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The Load-Carrying Capacity of Depth-Processed Snow on Deep Snowfields

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Abstract

Extensive experiments have been conducted by the Naval Civil Engineering Laboratory, Port Hueneme, California, U.S.A., to produce high-strength snow by mechanical acceleration of the natural metamorphic processes occurring in snow. Snow roads have been developed for vehicles weighing up to 70 000 pounds (31 752 kg) with high-flotation tires inflated up to 30 psi (2.11 kg/cm^2). Snow runways have been developed for aircraft weighing up to 135 000 pounds (61 236 kg) with main-wheel inflation pressures up to 95 psi (6.7 kg/cm^2).

A punching failure directly under the wheel is the principal type of failure occurring under a moving-wheel load on compacted snow. Based on this type of failure, a confined shear test is presently used to approximate the unit load-carrying capacity of compacted snow. For more precise field measurements, a rolling-wheel test vehicle is being developed to simulate moving vehicle and aircraft wheel loads on snow.

A 2-layer, 32-inch-thick (80 cm) experimental compacted-snow runway on the Ross Ice Shelf, Antarctica, was tested with aircraft during the summer season of 1964–65. As snow is a temperature-dependent material, the strength of the runway varied with changes in temperature at the test site. Its average total load-carrying capacity, however, exceeded that required for the test aircraft at all times. Because of processing misses, areas of low-strength snow in the top layer resulted in runway failures during the initial aircraft tests. Repair of these areas permitted multiple landings, takeoffs, and taxi runs on wheels in the final aircraft test.

I. Introduction

Extensive experiments have been conducted in the polar regions and in the Sierras of California by the Naval Civil Engineering Laboratory (NCEL) to develop cold-processing snow-compaction techniques and equipment for building trails on deep snow for light vehicles with high-flotation tires, snow roads for heavy cargo vehicles, and snow runways capable of supporting fully loaded LC-130F-type aircraft on wheels.

The basic NCEL cold-processing compaction technique is founded on *in-situ* acceleration of the natural processes occurring in snow. It consists of depth-processing followed by compressive compaction. Other techniques developed to improve the strength of snow include layered compaction and surface-hardening.

II. Snow Characteristics

Snow is a temperature-dependent crystalline material; its metamorphic processes can be accelerated and its strength characteristics can be improved by mechanical agitation. Agitation increases density and accelerates sintering, or the development of bonds between adjacent snow grains. Bonding is responsible for increased strength in compacted snow.

The process of sintering is both density- and temprature-dependent. Following sintering, the strength of snow, without a change in density, varies inversely with temperature. The characteristics of natural and compacted snow have also been investigated by the U. S. Army Cold Regions Research and Engineering Laboratory (CRREL) (Abele, Ramseier and Wuori, 1966).

III. Snow-Compaction Techniques

Leveling and rolling are required to prepare a snowfield for compaction with the NCEL techniques and equipment. The area is alternately rolled with a large-diameter snow-compaction roller, and graded with a snowplane until it is fairly smooth and level. These preparations not only produce a level area for depth-processing, but also develop fairly uniform strength in the top 8 inches (20 cm) of snow (Moser, 1963).

Compressive compaction. Compressive compaction with a large-diameter roller is used for initial compaction of a snowfields; it is used also after depth-processing for increased strength in processed snow. The number of roller passes required for optimum packing is dependent upon the type of snow being rolled and the prevailing temperatures.

Depth-processing. Depth-processing is accomplished with a snow mixer employing a power-driven rotor to pulverize the snow. Pulverization disaggregates and densifies the snow; sintering of the individual snow particles after depth-processing develops strength. The number of snow mixer passes required for a desirable range and distribution of snow particles for optimum packing and maximum sintering is dependent on the type of snow being processed. A single layer of depth-processed snow up to 20 inches (50 cm) thick can be developed with the present NCEL snow mixer.

Layered compaction. Layered compaction, which consists of two or more 16- to 20-inch (40 to 50 cm) thicknesses of compacted snow, offers several advantages over a single-layer thickness:

1. It elevates the compacted area above the natural surface for drift control.
2. Within limits, the increased thickness reduces the average unit strength required to support a given load.
3. It permits small sporadic areas of low-strength snow in the lower layers without affecting overall strength.

Surface-hardening. To improve the trafficability of compacted snow, a pneumatic-tired roller is presently used to increase the strength in the top 6 inches (15 cm) of the processed-snow layer. Following this rolling, a finishing drag is used to develop a smooth, hard finish on the snow. Other methods of surface-hardening currently under investigation are the addition of free water to a compacted-snow surface and the controlled use of solar radiation under favorable conditions.

IV. Snow Test Methods

The CRREL Rammsonde cone penetrometer was used extensively by NCEL for strength measurements in compacted snow prior to 1963. A study, however, showed that a punching failure, or wheel breakthrough, directly under the wheel was the principal type of failure occurring in compacted snow (Coffin, 1965). It was also observed that only the snow directly under the wheel was displaced in the failure area regardless of the length of the failure. Examination showed that the snow was sheared around the perimeter of the wheel contact area, and the snow under the wheel was disaggregated and either compressed under the wheel or displaced from the wheel track.

