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AN EXPERIMENTAL SNOW RUNWAY PAVEMENT IN ANTARCTICA

Gunars Abele

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U.S. ARMY MATERIEL COMMAND
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PREFACE

This study was conducted by Mr. Gunars Abele, Research Civil Engineer, of the Applied Research Branch (Mr. Albert F. Wuori, Chief), Experimental Engineering Division (Mr. Kenneth A. Linell, Chief), Cold Regions Research and Engineering Laboratory (CRREL) of the U.S. Army Terrestrial Sciences Center (USA TSC).

The study was performed by CRREL in response to a request by the U.S. Naval Support Force, Antarctica, during Operation Deepfreeze 66 at McMurdo, Antarctica. Field tests were continued by the Naval Civil Engineering Laboratory, Port Hueneme, California, during the latter part of Operation Deepfreeze 66 and Operation Deepfreeze 67.

The study was performed in cooperation with the Polar Division (Mr. Earl H. Moser, Jr., Director) of NCEL. The author expresses appreciation to the NCEL Field Team for its cooperation and assistance during this project.

Mr. Francis Gagnon, Supervisory Equipment Specialist, CRREL, and SP4 Richard Haney, U.S. Army Research Support Group, assisted in the construction of the runway test strip and participated in the performance of the field tests.

The Antarctic Support Activities and Mobile Construction Battalion 6, U.S. Navy, provided equipment and operator support.

The author would like to thank Mr. E.H. Moser, Jr. and Mrs. N.S. Stehle of NCEL for review of the manuscript.

Citation of trade names or manufacturers in this report is for information only and does not constitute official approval or endorsement.

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ABSTRACT

The strength properties of a Peter miller-processed and -compacted snow runway test strip at McMurdo, Antarctica, and the snow pavement performance during simulated C-130 and C-121 aircraft wheel-load tests are discussed and evaluated.

The correlation of shear strength, obtained by a test method developed by NCEL, with ram hardness and unconfined compressive strength of high-density snow is discussed and an approximate relationship is developed.

Data from actual aircraft and simulated aircraft wheel-load tests on snow pavements are compared with previously developed criteria for snow pavement supporting capacity. The agreement between predicted values and actual test data is generally good; the predicted required strength values are somewhat higher than actual required strength values.

The production data from the test strip construction are included.

AN EXPERIMENTAL SNOW RUNWAY PAVEMENT IN ANTARCTICA

by

Gunars Abele

INTRODUCTION

During Operation Deepfreeze 65, at the invitation of the U.S. Navy, USA CRREL participated in a joint project with NCEL to investigate the feasibility of snow runways in Antarctica and their construction techniques. Before the study was completed, a section of the experimental runway was destroyed by an unexpected ice breakout. The results from that study have been reported (Abele and Frankenstein, 1967).

The joint project was continued at a different location at McMurdo during Operation Deepfreeze 66, and additional tests were conducted by NCEL during Operation Deepfreeze 67.

Related studies on snow runway construction and performance have been reported by the Frost Effects Laboratory, New England Division, Corps of Engineers (1947, 1949), Arctic Construction and Frost Effects Laboratory (1954), Reese (1955), Bender (1957), Moser (1962, 1963, 1964, 1966), Moser and Sherwood (1966), Moser and Stehle (1964), Paige (1965a, 1965b), Coffin (1966), Wuori (1959, 1960, 1962, 1963), Abele (1964a), and Abele, Ramseier and Wuori (1966).

The results reported here are from the experimental test strip processed with a Peter miller during Operation Deepfreeze 66 in November 1965.

CONSTRUCTION OF TEST STRIP

The site of the experimental runway test strip was approximately 1 mile (1.6 km) northeast of the NCEL Camp (see Fig. 1).

The proposed 800 by 100-ft (244 by 30.5-m) test strip area was first elevated by blowing additional snow with a Peter miller from the sides onto the strip area to a height of approximately 2 ft (0.6 m). The snow surface was then leveled with a low-ground-pressure (LGP) D-8 bulldozer.

A 60- to 65-ft (18- to 20-m) width of the test strip was then processed with a Peter miller to a depth of 3 to 3.5 ft (0.9 to 1.1 m). The Peter miller processing method has been discussed by Wuori (1959, 1960, 1962, 1963). Because of mechanical difficulties with the Peter miller (defective steering and cutting-depth-control mechanism), it was necessary to winch the plow with an LGP D-8 tractor during most of the processing.

Compaction and rough leveling were performed with an LGP D-8 bulldozer after each two adjacent processing passes. (Two adjacent passes with the Peter miller were required to accommodate the width of the LGP D-8.) The comparative effectiveness of various compaction methods has been discussed by Wuori (1960).

Final leveling was performed with the Gurries Automatic Finegrader (Abele, 1964b).

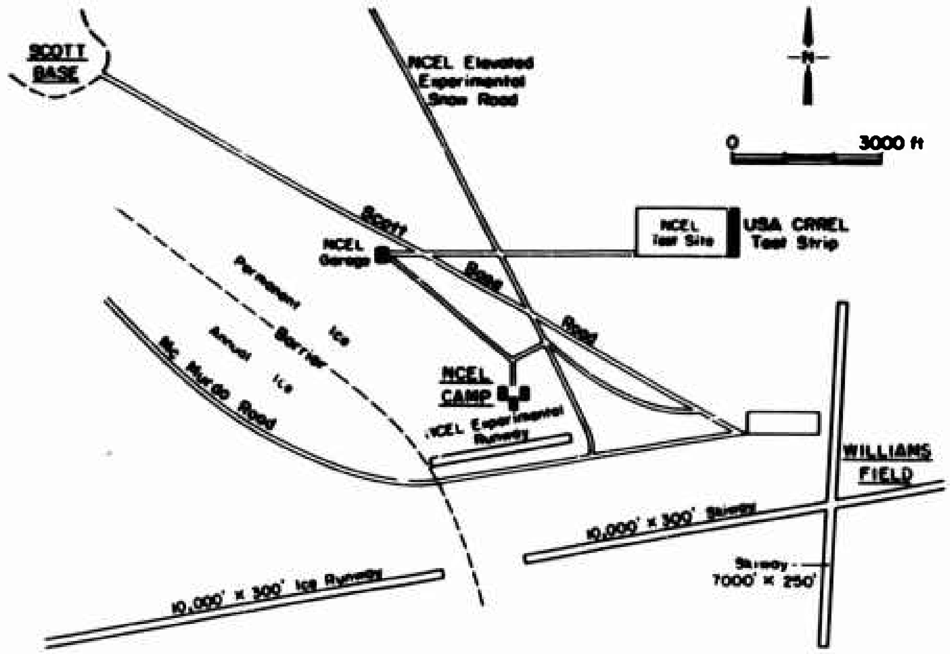


Figure 1. Location of test site.

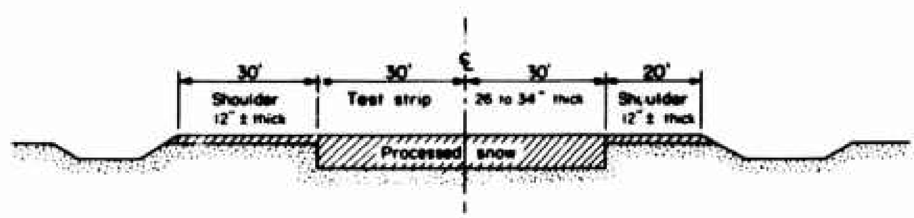


Figure 2. Cross section of test strip.

The resulting thickness of the processed, compacted snow pavement after final leveling was from 26 to 34 in. (66 to 86 cm). Figure 2 shows a cross section of the test strip. Figures 3 and 4 show general views of the test strip.

