 6). However, this snow was processed and



a. Density.

b. Unconfined compressive strength. Average, 16th day after laying base course.

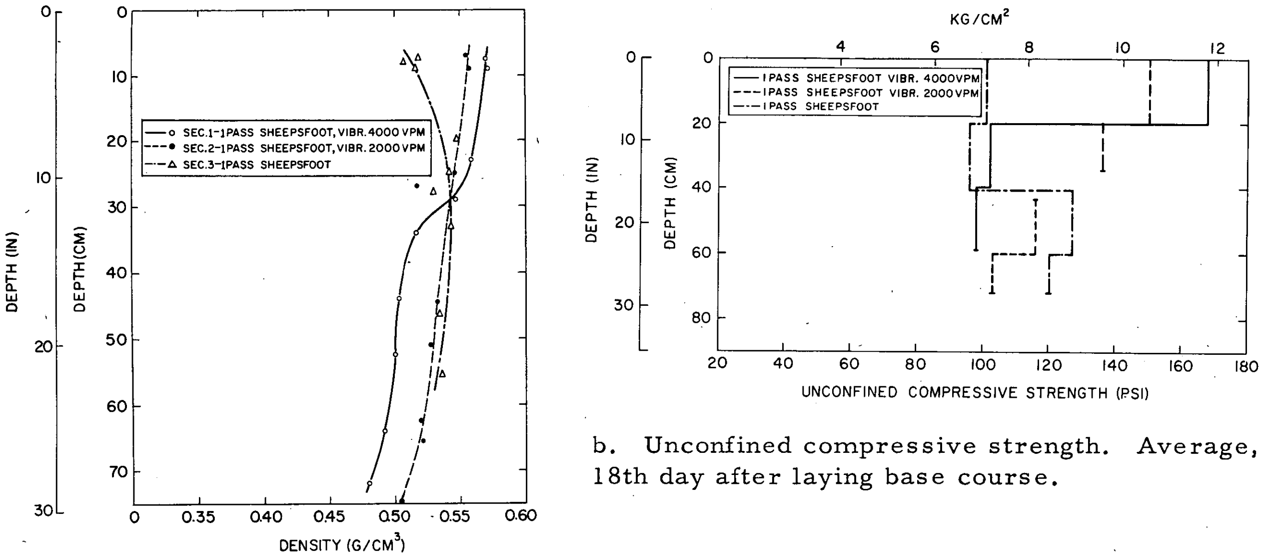


c. Ram hardness. Average, 19th day after laying base course.

Figure 8. Density and strength of Peter snow, vibrated and then rolled with sheepsfoot roller, test lane F.

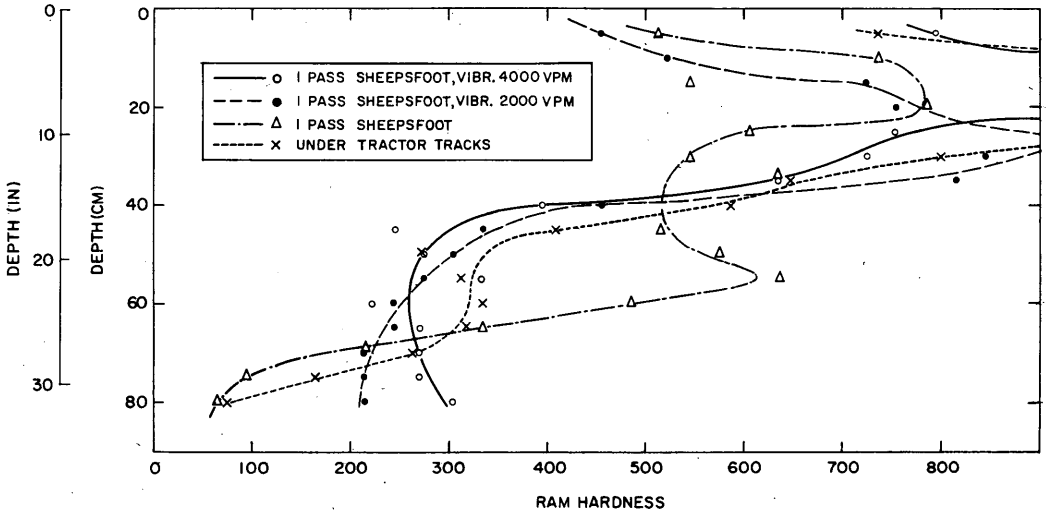
compacted when the air temperature was at 0C, a condition which is very desirable for rolling compaction (Wuori, 1959). The rolled snow was less hard than the tractor compacted snow (Fig. 6c).