Confined shear test. To relate the shear strength of snow to the moving-wheel loads of vehicles and aircraft, NCEL developed a confined shear test apparatus for compacted snow in 1962 (Moser and Stehle, 1964). This apparatus is designed to receive 1- to 3-inch-long (2.5 to 7.6 cm) compacted-snow core specimens obtained with the 3-inch-diameter (7.6 cm) CRREL ice coring auger. The shear strength is obtained by placing the specimen in a confined cylinder and applying a shearing force through heads which are positioned to align the shearing edges of the device. The specimens fit the cylinder snugly without binding, and the heads fit loosely. Force, applied to the heads with a hydraulic plunger mounted on a soil-type compression tester frame, is measured with a load cell resting on the lower plate of the compression tester frame. The force is recorded directly with time on a strip recorder.

Usage shows that 3-inch-long (7.6 cm) core specimens or 9 square inches (58.1 cm^2) of shear area give the most consistent results. The confined shear strength for individual core specimens is converted to pounds per square inch (kg/cm^2); the total resistance to confined shear for a given location and thickness of compacted snow is obtained by summarizing the individual strengths for each 1-inch increment (2.5 cm) of thickness at the test location. Initial analysis of this data indicated that the load-carrying capacity of compacted snow in pounds per square inch (kg/cm^2) of surface area, regardless of thickness and temperature, ranged between 24 and 27% of its total resistance to confined shear (Moser and Stehle, 1964). More recent tests around wheel failures have confirmed this relationship.

The compressive strength of compacted snow may influence the relationship between confined shear strength and load-carrying capacity. To refine the small-scale strength measurements, studies are being made to establish the extent of this influence. Pending this refinement, 25% of the total resistance to confined shear of a compacted-snow layer is used as its load-carrying capacity in pounds per square inch (psi) or kilograms per square centimeter (kg/cm^2).

Rolling-wheel test vehicle. For more precise knowledge on the load-carrying capacity of compacted snow, a rolling-wheel test vehicle is being developed to simulate actual vehicle and aircraft moving-wheel loads on compacted snow (Goldberg, 1965). For field use, a truck-tractor and 20-ton (18 144 kg) semi-trailer, fitted with 10 high-flotation tires inflated to only 20 psi (1.41 kg/cm^2), was selected as the carrier for this test vehicle. Loads up to 38 500 pounds (17 464 kg) can be applied to various size test wheels under the deck of the trailer through a power-operated hydraulic system. Uplift caused by the test wheels is resisted by 20 tons (18 144 kg) of ballast on the deck of the trailer. Interchangeable test wheels having tires with inflation pressures of 10 to 145 psi (0.70 to 9.49 kg/cm^2) have been selected for use with the test vehicle. The maximum gross weight of the test vehicle is 75 000 pounds (34 020 kg); it can travel at speeds of 1 to 45 mph (2 to 72 km/hr).

V. Trails and Roads

NCEL snow-compaction techniques were used in 1960 to build sawdust-covered roads and parking areas for the VIII Olympic Winter Games at Squaw Valley, California (Moser, 1963). A 6-lane, 1-mile-long (1.6 km) compacted-snow road was trafficked by 100 000 privately owned automobiles, and 60 000 cars used the parking area over a 10-day period in February 1960. Since that time, techniques have been developed in Antarctica for rapidly building trails for light vehicles with high-flotation tires at McMurdo and Byrd Stations, and for building elevated roads for heavy trucks and trailers on the Ross Ice Shelf near McMurdo Station.

Trails. In December 1964, tests were made on the Ross Ice Shelf near McMurdo Station (Beard and Sherwood, 1965) to determine the minimum effort required to rapidly develop trails on deep snow for light vehicles weighing up to 10 000 pounds (4 536 kg) fitted with low-pressure high-flotation tires inflated up to 10 psi (0.70 kg/cm^2). These tests were made on natural windpacked snow. The average load-carrying capacity in the top 8 inches (20 cm) of the snow in the test area was only 4.8 psi (0.34 kg/cm^2). It would not support a 6 000-pound (2 722 kg) pickup-type vehicle with its tires inflated to 8 psi (0.56 kg/cm^2).

Six test trails were made by different methods of compaction. The first three trails were made with one, three, and six passes of a 33 000-pound (14 969 kg) snow tractor with a ground-bearing pressure of 5 psi (0.35 kg/cm^2); the next three were made with one, three, and six passes of the tractor towing a 10 000-pound (4 536 kg) snow-compaction roller. One day later, all of the trails were tested with the 6 000-pound (2 722 kg) pickup. It traversed all of the trails, but left wheel tracks up to 4 inches (10 cm) deep in the single-pass tractor trail. The most promising trail was the one made with a single pass of the tractor and roller. The vehicle traveled over this trail with ease; its wheel tracks were 1 inch (2.5 cm) or less in depth. Confined shear tests showed that the average load-carrying capacity in the top 8 inches (20 cm) of this trail was 11 psi (0.77 kg/cm^2), or almost 2 1/2 times that of the natural snow and almost 1 1/2 times that of the 8-psi (0.56 kg/cm^2) tire inflation pressure on the test vehicle. The density of the snow in this trail was 0.48 g/cm^3 compared with 0.36 g/cm^3 in the natural snow.