The test strip construction data are shown in Appendix A. The construction times and rates for the various construction phases can be summarized as follows:

1) Buildup

Peter miller time (not including major delays)	= 8 hr
Rate of snow deposition	= 26,700 ft^3/hr (756 m^3/hr)
	= 414 tons/hr (375 metric tons/hr)

2) Processing (total area = 52,000 ft^2 or 4830 m^2)

Peter miller time (not including major delays)	= 11.5 hr
Rate of processing	= 6120 ft^2/hr (568 m^2/hr)

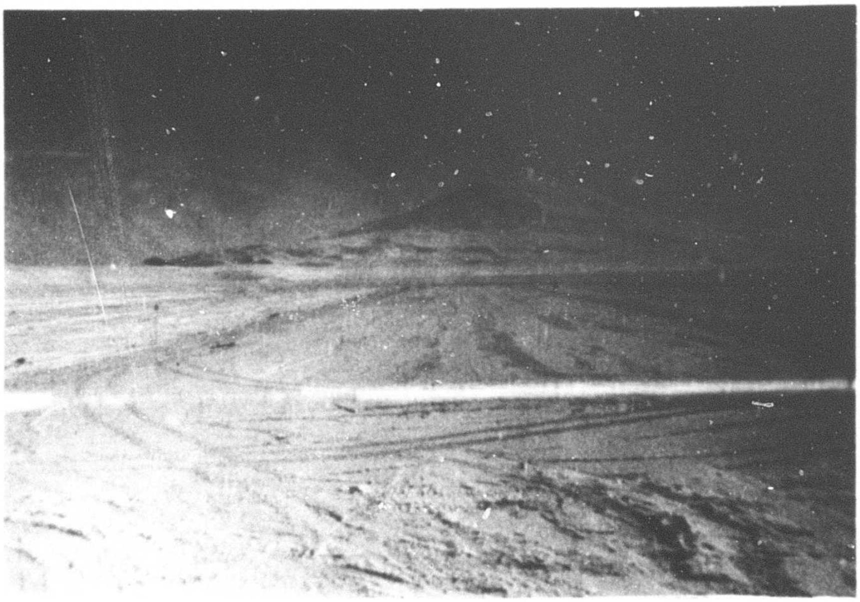


Figure 3. View of test strip (looking north).

Figure 4. View of test strip (looking south).

3) Compaction and leveling

LGP D-8 time	= 8 hr
Gurries Finegrader time	= 6 hr
Rate of compaction and leveling	= 3720 ft²/hr (345 m²/hr)

These figures, which include turnaround time and miscellaneous minor delays, can be considered characteristic for a strip length of 800 ft (244 m). In general, the production rates increase somewhat with an increase in runway strip length, since turnaround times remain essentially constant.

The time required to complete the test strip construction was 11 days; of these one day was lost due to adverse weather, most of one day was needed to change chutes on the Peter miller, and three full days as well as parts of several other days were lost because of mechanical difficulties and breakdowns of equipment.

PROPERTIES OF SNOW PAVEMENT

Grain size distribution

Figure 5 shows the grain size distribution in the Peter snow, obtained immediately after processing. The median grain size (at 50% finer) was between 0.6 and 0.7 mm. The median grain size of Peter processed snow in the old Williams Field area, McMurdo, during Operation Deepfreeze 65 was 0.8 mm; that is, the snow was somewhat coarser, because of the presence of more ice lenses and depth hoar, in the old Williams Field area. In comparison, the median grain size of Peter-miller processed snow on the Greenland Ice Cap, where ice lenses and depth hoar are less predominant, is usually between 0.5 and 0.6 mm.

The "uniformity coefficient" was approximately 2, comparable to that of Peter miller-processed snow elsewhere.

Density

The density profile of the test strip, obtained from observations at several different locations, is shown in Figure 6. The mean density at the surface was approximately 0.6 g/cm³, gradually decreasing to approximately 0.5 g/cm³ at the bottom of the processed snow pavement.

Unconfined compressive strength

Unconfined compressive strength tests were performed at various random locations of the test strip after 2 weeks of age hardening (core size: 3-in. or 7.6-cm diam, 6 in. or 15.2 cm long; rate of deformation: 2 in./min or 5.1 cm/min). A considerable variation in strength properties over the total strip area was observed (Fig. 7). The area where the low strength values were obtained corresponded to the location where the Peter miller breakdown occurred, resulting in a depression which later had to be filled by bulldozing processed snow into it. Compaction was consequently delayed by several hours.

Density measurements (shown in Fig. 6) were obtained from most of the cores used for the unconfined compressive strength tests. The unconfined compressive strength vs density data are shown in Figure 8.

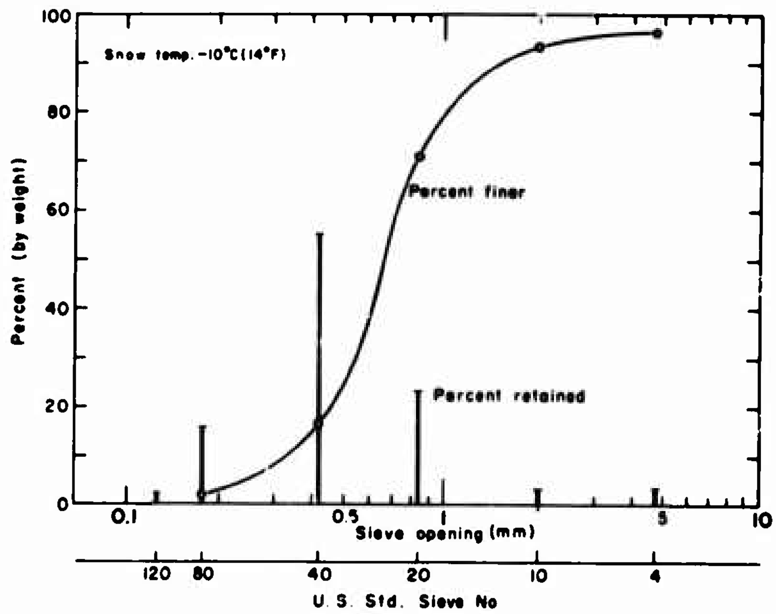


Figure 5. Grain size distribution of Peter snow.

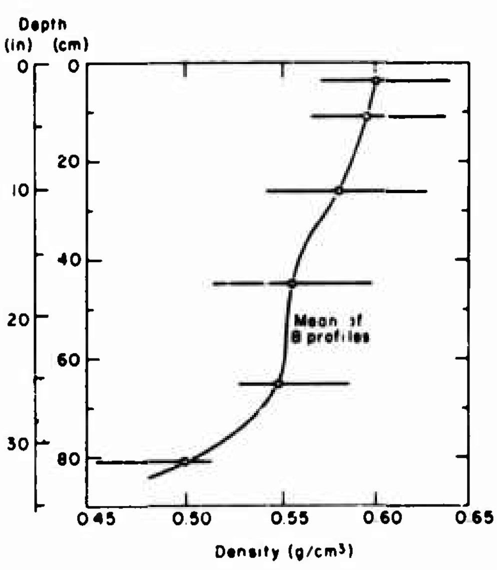


Figure 6. Density profile of test strip.

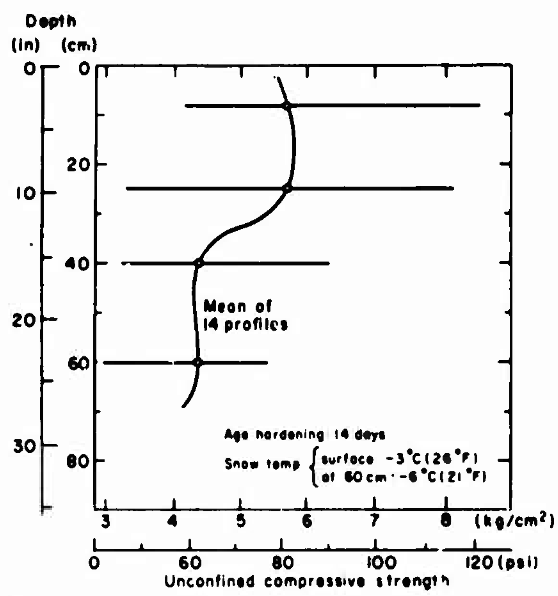


Figure 7. Unconfined compressive strength profile of test strip.

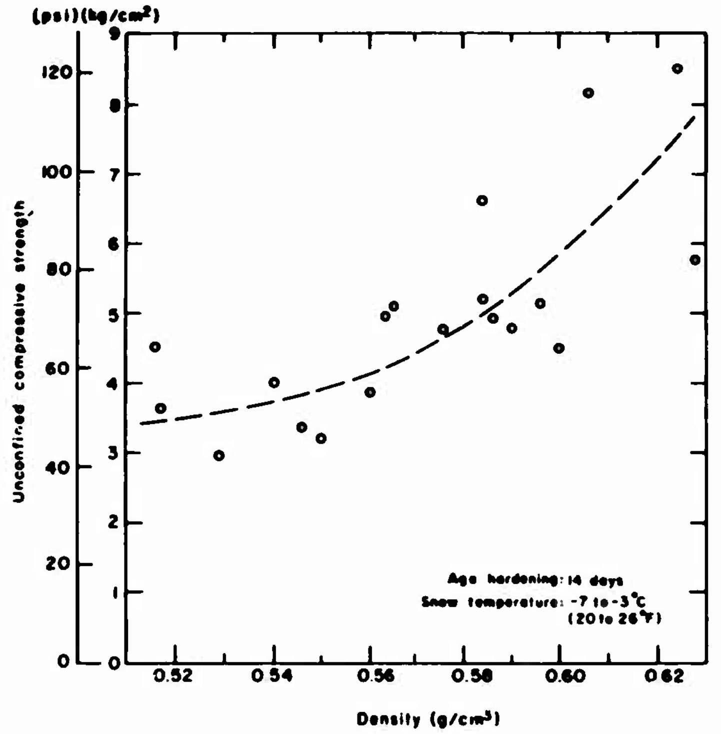


Figure 8. Unconfined compressive strength vs density.