The sheepsfoot roller which is used in soils work was too heavy for use on processe snow. The feet penetrated completely into the snow, and the roller was supported by the solid drum. The contact area of the feet should be increased so that a lower contact pressure would result. A foot area double the original of 5 in.² may be more effective.



b. Unconfined compressive strength. Average, 18th day after laying base course.

a. Density.

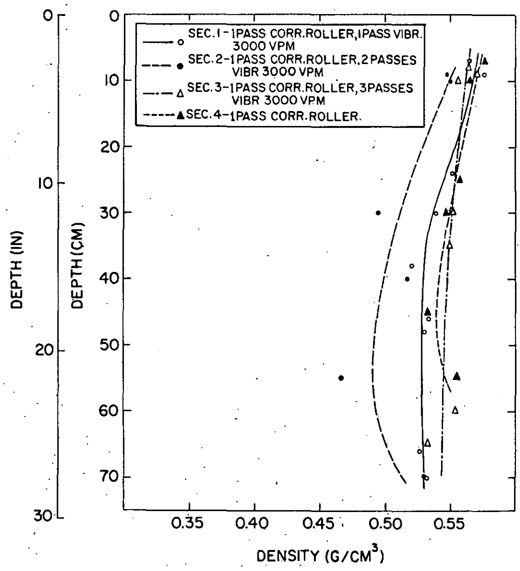


c. Ram hardness. Average, 22nd day after laying base course.

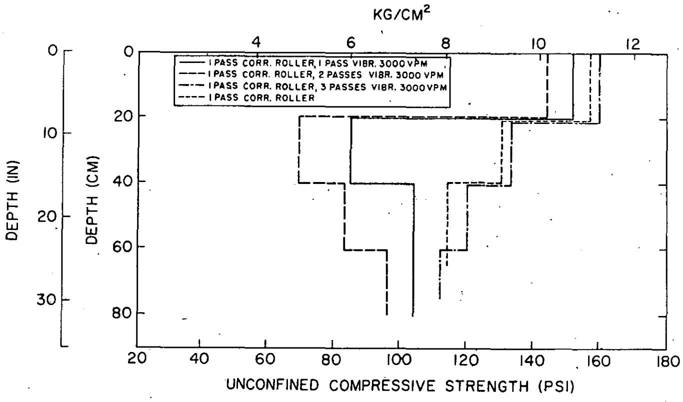
Figure 9. Density and strength of Peter snow rolled with sheepsfoot roller and then vibrated, test lane G.