In 5 days, the load-carrying capacity in the single-pass tractor and roller trail reached 30 psi (2.11 kg/cm^2). In a test run, at speeds up to 25 mph (40 km/hr), the pickup, at a gross vehicle weight of 9 000 pounds (4 082 kg), only marked the surface of this trail with its tire prints.

Similar trails are currently in use at McMurdo Station to service outlying work centers with pickup-type vehicles. A tractor-packed snow trail is also being used at Byrd Station, Antarctica, to service an outlying substation. This trail is about 10 miles (16 km) long.

Roads. Experiments in the McMurdo area showed that equipment-packed trails are not adequate for 10 000- to 70 000-pound (4 536 to 31 752 kg) gross weight vehicles fitted with high-flotation tires inflated up to 30 psi (2.11 kg/cm^2). To determine the minimum road requirements on deep snow for vehicles of this weight and tire pressure, two experimental snow roads (Beard and Sherwood, 1965) were built on the Ross Ice Shelf near McMurdo Station in December 1964. One was paved with blown-snow taken from borrow pits along each side of the roadway with a side-casting snow-plow. This technique resulted in lightly processed snow being used to elevate the road about 2 feet (60 cm) above the natural snow surface. After the snow was cast into place, the road was graded and leveled with a snowplane and rolled with a compaction roller. The other road was paved by depth-processing the natural snow to a depth of 16 inches (40 cm) with a snow mixer and packing the processed snow with a compaction roller. This road was about 8 inches (20 cm) below the natural surface.

Strength curves for the 16-inch-thick (40 cm) snow pavements on the blown-snow road and the mixer-snow road are shown in Fig. 1. The average load-carrying capacity in the traffic lane on the blown-snow road, as determined by confined shear, was 10 psi (0.70 kg/cm^2) after 5 days of sintering; after 22 days, the average strength in this pavement was 30 psi (2.11 kg/cm^2). The average load-carrying capacity in the traffic lane on the mixer-snow road was 38 psi (2.68 kg/cm^2) after 1 day of sintering; after 22 days, the average strength in this pavement was 180 psi (12.66 kg/cm^2). The density of the snow in the blown-snow pavement was 0.51 g/cm^3; in the mixer-snow pavement, it was 0.57 g/cm^3. Before processing, the density of the natural snow was 0.36 g/cm^3.

Confined shear tests in an untrafficked lane on the mixer-snow road 22 days after processing showed that its average load-carrying capacity was 130 psi (9.14 kg/cm^2), or 30% less than the average for the trafficked lane. This same relationship also existed after 47 days.

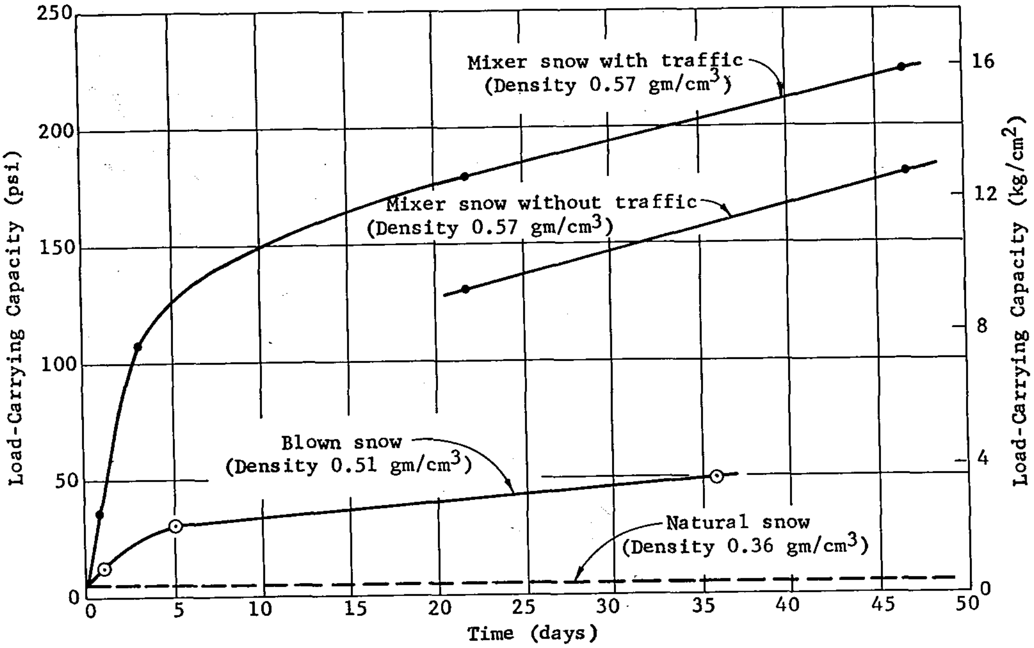

Fig. 1. Strength growth in two types of 16-inch-thick processed snow roads

Three days after processing, the mixer-snow road was trafficked with a 70 000-pound (31 752 kg) gross weight vehicle with its high-flotation tires inflated to 20 psi (1.41 kg/cm^2). The road was only marked with tire prints in this test. Low-strength areas in the snow pavement on the blown-snow road immobilized this size of vehicle during the first 22 days of use. Even then, vehicles of this weight made wheel tracks up to 1 inch (2.5 cm) deep in the surface of this road. Subsequent tests showed that repeated traffic with 70 000-pound vehicles at speeds up to 45 mph (72 km/hr) rapidly disaggregated the top 4 inches (10 cm) of the mixer-snow pavement and deteriorated the blown-snow pavement beyond use.