Ram hardness*

Periodic ram hardness measurements were obtained until 17 days of age hardening. At this time most of the test strip surface had reached a hardness beyond which the Rammsonde cone penetrometer data became unreliable.

The mean ram hardness profiles of the test strip after 1, 2, 6, 8 and 17 days of age hardening are shown in Figure 9. The progressive increase in hardness with time at various depths below surface is evident.

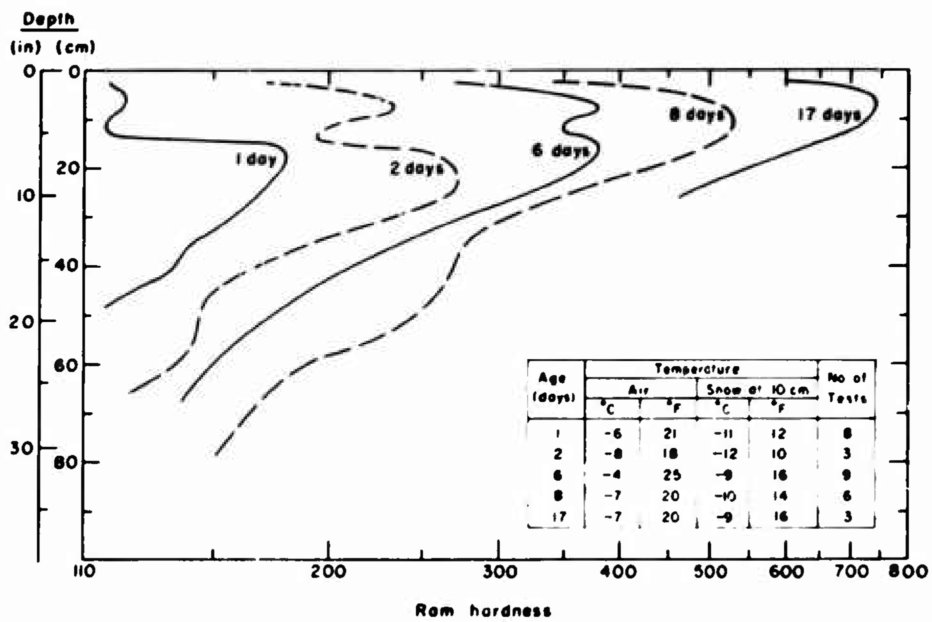
The mean sintering (age hardening) curves for the top 9-in. (23-cm) thickness and the top 18-in. (46-cm) thickness of pavement are shown in Figure 10.

The effect of temperature on the rate of age hardening (sintering) or strength increase with time has been discussed by Ramseier and Sander (1965, 1966) and Ramseier (1966).

Shear strength

Since the Rammsonde cone penetrometer is not suitable for use in very hard snow and the conducting of unconfined compressive strength tests is quite time-consuming, NCEL has developed a somewhat more convenient method for determining a strength index of snow: the direct

* The ram hardness values reported here were obtained with the standard Rammsonde instrument having a 4-cm (≈ 1.6-in.) cone and the 3-kg (≈ 6.6-lb) drop hammer. The relationship between these ram hardness values and the hardness index used and reported by NCEL (after 1963), which were obtained with a modified ram hardness instrument and then corrected (Moser, 1964), is shown in Appendix C. All NCEL ram hardness data quoted in this report have been adjusted to the standard ram hardness.



Age (days)	Temperature				No of Tests
	Air		Snow at 10 cm		
	°C	°F	°C	°F	
1	-6	21	-11	12	8
2	-8	18	-12	10	3
6	-4	25	-9	16	9
8	-7	20	-10	14	6
17	-7	20	-9	16	3

Figure 9. Ram hardness profiles of test strip.

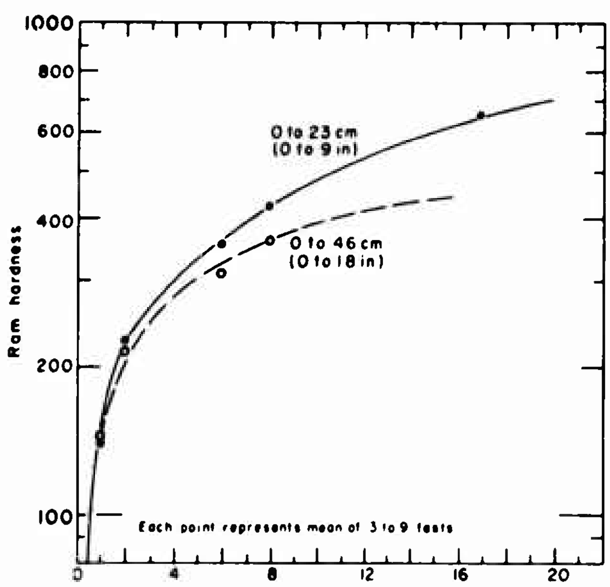


Figure 10. Ram hardness vs time.

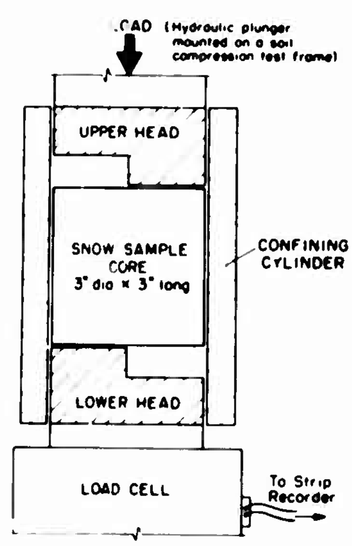


Figure 11. Cross section of shear test apparatus.

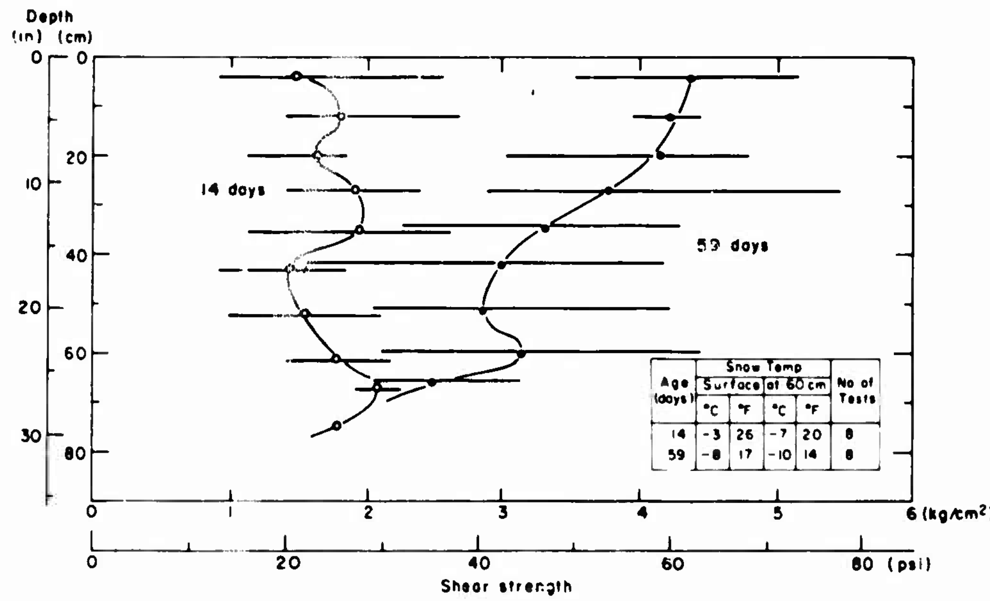


Figure 12. Shear strength profiles of test strip.

shear strength method (Moser and Stehle, 1964; Paige, 1965b). A 3-in. (7.6-cm)-diam, 3-in. (7.6-cm)-long core is sheared vertically through the center at a deformation rate of 8 in./min (20 cm/min). The setup of the test apparatus is shown in Figure 11. This test was used to monitor the sintering of the snow pavement and to evaluate the wheel load supporting capacity of the pavement.