Combined rolling and vibratory compaction

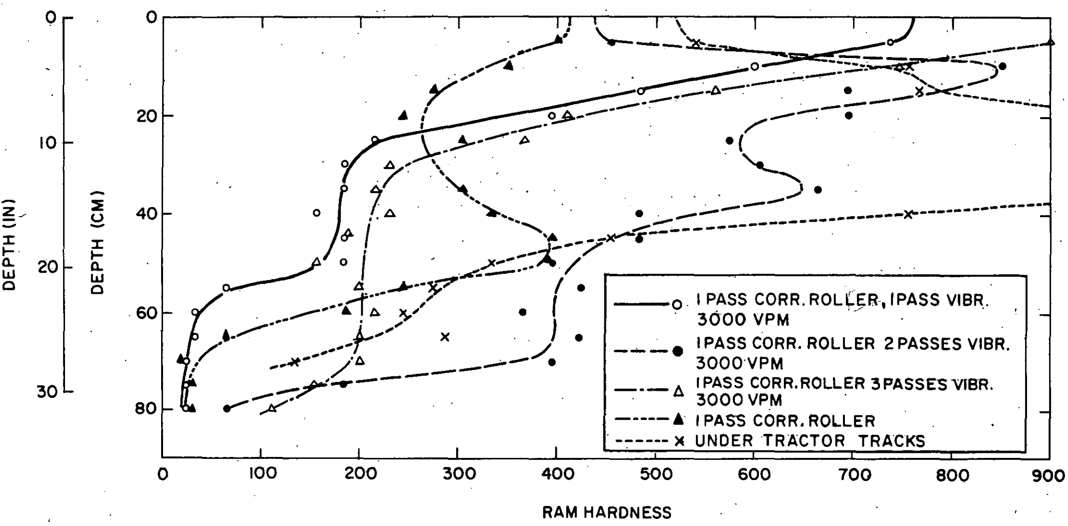
On test lanes F, G, and H, rollers were used in combination with the vibratory compactors. Lanes F and G were similarly processed using the sheepsfoot roller and the vibratory compactors, except that the operations were reversed. In test lane F the density, hardness, and strength of the section processed with the sheepsfoot roller only were higher than on the sections processed also with the vibratory compactors (Fig. 8). However, the data for test lane G (Fig. 9) show that the sections which were rolled first and then vibrated were considerably stronger than the section which was rolled only.



a. Density.



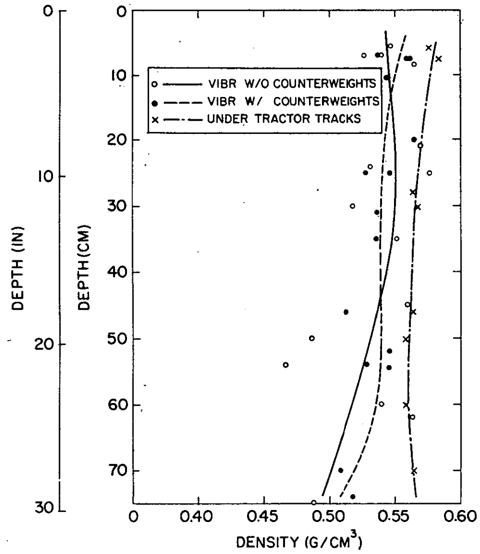
b. Unconfined compressive strength. Average, 10th day after laying base course.



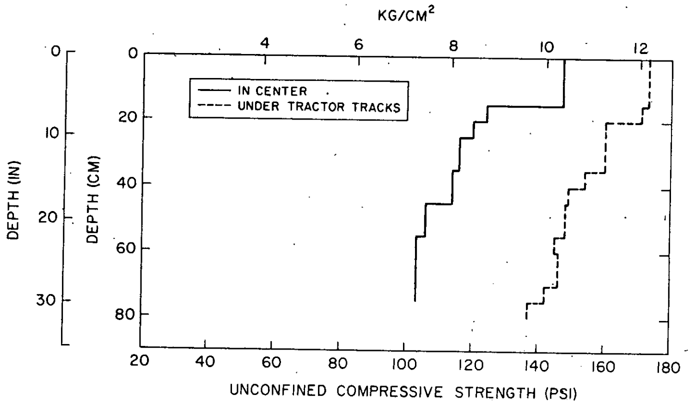
c. Ram hardness. Average, 20th day after laying base course.

Figure 10. Density and strength of Peter snow rolled with corrugated roller and then vibrated, test lane H.