Current studies are directed towards development of a wearing surface suitable for high-speed heavy truck traffic on the polar snow roads. In the interim, 14 miles (22 km) of mixer-snow roads are in use around McMurdo Station. They connect the station with its outlying activities on the Ross Ice Shelf.

VI. Runways

In November 1964, a 150-foot-wide by 6 000-foot-long (46 m wide by 1 830 m long) by 16-inch-thick (40 cm) layer of compacted snow was depth-processed over a 1-year-old, 16-inch-thick (40 cm) layer of compacted snow on the Ross Ice Shelf near McMurdo Station, Antarctica (Coffin, 1965). Winter snow drift over the 1963 layer was used for the 1964 layer. Following compaction, the new layer was surfaced with a pneumatic-tired roller.

The 2-layer experimental runway was maintained through the austral summer of 1964–65 and tested with aircraft at intervals of 12 to 21 days. Processing misses in the 1964 layer, where adjacent snow mixer lanes failed to overlap and where the snow mixer failed to penetrate the entire depth of new snow, were detected during the initial aircraft tests. They were repaired by reprocessing the snow in the failure areas.

Confined shear tests. Between 25 November 1964 and 14 February 1965, random-sample, confined shear tests were made in the 1964 layer of compacted snow at 4- to 22-day intervals. This data was used to approximate the average load-carrying capacity of the layer at the time of testing. The curve for this average and those for the maximum and minimum load-carrying values observed during these tests are shown in Fig. 2. Also shown are the average monthly temperature and the total monthly solar radiation at the test site between November and February.

The average load-carrying capacity of the 1964 layer after 8 days of sintering was 162 psi (11.4 kg/cm^2); the maximum at this time was 235 psi (16.5 kg/cm^2) and the minimum was 112 psi (7.9 kg/cm^2). After 22 days, or near the middle of December, the average was 184 psi (12.9 kg/cm^2), for an increase of 14% in 14 days. During the next 20 days, the average decreased 33% because of rising temperatures and intense solar radiation at the test site. Between early January and mid-February, this average increased 123% because of declining temperatures and decreasing solar radiation. On 14 February, the average was 276 psi (19.4 kg/cm^2), or 70% higher than it was in early December. The maximum at this time was 332 psi (23.4 kg/cm^2) and the minimum was 255 psi (17.9 kg/cm^2).