The shear strength profiles of the snow pavement after 14 and 59 days of age hardening are shown in Figure 12. The mean shear strength for the top 9-in. (23-cm) thickness of the pavement vs time is shown in Figure 13. The effect of temperature on the shear strength can be observed by comparing the strength curve with the temperature data in Appendix B. At 59 days, the strength has increased sharply due to a recent drop in temperature (see Fig. 13 and Appendix B). At 69 and 80 to 82 days, the strength values have dropped because of a recent increase in temperature.

The rather limited range of strength values did not permit establishment of a reliable relationship between shear strength (σ_s) and unconfined compressive strength (σ_u). However, the data that were obtained by performing shear and unconfined strength tests on adjacent cores from the pavement indicated the relationship between the two types of strength values (Fig. 14):

$$\sigma_s \approx 0.3\sigma_u . \qquad (1)$$

A linear relationship was assumed. For simplicity it was also assumed that $\sigma_s = 0$ at $\sigma_u = 0$; actually very low density snow, whose unconfined strength is zero, may exhibit some shear strength (by this method). However, as will be shown in Figure 15, the relationship as expressed by eq 1 is not very reliable.

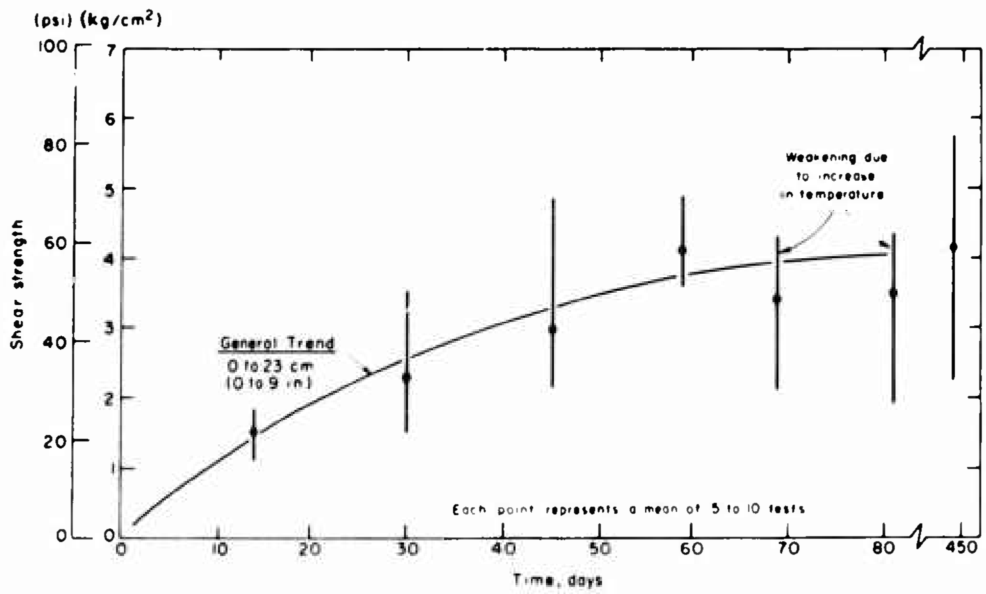


Figure 13. Shear strength vs time.

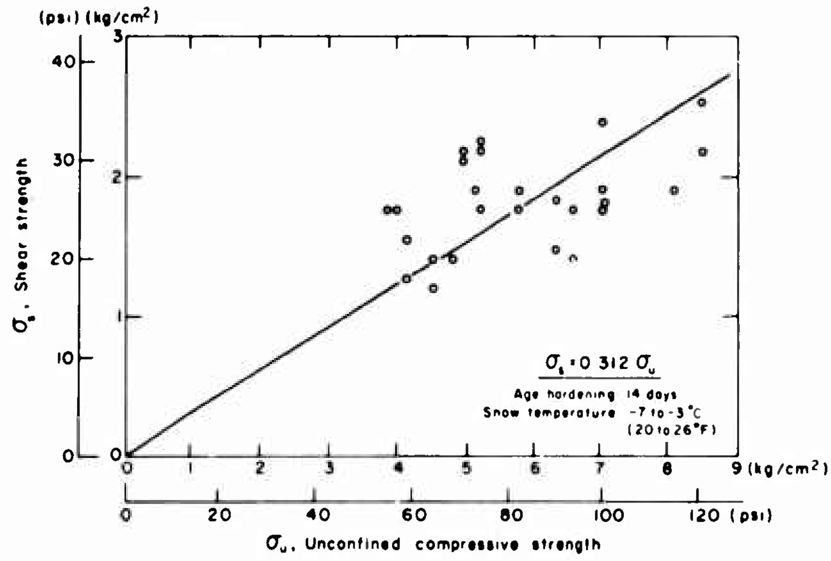


Figure 14. Shear strength vs unconfined compressive strength.

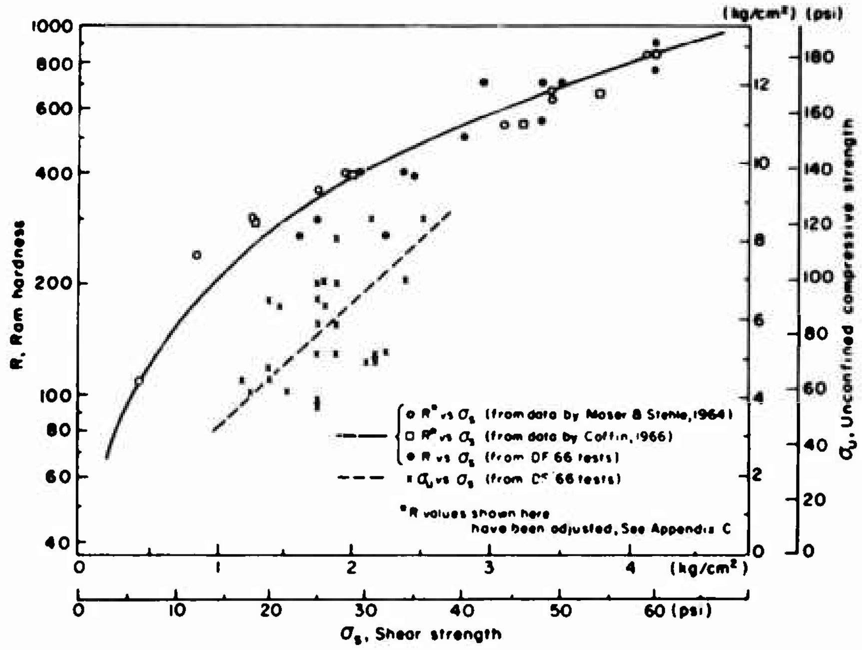


Figure 15. Relation of shear strength to ram hardness and unconfined compressive strength.

The relation of shear strength to ram hardness and unconfined compressive strength

When the predicted required shear strength values computed from the σ_s vs σ_u relationship (shown in Fig. 14) were compared with available data from various NCEL reports, it became apparent that the predicted required shear strength values were not realistic. The NCEL-reported shear strength values required to hold a particular wheel load were always considerably lower than the predicted values.

It was quite obvious that the σ_s vs σ_u relationship (Fig. 14) and, therefore, the resulting indirect σ_s vs ram hardness (R) relationship, was not reliable. This conclusion was further verified by available σ_s vs R data and by comparing the R vs time and the σ_s vs time curves (Fig. 10 and 13).

During Operation Deepfreeze 66, ram hardness and shear strength data were obtained from approximately the same locations on the test strip and at similar periods of age hardening. These σ_s vs R data and the σ_s vs R data* reported by NCEL (Moser and Stehle, 1964; Coffin, 1966) are plotted in Figure 15. The agreement between the adjusted NCEL data (which represent the mean values of a great number of tests) and the Operation Deepfreeze 66 data of individual tests is quite good.

It is apparent that the resulting σ_u vs σ_s relationship, obtained from the log R vs σ_s and σ_u vs R relationships (Abele, 1963), is not linear, as would have been expected. Both the NCEL data and the σ_u vs R relationship have high statistical reliability. It therefore becomes obvious that the validity of the σ_s vs σ_u relationship, shown earlier in Figure 14 and repeated in Figure 15, is of questionable value.

* The NCEL ram hardness values have been adjusted as shown in Appendix C.