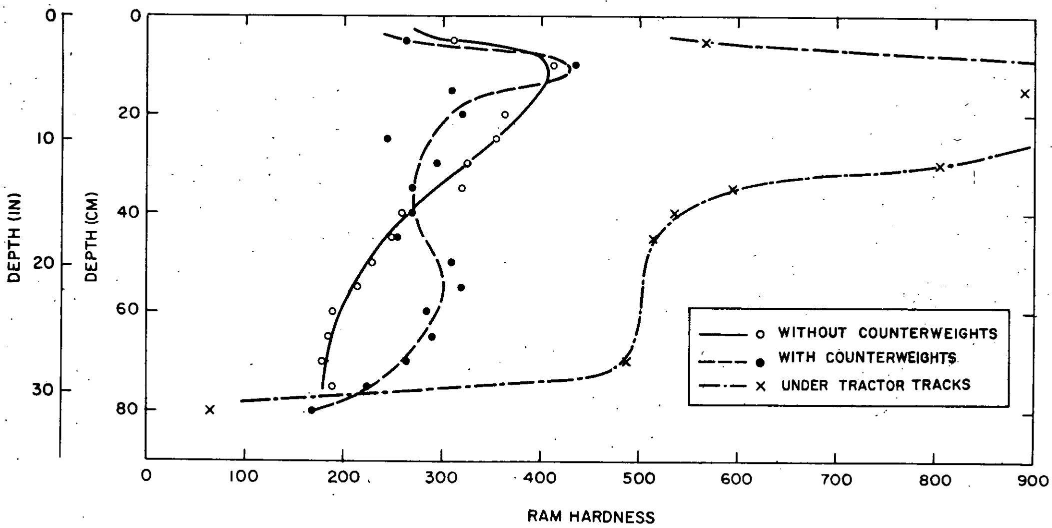
Test lane H, processed with the corrugated roller followed by the vibratory compactors (Fig. 10), showed no consistent variation in density for the various sections (Fig. 10a). The density profile of section 2 is lower than those of the other sections. This does not indicate that the surface processing was ineffective because the entire base course was at a lower density. This was probably due to an inconsistency in processing, such as stopping the plow while making the test lane. The hardness curves (Fig. 10c) show the increase in hardness of the rolled only section. The greatest hardness was again noted in the snow compacted by the tractor.



a. Density.



b. Unconfined compressive strength. Average, 19th day after laying base course.



c. Ram hardness. Average, 13th day after laying base course.

Figure 11. Density and strength of vibrated Peter snow showing the effect of vibrator weight, test lane I.

Processing at various speeds

The data from test lane D shows the effect of varying plow speed while processing. The normal forward speed of the plow, 25 ft/min, was used while processing sections 1 and 2, and slower speeds were used when processing sections 3 and 4. The milling drum speed was kept constant at 300 rpm. As shown in Table I and Figure 7, the slower forward speeds resulted in snow of a lower density and hardness. This was especially noticeable on section 4 which was processed at a speed of 16 ft/min. Sieve analyses on the snow from each section show that higher forward speeds produce finer snow (Fig. 4). The degree of fineness seems to be directly related to the forward speed. Therefore, these data seem to indicate that a finer, denser, and more desirable snow is produced when the plow is at its maximum operating speed.

These data, however, may be misleading, as seen by a closer look at the processing operation. As the snow emerges from the casting chutes it is thrown through the air to the surface behind the plow (Fig. 1). A considerable part of the fine particles is lost by blowing or drifting away. Therefore, when the plow is moving forward slowly and a small volume of snow is being thrown through the air, a larger percentage of fines are lost than when the plow is moving forward rapidly and a large volume of snow is thrown through the air. Thus, no definite conclusions on the effect of plow speed can be made from the data presented.

The use of special casting chutes which would discharge the snow immediately behind the plow would tend to eliminate this loss of fines and thus aid in producing a denser and harder snow.