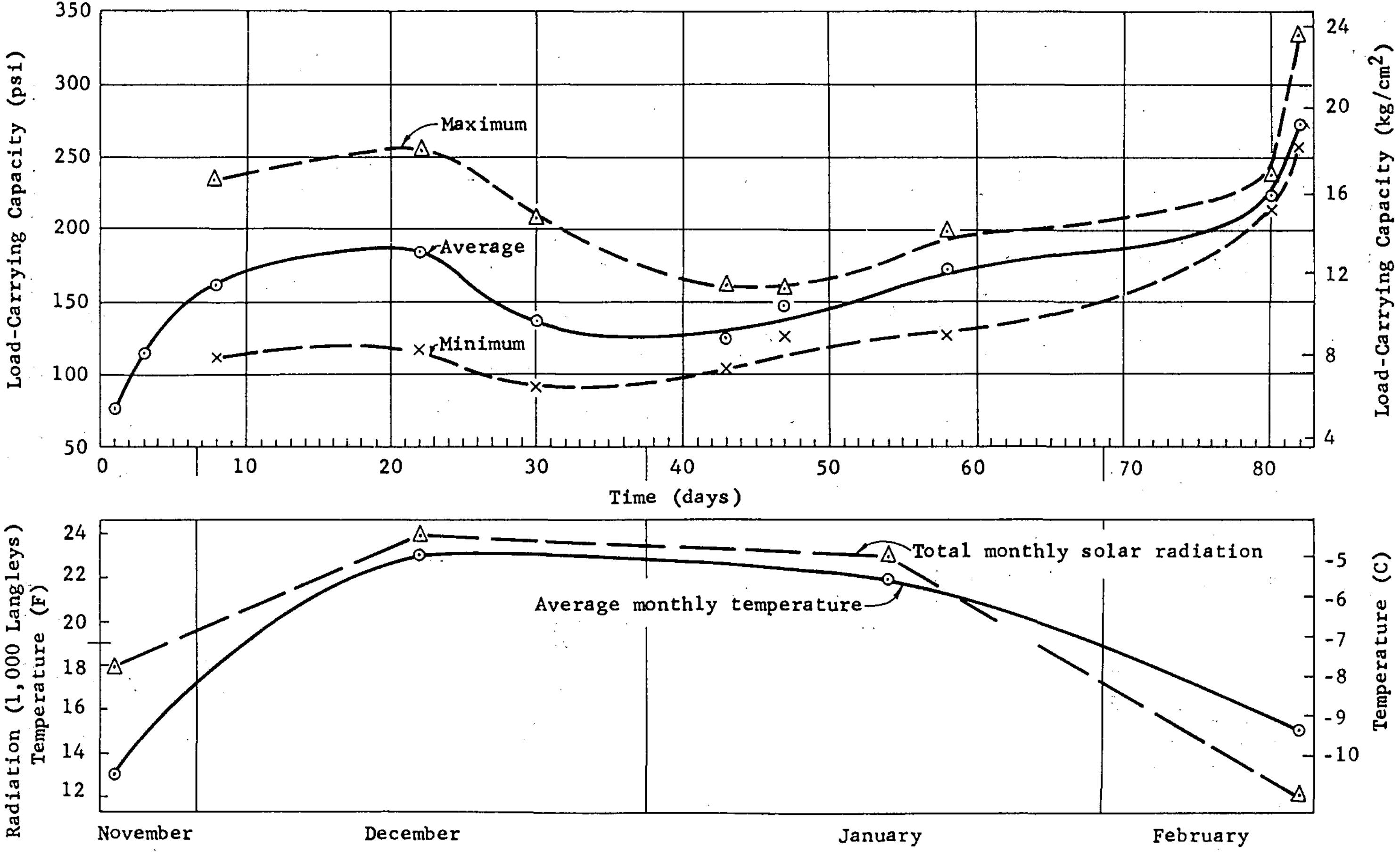

Fig. 2. Load-carrying capacity as determined by confined shear for the 1964 layer on the experimental runway

There was a marked decrease in difference between the maximum and minimum load-carrying values in this layer during the 82-day test period. Thirty days after processing, it was 125% ; 52 days later, it was less than 30%. Reprocessing the low-strength areas accounted for some of this decrease.

The 16-inch-thick (40 cm), 1-year-old 1963 layer was located directly below the 16-inch-thick (40 cm) 1964 layer. Its average load-carrying capacity in December and January is compared with the average for the 1964 layer in Fig. 3. In late December, the 1963 layer was 37% stronger than the 1964 layer ; by late January, this difference was less than 24%. Repairs to the 1964 layer account for most of this change but slightly colder temperatures and age contribute to the consistently higher strength in the 1963 layer. The 1963 layer also responded to changes in temperature. In early December, its average load-carrying capacity was 265 psi (18.6 kg/cm^2). In early January, it was 38% less but by late January, it was only 15% below its early December average.

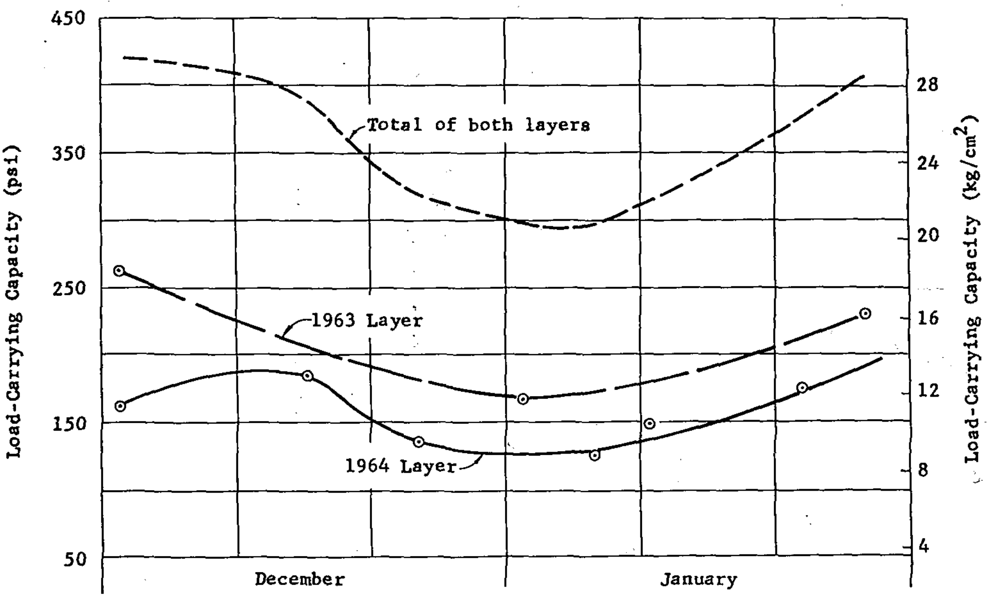

Fig. 3. Individual and total load-carrying capacity as determined by confined shear for 1963 and 1964 layers on the experimental runway

The average total load-carrying capacity for both layers is also shown in Fig. 3. In early December, this average was 420 psi (29.5 kg/cm^2). In early January, it was 42% less but by late January, it was only 2% below its early December average.