The best representation of the relationship between shear strength (σ_s) and ram hardness (R) or between σ_s and unconfined compressive strength (σ_u) is indicated by the solid line in Figure 15. While the apparent nonlinearity cannot be explained, this relationship between confined shear strength and ram hardness or unconfined compressive strength can be accepted as a reasonable approximation.

WHEEL LOAD TESTS

Previously developed criteria for wheel load supporting capacity of a snow pavement

The wheel load supporting capacity of a snow pavement has been correlated experimentally with the ram hardness of snow (Abele, *et al.*, 1966) by using a self-powered traffic test rig capable of applying loads up to 27,000 kg (60,000 lb) on a hydraulically operated test wheel (Wuori, 1962). By using the traffic test rig, it was possible to simulate realistic aircraft wheel loads with various aircraft tires.

The ram hardness (R) required to support wheel traffic can be expressed by:

$$R = \left[e^{4.94 + a(pW^{0.146})}\right] e^{0.7(\log n)^{0.5}} \qquad (2)$$

where

R = required mean ram hardness for pavement thickness 0 to r, where r is the radius of the equivalent circular contact area of the tire

p = average contact pressure

W = wheel load

a = 0.044 when p is expressed in kg/cm² and W in kg

= 0.00281 when p is expressed in psi and W in lb

n = number of repetitive wheel coverages (within a short period of time).

Failure was arbitrarily defined as a wheel penetration of more than 2 in. (5 cm). This relationship can be presented in a nomogram, as shown in Figure 16.

The aircraft gross weight and tire inflation pressure are of interest only in the way they influence the wheel load and the contact pressure: the latter two are the significant parameters for design criteria or the evaluation of snow runway supporting capacity.

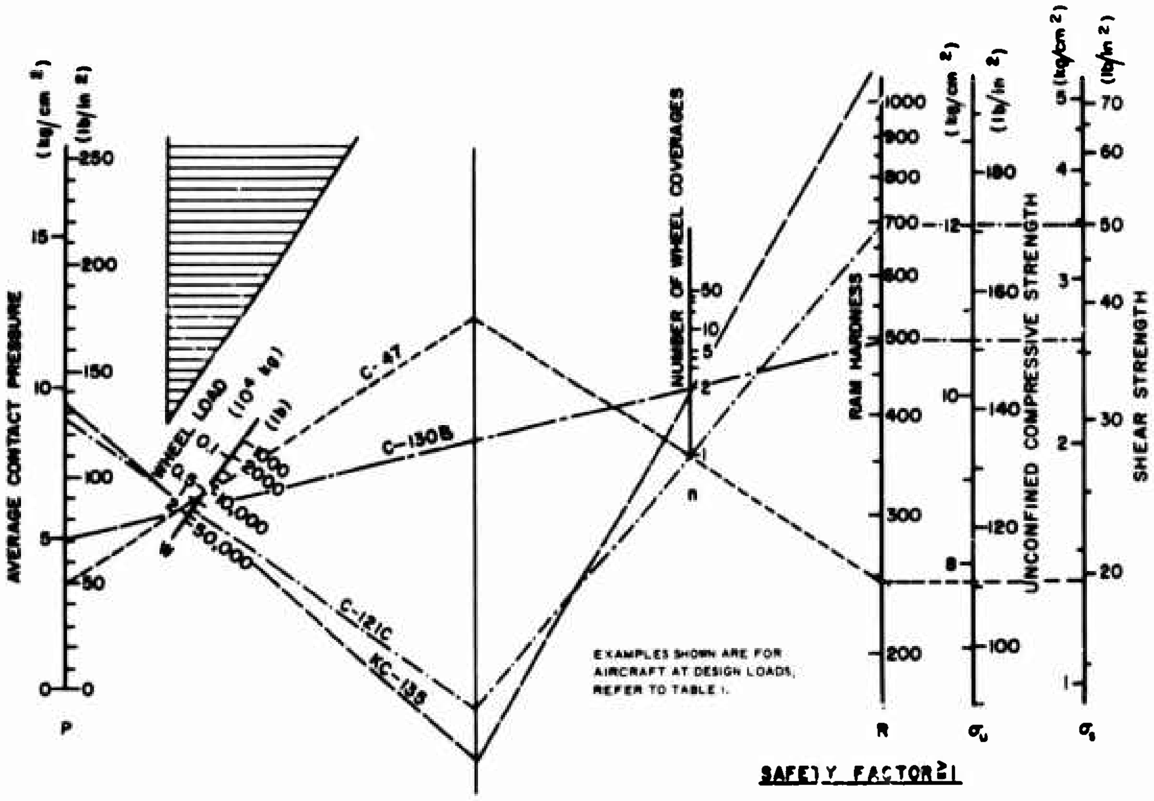
The method for determining R from the nomogram is shown in four examples: C-47, C-130B, C-121C, and KC-135 aircraft (see Table I). In the nomogram the lines for the C-130B and KC-135 aircraft are drawn through "2" on the n scale because of the tandem wheel configuration.

The unconfined compressive strength, computed from the ram hardness values (Abele, 1963) by

$$\sigma_u\,(\text{kg/cm}^2) \quad 4.078 \ln R - 14.72 \qquad (3)$$

is shown on a scale beside the ram hardness values.

The required ram hardness profiles for various load conditions have been computed using Boussinesq equations. Although snow is not an elastic, homogeneous, isotropic material, previous studies (Wuori, 1962) indicate that the Boussinesq solution could probably be used as an approximation for stress distribution in high-density snow.



Required hardness or strength for depth 0 to r (r = equivalent circular contact area radius.)

Figure 16. Required hardness or strength of a snow pavement for various wheel load conditions.

Table I. Aircraft specifications.

(From Portland Cement Association, 1955, 1960.)

Aircraft and type of gear	*Gross weight (lb)*	*Wheel load (lb)*	*Tire contact area (in.²)*	*Tire pressure (psi)*	*Avg contact pressure (psi)*	r* *(in.)*	r* *(cm)*
C-47 (single)	25,200	11,800	238	45	50	8.7	22
C-130B (single tandem)	135,000	28,500	405	85	70	12.5	32
C-121C (dual)	130,000	31,000	245	120	127	8.8	22
KC-135 (dual tandem)	250,000	33,500	250	134	134	8.9	23

* r = equivalent circular contact area radius.

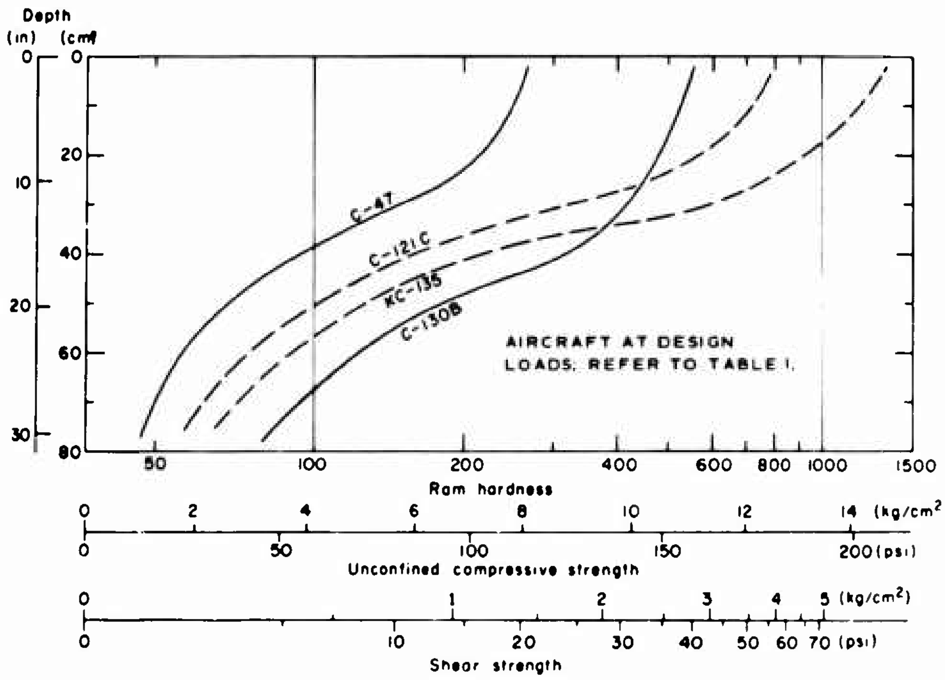


Figure 17. Required hardness or strength profiles for various aircraft.