Figure 7a shows that the maximum density of plow-deposited snow occurs at depths of 40 to 50 cm. This can be understood by studying the deposition pattern as the snow is thrown to the surface behind the plow. The leading edge of the deposition pattern deposits a small amount of snow on the surface; as the center of the pattern passes over, a much greater volume is being deposited and hits the surface with a greater force. Then as the trailing edge of the pattern passes over, a smaller amount of snow is again being deposited. This density profile is changed when surface processing is applied, as on the other test lanes.

Compaction by the D-8 LGP tractor

The density and hardness data from the test lanes show that the low ground pressure tracks of the D-8 tractor were more effective in compacting the freshly processed Peter snow than any of the other methods of surface compaction. The effectiveness of the tractor in compacting snow is probably due to several factors. First, the heavy gross load is effective. The weight of the tractor is over 30 tons. Secondly, a large volume of snow is under confinement beneath the tracks, as they are 54 in. wide. Another factor is the vibration of the tractor and its tracks as it moves along. These factors combine to make the D-8 an effective compactor. All of the tests show the compaction resulting from making at least three coverages with the tractor tracks.

The ram hardness profiles show that tractor-compacted Peter snow, when aged for 3 weeks, is sufficiently strong to accommodate several types of wheeled aircraft, including a C-124 and an F94-A, according to required ram hardness values computed by Bender (1956) (see Fig. 12). Therefore, two or three coverages of the D-8 LGP tracks may be adequate for compacting the leveled, freshly processed Peter snow.

CBR field bearing and plate bearing tests

The results of the CBR field bearing tests are shown in Table II. Most of the values represent an average of two tests.

Most of the CBR values are in the 20 to 40% range. In soils work this material would be classified by its CBR value as a very good subgrade to a good subbase material. However, the value of the CBR test is questionable in snow because of the differences in the material such as plasticity, compressibility, etc. The CBR values were found to be very temperature-dependent also because the test is made on an exposed surface.

It is evident that, although the CBR test produces some shear failure in the snow, the principal and primary effect is consolidation. Figure 13 shows some typical CBR curves. The initial portion of the curves represents consolidation, followed by rapid collapse and shearing through the compressed layer, followed again by slow consolidation.

An evaluation of the load-carrying capacity of these test sections by the CBR design method may not be realistic. In soils work the CBR value or resistance to penetration

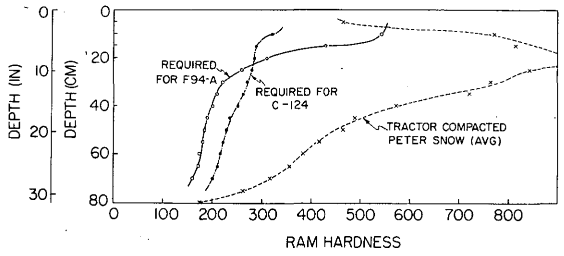


Figure 12. Average ram hardness profile of tractor-compacted Peter snow compared with the required profiles for landing of aircraft (from Bender, 1956).

F94-A: Wheel load 10,000 lb;
C-124: Wheel load 45,300 lb, tire pressure 78 psi.

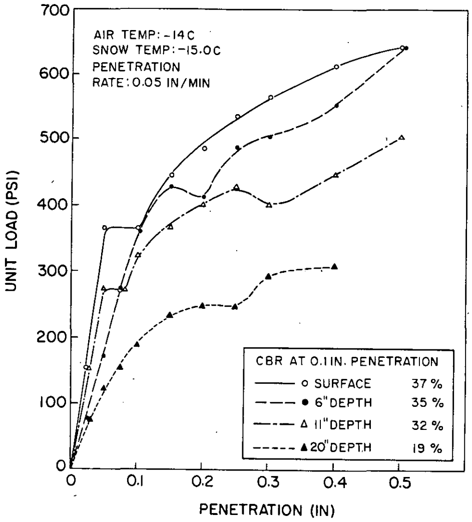


Figure 13. Typical in place CBR loading curves. 20 days after laying base course. Test lane H, sec 3.

is expressed as a percent of the resistance to penetration of standard crushed stone. These values are then used to evaluate the load-carrying capacity of pavement structures by empirical curves which were obtained as a result of a number of tests made on test sections subjected to traffic with various types of wheel loads. Since all of this work has been done with soils only, the relationship between load-carrying capacity and CBR value of snow should be further investigated in order for the test to be meaningful.