The average confined shear strength and density profiles for both layers on 2 December 1964 are shown in Fig. 4. The strength profile for the 1964 layer shows that the snow in the middle two-thirds of this 8-day-old layer was slightly stronger than the snow at the top and bottom of the layer. This is typical of young compacted snow processed with the NCEL Snow Mixers (Moser, 1963). The strength of the 1-year-old snow in the 1963 layer was 70% higher at the top of the layer than at the bottom. This profile is typical of compacted snow subjected to multiple rolling with a pneumatic-tired roller during near-thaw temperatures and intense solar radiation. The 1963 layer

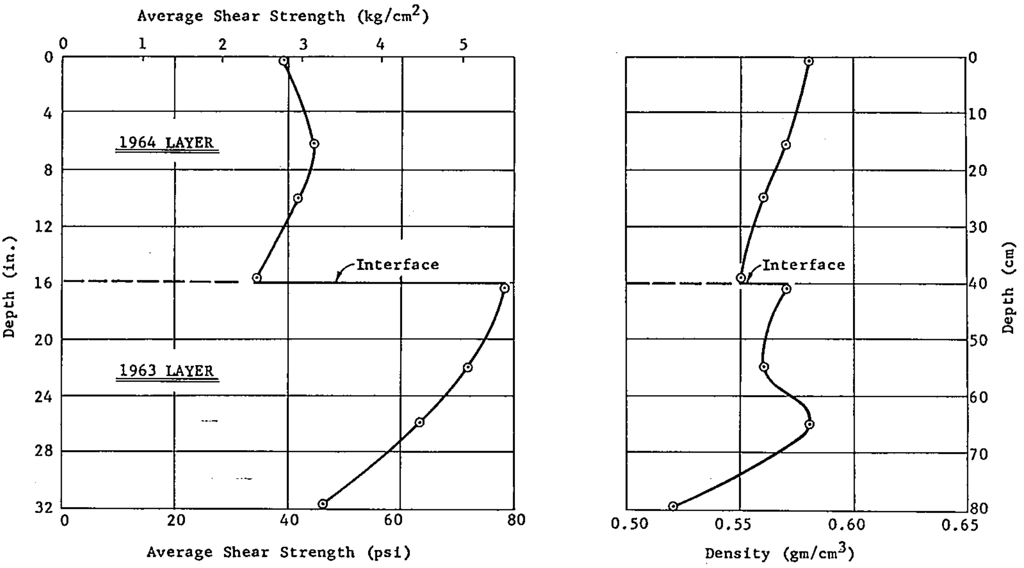

Fig. 4. Average shear strength and density profiles on 2 December 1964 in the 1963 and 1964 layers on the experimental runway

was subjected to such rolling in early January 1964 (Coffin, 1965).

The average density of the snow in the 1964 layer was 0.57 g/cm^3; in the 1963 layer, it was 0.56 g/cm^3. Before processing, the average density of the natural snow was 0.36 g/cm^3. After processing, there was no detectable change of density in either layer with time. The more consistent density profile in the 1964 layer is attributed to more uniform depth-processing of this layer compared to that achieved in the 1963 layer.

Reprocessing. Failures because of processing misses in the 1964 layer occurred during each aircraft test between early December and late January. Following each test, the failures were repaired by adding 3 inches of new snow and reprocessing the entire depth of the 1964 layer in the failure areas. After 2 to 3 days of sintering, the reprocessed areas were rolled with multiple passes of the pneumatic-tired roller.

The average load-carrying capacity for a typical failure area on the 1964 layer during the 24 December aircraft test was 80 psi (5.6 kg/cm^2). Fifteen hours after the area was reprocessed, its average was 39 psi (2.7 kg/cm^2); after 3 days, it was 110 psi (7.7 kg/cm^2). Twenty-five days later (24 January), its average was 174 psi (12.2 kg/cm^2), or the same as the average for the 61-day-old layer.

The average confined shear strength and density profile for the 25-day-old reprocessed area is compared with the averages for the original layers on 24 January in Fig. 5. The strength profile for the reprocessed area shows that multiple surface rolling of this area during near-thaw temperatures and intense solar radiation resulted in a strength profile similar to that achieved under similar conditions in the 1963 layer. The 53% difference in strength between the top and bottom of the less than 1-month-old reprocessed snow approaches the 24 January 75% difference in strength between the top and bottom of the 1-year-old 1963 layer. Its average strength, however, was 25% below the average for the 1963 layer.