The computed required pavement hardness or strength profiles for the four aircraft (at the design weights and tire inflation pressures) are shown in Figure 17.

The development of the design criteria, the nomogram, and the required strength profiles has been discussed in detail by Abele *et al.* (1966).

The preparation of a snow pavement capable of supporting aircraft such as the KC-135 would require surface hardening by heat treatment, additives, or some other type of reinforcement, in addition to dry processing and compaction.

Comparison of Operation Deepfreeze 66 wheel load test results with previously developed criteria

The locations of the wheel load tests, conducted with the NCEL traffic test rig, which is capable of simulating aircraft wheel loads, are shown in Figure 18. The mean shear strength values for the 0- to 9-in. (0- to 23-cm) depth of the pavement are also indicated at their respective locations.

The 3-in. thickness increment used in describing the pavement strength was selected because 1) the equivalent circular contact area radii (r) for three of the four selected aircraft are close to 9 in. (see Table I), and 2) the shear strength data obtained are at 3-in. increments, giving three values for calculating the mean for a 9-in. pavement thickness.

From the wheel test data, the locations with the lowest shear strength profiles where failure did not occur and the locations with the highest shear strength profiles where failure did occur were selected and compared with the predicted required strength profiles. The predicted strength values were obtained from the nomogram (Fig. 16) and the actual strength profiles established according to Boussinesq stress distribution (Fig. 17).

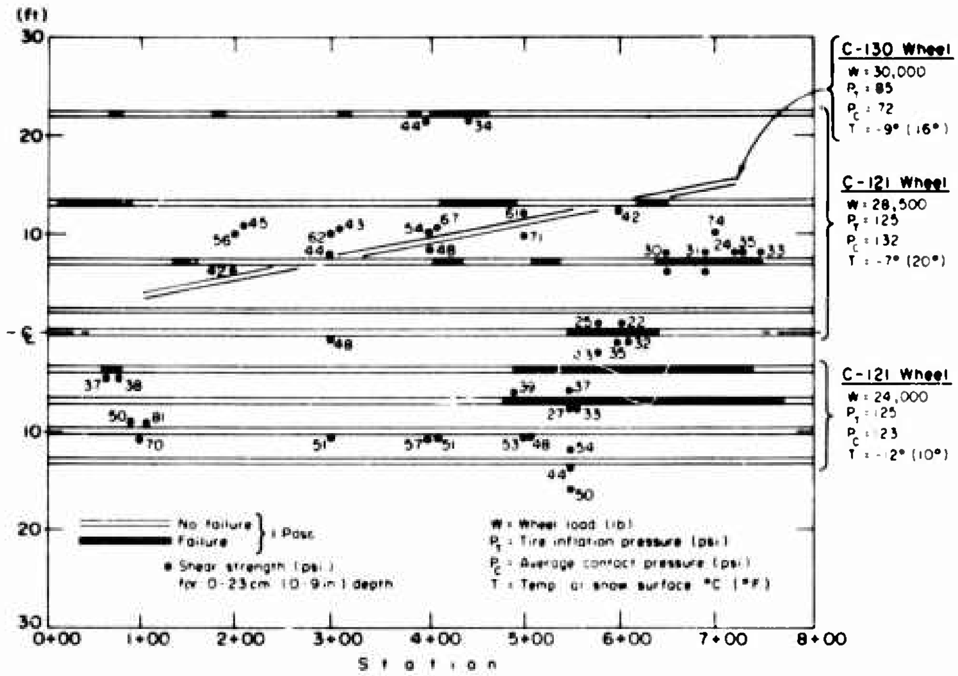


Figure 18. Wheel load test locations.

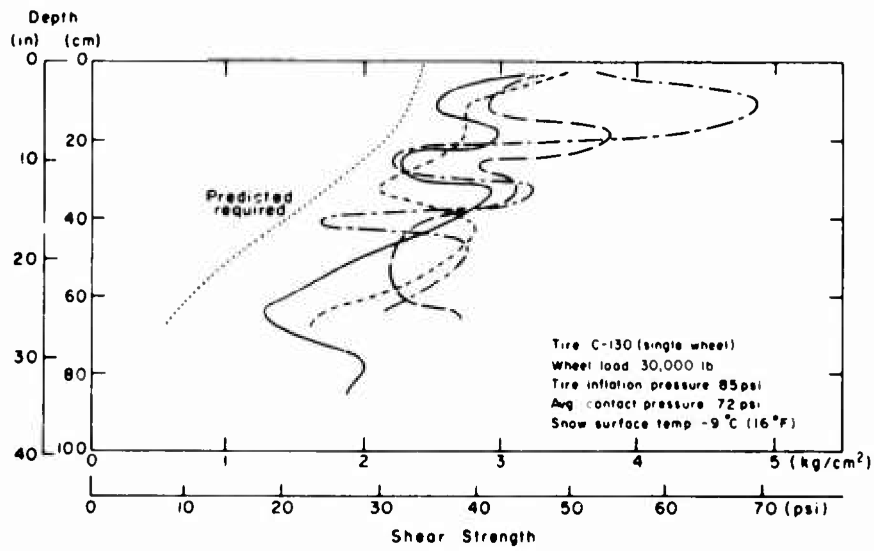


Figure 19. Shear strength profiles of no-failure areas (C-130).

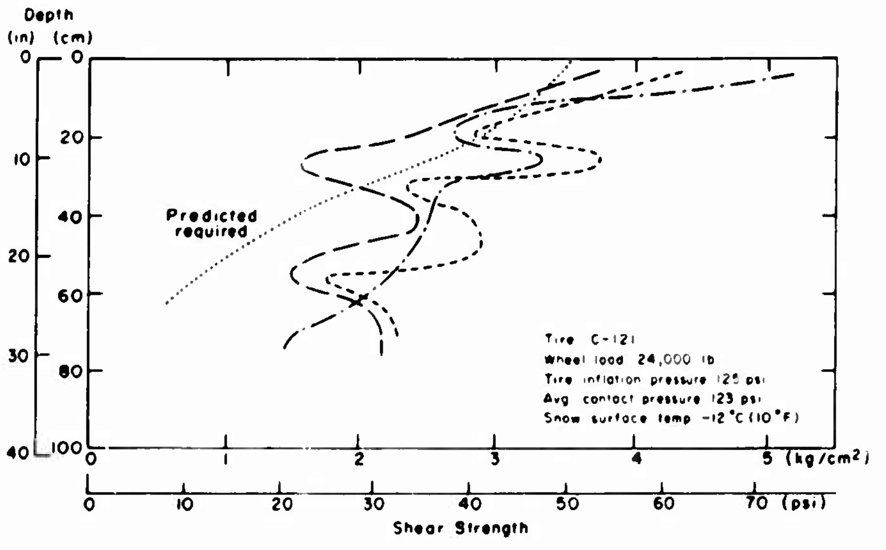


Figure 20. Shear strength profiles of no-failure areas (C-121).

Figure 19 shows the lowest shear strength profiles from locations where C-130 wheel tests were performed with the predicted required shear strength profile. No failures occurred on the test strip during the C-130 wheel tests. A 30,000-lb (13,600-kg) wheel load with a 72-psi (5-kg/cm²) average contact pressure (tire inflation pressure 85 psi or 6 kg/cm²) was used. The predicted required strength profile in Figure 19 is for a single wheel, since only the C-130 tire was used, not the tandem arrangement as on the landing gear. In this case, the line in the nomogram (Fig. 16) is drawn through "1" on the *n* scale.

The lowest strength profiles from the no-failure areas (Fig. 20) and the highest strength profiles from the failure areas (Fig. 21) during C-121 wheel-load tests show fair agreement with predicted required values. Wheel loads of 24,000 lb or 11,000 kg (contact pressure 123 psi or 8.6 kg/cm²) and 28,500 lb or 13,000 kg (contact pressure 132 psi or 9.3 kg/cm²) were used. Tire inflation pressure was 125 psi (8.8 kg/cm²).

Comparison of various aircraft and wheel load test results with predicted required pavement strength data

The available wheel load test data from various sources are summarized and compared with the predicted values in a graphical form as shown in Figure 22. The type of test, ram hardness or shear strength, used to evaluate the pavement strength is indicated.

Moser (1963) has reported that a snow pavement* having a mean ram hardness of between 250 and 260 supported a C-47 aircraft.† The predicted required value from Figure 16 is approximately 250. Coffin (1966) has reported that a pavement with a shear strength of 25 psi (1.76 kg/cm²) supported a C-47 aircraft. This value may not be the lowest supporting value; however, an 18-psi (1.27-kg/cm²) shear strength pavement failed. The predicted required value is 20 psi (1.4 kg/cm²).