At each CBR test pit, several Rammsonde tests were also made. The correlation is shown in Figure 14. Each point represents a single CBR value plotted against an average ram value at the same depth. The straight line was computed by the method of least squares. If the ram hardness R is known:

$$\text{CBR} = 17.58 + 0.018R \qquad [200 < R < 700].$$

The points are quite scattered, and the probable error in CBR is 4.37%. No data were obtained for ram values below 200 so the relationship in general has little meaning because of the small range of CBR values as compared with the range of ram values. A difference of 400 in ram hardness represents a difference of only 7% in CBR. This is probably because the two tests differ in their rate of loading. Both are indicator tests. The ram hardness test measures the work required to displace a volume of snow under impact load. It is primarily determined by the instantaneous strength of the snow, which varies greatly with density and age hardening time. The CBR test is performed under a very slow rate of loading (0.05 in./min) and measures the relative unit load required to produce a certain deformation. With the small amount of deformation involved, the resistance does not vary greatly.

Large plate bearing tests were made on several of the test sections. The procedure used in each test was to place a 20,000 lb load on the 84.5 in.^{2} plate (237 psi) and observe the settlement. Some tests were made with a larger plate, but, with a 20,000 lb load, very little settlement was noted. In most of the tests (Fig. 15) the settlement was approximately 1 in. in 6 min, and no shear failure was observed.

Table II. California Bearing Ratio test results

Test lane	Days of age-hardening	Snow temp. (C) 6-in. depth	CBR value (%) at 0.1 in. penetration			
			Surface	6-in. depth	11-in. depth	20-in. depth
A-1	30	-12	24	17	19	21
2	31	-13	37	26	19	21
3	31	-13	29	22	28	27
4	31	-13	20	23	32	25
B-3	12	- 9	19	17	25	25
4	12	- 9	31	36	26	-
			(In tractor tracks)			
F-1	19	-11	23	29	28	25
2	19	-11	13	29	34	16
3	19	-11	24	36	30	20
G-1	10	-14	34	32	19	16
H-3	20	-14	37	35	32	19
I-1a	19	-15	-	16	8	14
2a	19	-15	33	25	23	-
3a	19	-15	37	27	19	18

Unconfined compression tests

The unconfined compression tests, as shown for each test lane, were made for a comparative strength analysis of each test section. They were also used along with additional tests, not shown in this report, to correlate unconfined compressive strength with ram hardness. This study is described in another report (Brunke, 1959).

CONCLUSIONS AND RECOMMENDATIONS

Several of the methods of compacting dry processed snow as described in this report were found to be effective in producing a surface apparently capable of supporting certain types of aircraft (Fig. 16). However, compaction of the Peter snow with the low ground pressure tracks of the D-8 tractor was most effective.

When the vibratory compactors were used, no great change in the resulting compaction was observed with a variation in vibration frequency. However, there were indications that a frequency of 3000 vpm was the most effective. Pre-compaction with the sheepsfoot roller before vibration apparently contributed greatly to the resulting density and hardness. The standard sheepsfoot roller could probably be made more effective by increasing the foot contact area.

The forward speed of the snow miller was found to have an effect on the resulting snow density and hardness. A more desirable snow resulted at the normal, higher operating speed than at lower speeds. However, the effect may be somewhat different when casting chutes that discharge the snow directly behind the plow are used.