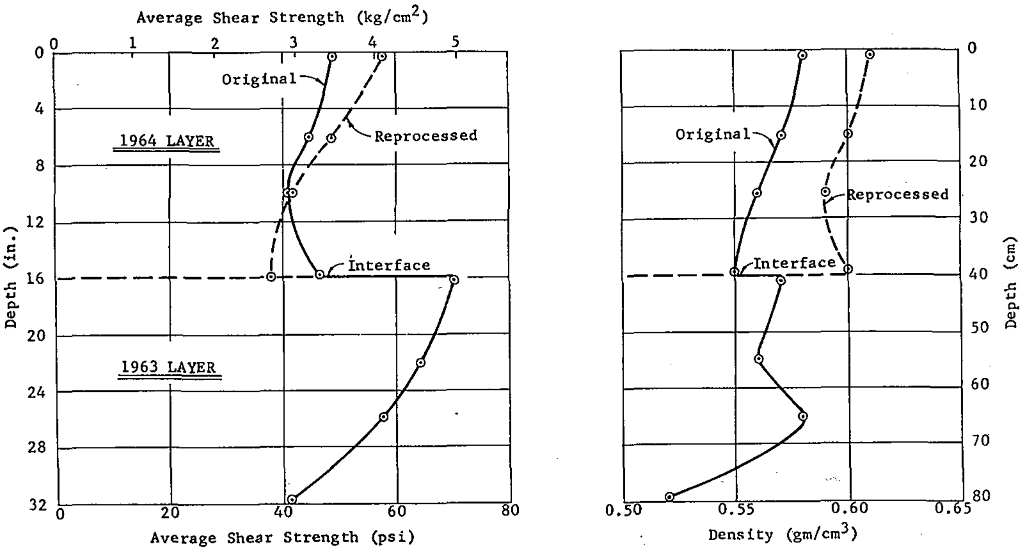

Fig. 5. Comparison of the average shear strength and density profiles on 24 January 1965 in the original and reprocessed snow in the 1964 layer on the experimental runway

During the 53-day interval between Figs. 4 and 5, there was a moderate increase in strength at the top and bottom of the original 1964 layer. The increase at the top of this layer is attributed to traffic; the increase at the bottom is unexplained. During this same interval, the distribution of strength in the 1963 layer remained unchanged, but slightly higher snow temperatures in this layer on 24 January (Fig. 5) resulted in 10% less total strength in this layer than that observed on 2 December (Fig. 4).

The average density of the reprocessed snow was 0.60 g/cm^3 compared with the 0.57 g/cm^3 average originally achieved in the 1964 layer. Also, as shown in Fig. 5, the density profile for the reprocessed snow was slightly more uniform because of increased quality control and more uniform depth-processing during reprocessing. All of these contributed to the 5% increase in density.

Aircraft tests. On 6 December, an LC–130 F aircraft weighing 90 000 pounds (40 924 kg), with the tires on its tandem main wheels inflated to 95 psi (6.7 kg/cm^2), made wheel takeoffs, landings, and taxi runs on the experimental snow runway. The runway supported this load where the load-carrying capacity of the 1964 layer, as measured by confined shear, exceeded 113 psi (7.9 kg/cm^2), but failed under the main wheels of the aircraft where the load-carrying capacity of this layer was 89 psi or less (6.3 kg/cm^2).

Similar aircraft tests were made on 24 December, 11 January, and 24 January at aircraft weights of 102 000, 115 000, and 125 000 pounds (46 267, 52 164, and 56 700 kg). In these tests, however, the tires on the main wheels of the aircraft were inflated to only 85 psi (6.0 kg/cm^2). Failures occurred directly under the main wheels in each of these tests where the load-carrying capacity of the 1964 layer, as determined by confined shear, was 85 psi or less (6.0 kg/cm^2). In each test, however, the main wheels regained the surface of the 1964 layer once its load-carrying capacity exceeded 85 psi (6.0 kg/cm^2). Following each test, the failure areas were repaired by reprocessing.

The final test on the experimental runway was made on 14 February with an LC-130 F aircraft weighing 135 000 pounds (61 236 kg) with its main wheels inflated to 95 psi (6.7 kg/cm^2). As the load-carrying capacity of the 1964 layer was fairly uniform over the entire runway for this test, there were no failures. The aircraft made four landings on wheels, five takeoffs, and trafficked the runway at speeds up to 30 mph (48 km/hr), for a total distance of 10.7 miles (17.1 km). In this test, the aircraft only marked the surface with tire prints, even where it traveled three times over the same track.

Minimum support requirements. Confined shear measurements were made around the failure areas in the 1964 layer following each of the December and January aircraft tests. They showed that the load-carrying capacity in the top 16 inches (40 cm) of compacted snow must equal or slightly exceed the tire inflation pressure of the main aircraft wheels for marginal support of the aircraft.

The progressive minimum load-carrying capacity profile required in the 16-inch-thick (40 cm) 1964 layer to support the tandem-wheel LC-130 F aircraft at a weight of 125 000 pounds (56 700 kg) with its main-wheel tires inflated to 85 psi (6.0 kg/cm^2) is shown in Fig. 6. As determined by confined shear, this minimum was 90 psi (6.3 kg/cm^2). In the first test on the experimental runway, a similar progressive load-carrying capacity profile with a maximum capacity of 89 psi (6.2 kg/cm^2), in the 1964 layer failed to support this aircraft at a weight of 90 000 pounds (40 824 kg) with its main-wheel tires inflated to 95 psi (6.7 kg/cm^2). The progressive minimum load-carrying capacity profile required in