* The ram hardness and strength data discussed and compared throughout this report are for a pavement thickness of at least *r* as shown in Table I. In the case of C-47 and C-121, this thickness is approximately 9 in.; for C-130 it is approximately 12.5 in. Also, the strength at any point below the depth *r* is at least equal to the strength value indicated by the Boussinesq stress curve (refer to Fig. 17).

† Aircraft wheel load and contact pressure similar to design values, as shown in Table I.

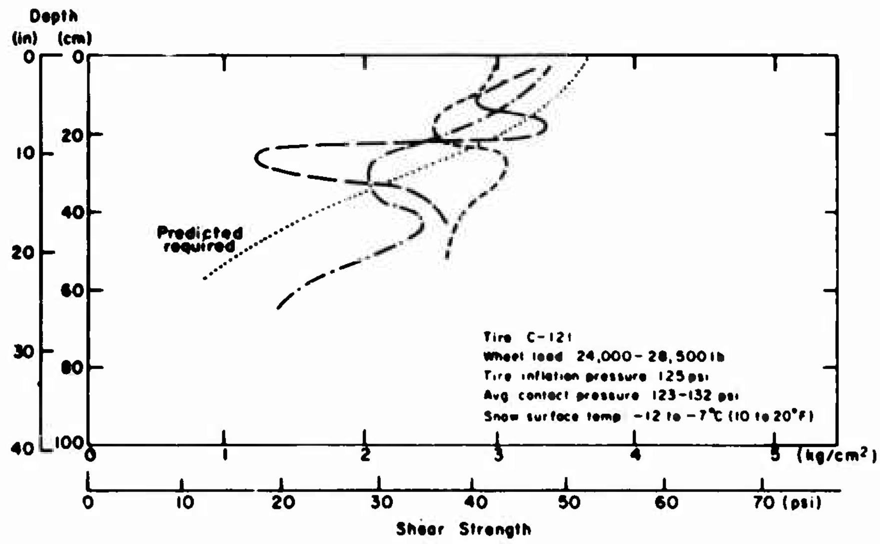


Figure 21. Shear strength profiles of failure areas (C-121).

Moser (1966) has also reported that ram hardness* between 355 and 400 was sufficient to hold a C-130 aircraft. Paige (1965a) reported a value of 370; Coffin (1966) has reported that 350 failed, 360 provided marginal support, and 370 held. The predicted required value from Figure 16 is approximately 500. Moser (1966) also reported that a shear strength of 25 to 30 psi (1.76 to 2.1 kg/cm^2) gave marginal support, and 30 psi held a C-130 aircraft. Moser found that a pavement having a shear strength of 25 psi for 0-4 in., 28 psi for 4-12 in., and 20 psi for 12-16 in. (mean for 0-12 in. = 27 psi or 1.9 kg/cm^2) is required to support a C-130 aircraft. Other test data, however, have indicated that this criterion may be very marginal. The predicted required values (from Fig. 16) are 500 ram hardness or 36 psi (2.5 kg/cm^2) shear strength, which appear to be high. Judging from all available shear strength data, ram hardness of 400 or shear strength of 30 psi (2.1 kg/cm^2) appear to be more realistic required strength values for a C-130 aircraft.

The requirement (Moser, 1966) for a lower strength at the surface (0-4 in.) than for the 8-in. layer below is not realistic. The amount of stress applied at the surface of the pavement will decrease with depth, either according to Boussinesq theory or in some other manner, depending on the pavement material characteristics. Consequently, the minimum strength required at any point below the surface will be less than the minimum strength required at the surface.

The lowest shear strength encountered in the snow pavement during the simulated C-130 single-wheel tests during Operation Deepfreeze 66 (refer to Fig. 18) was 42 psi (3 kg/cm^2) which easily held the load. The predicted required value is 26 psi (1.8 kg/cm^2).

The predicted required strength values for a C-121 aircraft are 50 psi (3.5 kg/cm^2) shear strength or 700 ram hardness. Simulated aircraft test data during Operation Deepfreeze 66 and Operation Deepfreeze 67 indicated that pavement shear strength of approximately 45 psi or 3.2 kg/cm^2 (or ram hardness of approximately 600 to 650) is sufficient to support the aircraft (Fig. 22).

The predicted required ram hardness for supporting a P2V aircraft is approximately 400 (not shown as an example in Fig. 16, 17 or 22). Coffin (1966) has reported that a ram hardness of 320 provided marginal support.

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*. Adjusted values, see Appendix C.

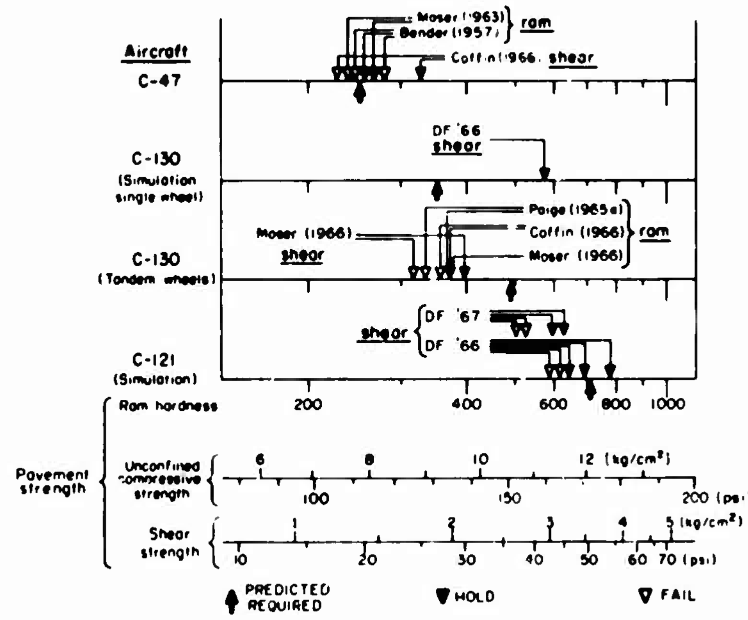

Figure 22. Comparison of predicted required pavement strength with wheel load test results.

An increase in aircraft wheel load does not require as much of an increase in the pavement strength as might intuitively be assumed. An increase in the wheel load causes an increase in the tire contact area due to tire deflection (assuming design inflation pressure), thus resulting in only a slight increase in the contact pressure (Wuori, 1962b). As can be observed from the *W* scale in the nomogram (Fig. 16), the relative effect of wheel load itself on the required pavement strength is not as significant as that of contact pressure. The relative effect of tire inflation pressure (and thus the contact pressure) is considerably more pronounced. This has also been reported by Moser and Sherwood (1966). Usually, at design loads and inflation pressures, the average contact pressures of aircraft tires are approximately the same as their inflation pressures (refer to Table I).

As mentioned earlier, the predicted values were obtained from the nomogram (Fig. 16 and eq 2) which was developed from a great number of wheel load tests conducted at the USA CRREL Keweenaw Field Station during 1959, 1960, 1961 and 1962.

A comparison of actual aircraft tests (C-47, C-130), simulated aircraft wheel load tests (C-130 and C-121) and the predicted required snow pavement strength characteristics indicates that the criterion (Fig. 16 and 17) is somewhat on the safe side, the safety factor being 1.2 or less (refer to Fig. 22).

CONCLUSIONS

Aircraft wheel load test results indicate that the strength properties of a snow pavement required to support aircraft are slightly less than the predicted required strength values. It therefore appears that the nomogram (Fig. 16), which has been developed as an aid for establishing snow runway design criteria, is valid but contains a safety factor of approximately 1.1 to 1.2.

It is also quite apparent that it is possible to construct snow runways capable of supporting wheeled aircraft such as the C-130 and C-121 if the need for such runways justifies the considerable effort involved in their construction.

Quality control during processing and compaction has been difficult to maintain mainly because of deficiencies in existing equipment and difficulties in their operation. Consequently, construction of uniform-strength, highly dependable snow runways for use during temperatures above 23F (-5C) has not been completely successful. The use of such runways at lower temperatures, however, has been successful, as experienced with C-130 aircraft tests on the NCEL runway during February 1965 (Moser, 1966).