The resulting density and hardness of the tractor-compacted Peter snow seem sufficiently high for supporting loads equivalent to that of several types of wheeled aircraft. Therefore, because of its greater compaction effect and because it is a standard military item in Greenland, the D-8 LGP tractor could be used for compacting Peter snow, instead

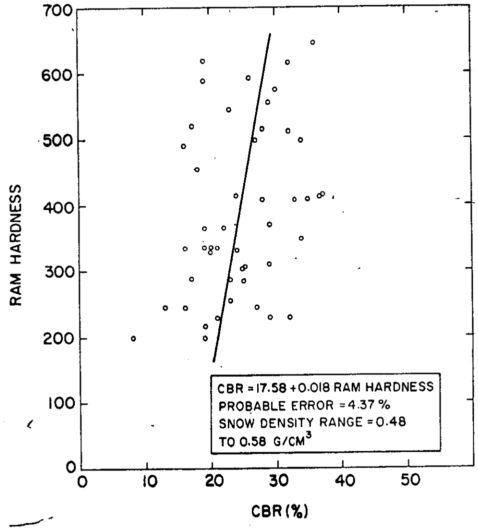
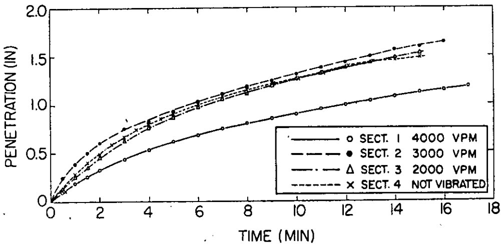
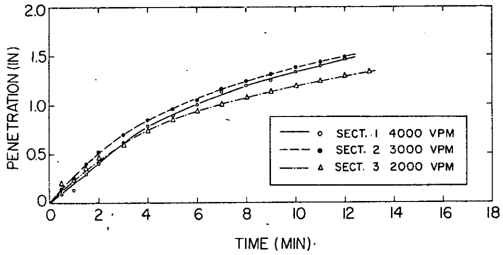


Figure 14. Correlation of CBR values with ram hardness.



a. Test lane A. Avg, 19th day after laying base course.



b. Test lane B. Avg, 20th day after laying base course.

Figure 15. Plate-bearing tests on vibrated Peter snow. Bearing plate 84.5 in^2; constant load 20,000 lb.

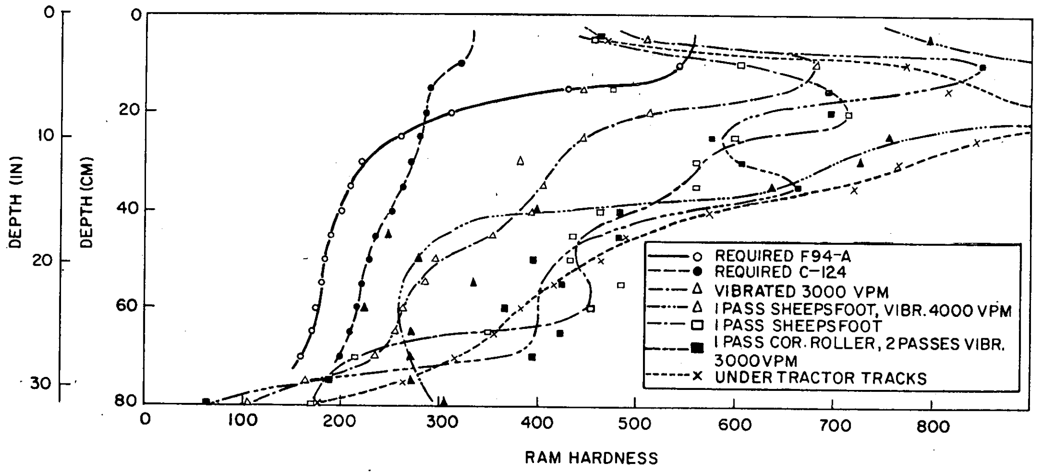


Figure 16. Average ram hardness profiles of snow compacted by the most satisfactory methods compared with the required profiles for landing of aircraft.