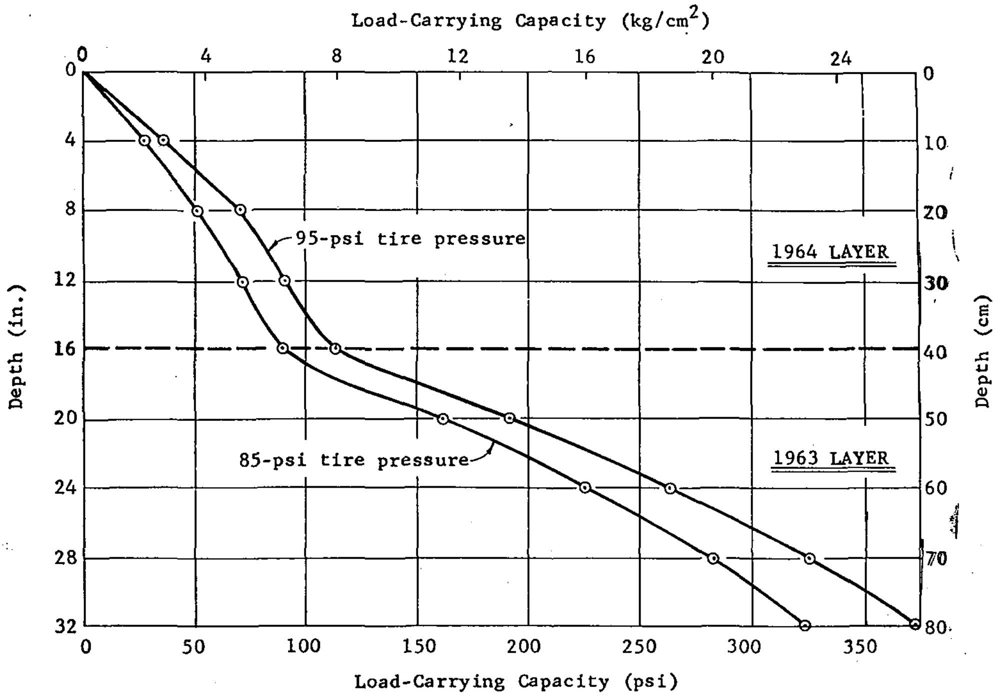

Fig. 6. Compacted-snow strengths required for minimum support of tandem-wheeled aircraft with tire pressures between 85 and 95 psi (6.0 to 6.7 kg/cm^2) and aircraft weights between 90 000 and 125 000 (40 824 and 56 700 kg) pounds

the 16-inch-thick (40 cm) 1964 layer to support this tandem-wheeled aircraft with its main-wheel tires inflated to 95 psi (6.7 kg/cm^2) is also shown in Fig. 6. As determined by confined shear, this minimum was 113 psi (7.9 kg/cm^2).

No assessment of the progressive load-carrying capacity required in the second layer of the experimental runway was possible in these tests. Other tests (Coffin, 1965) have shown, however, that a single 16-inch-thick layer of compacted snow will support aircraft weighing up to 30 000 pounds (13 608 kg) with its main-wheel tires inflated to 60 psi (4.2 kg/cm^2), but it will not support aircraft of greater weight and higher main-wheel tire inflation pressures.

The tests showed that the load-carrying capacity of compacted snow is more sensitive to the tire inflation pressure of main aircraft wheels than it is to the total aircraft weight. In the first aircraft test, the 1964 layer failed under a 90 000-pound (40 824 kg) aircraft with its main-wheel tires inflated to 95 psi (6.7 kg/cm^2). In another test over snow of similar strength, it supported a 125 000-pound (56 700 kg) aircraft with its main-wheel tires inflated to only 85 psi (6.0 kg/cm^2) even though the total weight of the aircraft was 39% higher. Current investigations are directed toward developing runways on snow for aircraft weighing up to 200 000 pounds (90 720 kg) with main-wheel tire inflation pressures up to 145 psi (10.2 kg/cm^2).

VII. Summary

Development of high-strength snow pavements capable of supporting heavy vehicles and large aircraft on wheels is possible by accelerating the natural metamorphic processes in snow by mechanical agitation. As punching failures directly under the wheels predominate in moving loads on compacted snow, a confined shear test method has been developed to measure its load-carrying capacity using small core samples. The present accuracy of this method ranges between 105 and 120%; current studies are being made to improve this accuracy.

Adequate strength to support vehicles weighing up to 10 000 pounds (4 536 kg) fitted with high-flotation tires inflated up to 10 psi (0.7 kg/cm^2) on deep snow can be achieved by merely trafficking a trail over the snow with tractors and rollers. Depth-processed snow pavements are required for snow roads to support vehicles weighing up to 70 000 pounds (31 752 kg) fitted with high-flotation tires inflated up to 30 psi (2.11 kg/cm^2) at speeds up to 45 mph (72 km/hr).

A single-layer, 16-inch-thick (40 cm) snow pavement will support aircraft weighing up to 30 000 pounds (13 608 kg) with its main-wheel tires inflated up to 60 psi (4.2 kg/cm^2) provided the load-carrying capacity of the snow pavement equals or exceeds the main-wheel tire inflation pressure. A 2-layer, 32-inch-thick (80 cm) snow pavement will support aircraft weighing up to 135 000 pounds (61 236 kg) with its main-wheel tires inflated up to 95 psi (6.7 kg/cm^2) provided the load-carrying capacity of the top 16 inches (40 cm) equals or exceeds the main-wheel tire inflation pressure. High-strength snow pavements can be produced and repaired with the existing NCEL techniques and equipment. Improved quality control techniques and equipment, however, are needed to produce snow roads and runways capable of supporting heavier loads and repeated traffic under varying conditions.

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