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1. Buildup of test strip

Length = 800 ft
Width = 100 ft
Height = 2 ft (avg)

Total volume of snow deposited = 160,000 ft^3

Avg density of snow deposited = 0.5 g/cm^3
= 31 lb/ft^3

Total weight of snow deposited = 2,480 tons

Total volume of snow excavated = 218,800 ft^3

Avg density of snow excavated = 0.4 g/cm^3
= 25 lb/ft^3

Total weight of snow excavated = 2,740 tons

Loss = weight excavated − weight deposited = 260 tons = 9.5% of weight excavated

(Loss denotes the amount of snow lost to wind and amount of snow deposited between excavation and test strip; that is, amount of snow that did not reach test strip, part of this amount being handled twice by the Peter miller.)

Avg speed of Peter miller during excavation while taking a 4-ft-deep cut = 16 ft/min; *output = 432 tons/hr.*

Avg speed of Peter miller during excavation while taking a 1.8-ft-deep cut = 40 ft/min; *output = 485 tons/hr.*

Total excavation time:

Actual cut time	=	6 hr
Total turnaround time	=	1 hr
Misc. minor delays	=	1 hr
Total		8 hr (± 15 min)

Avg output of Peter miller during excavation in terms of amount of snow effectively deposited during actual cut time = 26,700 ft^3/hr
= *414 tons/hr*

2. Processing of test strip

Length = 800 ft
Width = 65 ft (avg)
Thickness = 30 in. (avg)

Total area processed = 52,000 ft^2

Avg speed of Peter miller during processing (actual forward speed during cutting) = 18 ft/min

Avg effective speed of Peter miller during processing (including time lost due to moving LGP D-8 tractor forward and letting out winch cable) = 13.3 ft/min

Total processing time	=	7.5 hr
Total turnaround time	=	1 hr
Minor mech. difficulties and delays	=	3 hr
Total	=	11.5 hr (± 15 min)

(Plus major mech. difficulties = 2 days)

Avg rate of processing (not including turnaround time and delays due to mech. difficulties) = 6940 ft^2/hr ≈ *7000 ft^2/hr*

Avg rate, including turnaround time (but not including other delays) = **6120 ft^2/hr**

3. Compaction and leveling

Total LGP D-8 time (compacting and rough leveling) = 8 hr

Total Gurries Automatic Finegrader time (final leveling) = 6 hr

Total = 14 hr

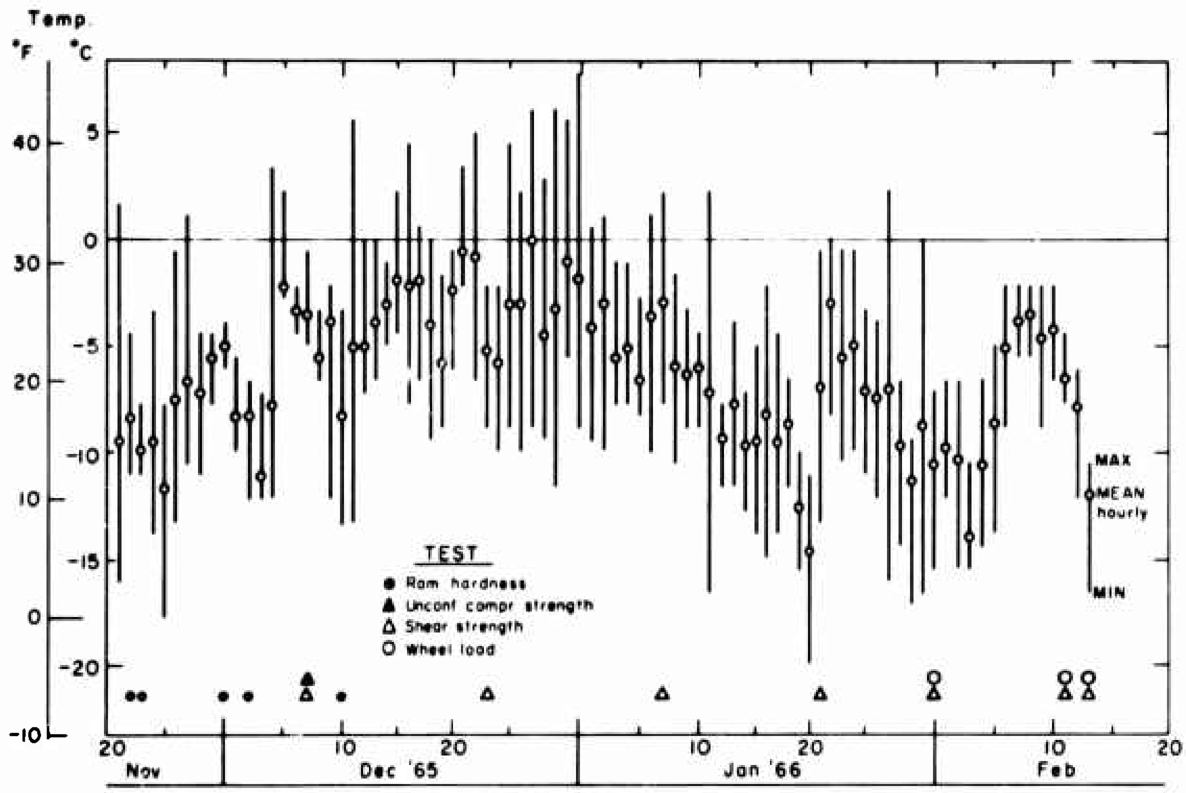
Avg rate (compaction and all leveling) = **3720 ft^2/hr**

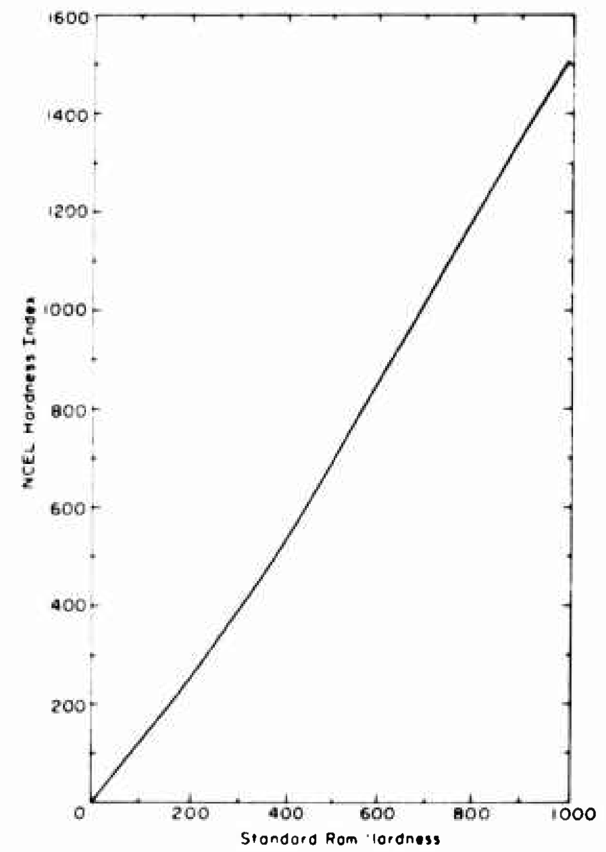
4. Snow removal (with LGP D-8 bulldozer)

Thickness of snow removed	=	3 in.
Total time	=	6 hr
Avg rate	=	8,660 ft^2/hr
Plus dragging time (NCEL drag)	=	1 hr

APPENDIX B: AIR TEMPERATURE DATA AND DATES OF FIELD TESTS

(Data from NCEL)





The NCEL ram ha.uness index is obtained with a 2.5 cm diameter cone and a 3 kg drop hammer and then converted to an equivalent hardness value obtained with a 4 cm diameter cone and a 1 kg drop hammer (Moser, 1964).

The standard ram hardness value is obtained with a 4 cm diameter (60°) cone and a 3 kg drop hammer.

Unclassified

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13. ABSTRACT

The strength properties of a Peter miller-processed and -compacted snow runway test strip at McMurdo, Antarctica, and the snow pavement performance during simulated C-130 and C-121 aircraft wheel-load tests are discussed and evaluated. The correlation of shear strength, obtained by a test method developed by NCEL, with ram hardness and unconfined compressive strength of high-density snow is discussed and an approximate relationship is developed. Data from actual aircraft and simulated aircraft wheel-load tests on snow pavements are compared with previously developed criteria for snow pavement supporting capacity. The agreement between predicted values and actual test data is generally good; the predicted required strength values are somewhat higher than actual required strength values. The production data from the test strip construction are included.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Snow runway						
Snow strength						
Snow construction						
Antarctica-construction						
Snow pavement						
Operation Deepfreeze 66-67						

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