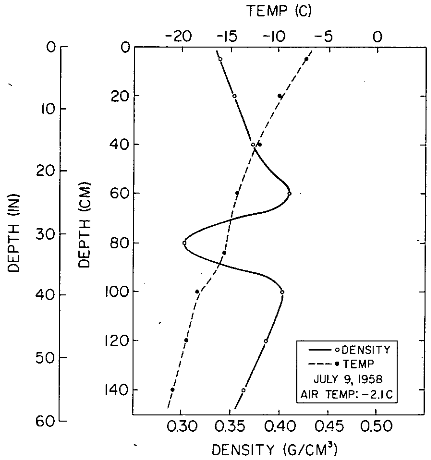


Figure 17. Density and temperature profile of undisturbed snow in the test area.

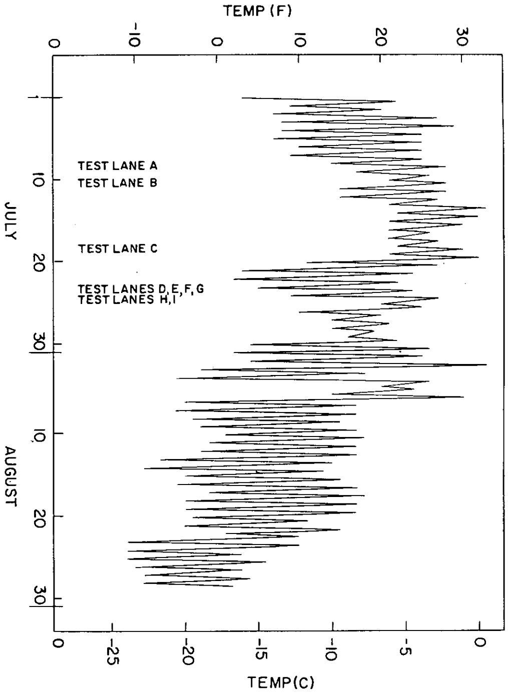


Figure 18. Air temperatures during the 1958 test season.

of special vibrators or rollers. More work should be done to determine the number of passes necessary to obtain the desired compaction with the tractor.

Leveling of the Peter snow is still a problem, especially as the material must be leveled immediately after processing while still in a soft or loose condition. It is recommended that a snow planer having adequate controls for producing a level surface be designed to mount to the rear of the processing unit. The use of a special rear discharge chute, which would distribute the snow more evenly behind the plow, would also aid the leveling problem.

More realistic tests, such as the application of wheel loads using actual aircraft tires, should be made on the compacted snow pavements to evaluate the bearing capacity.

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Brunke, H. C. (1959) *A correlation of crushing strength and hardness values of processed snow*, Michigan College of Mining and Technology, Houghton, Michigan. Unpublished thesis.

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APPENDIX A: EQUIPMENT

Compactors, vibratory, Jackson. Electrically operated. 110 volts supplied by a 7.5 KVA generator. Weight each unit - 410 lb including counterweight. Contact area per unit 364 in^2. Vibration frequency 2000 to 4200 blows per minute. Five (5) units were mounted to the blade circle of an Adams towed-type grader.

Grader, road, towed-type, Adams, 12 ft moldboard, Model 124-S, ski-mounted.

Machine, snow milling, Peter Model DHR 1-230/ w/GM diesel engine type 110, Model 62306 RD, w/2 ejection chutes.

Roller, snow, corrugated-type, Canadian, single unit, length 10 ft, diam 5 ft, weight 4000 lb.

Roller, sheepsfoot, American Steel Works Model MT-144, 3 unit. Specifications for each unit: Length 4 ft; diam w/feet 4 ft 10 in.; weight 6040 lb; no. of feet 88, 22 rows, 4 ft/row; length of feet 8 in.; area of foot face 5-1/16 in^2; estimated pounds pressure/area of tamping surface (in snow) = 80 psi.

Tractor, crawler, D-8 LGP, w/hydraulic blade.
Weight: 77,000 lb w/stern, belly and bow tanks filled.
Track length: 159 in.
Track width: 53 in.
Avg ground pressure: 4.5 psi.