ENGINEERING ASPECTS AND SOILS INVESTIGATIONS

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My area of interest in the Ice-Free Land Program this past summer concerned the airstrip sites of Polaris Promontory. The primary site under investigation is in the eastern portion of the lowland of the promontory, 6 miles inland from Newman Bay, and on an extremely flat river terrace on the west bank of one of the larger rivers. This terrace is approximately 10 miles long and covers an area of 15 to 20 square miles. Initial work during our first visit, in the summer of 1958, included a general reconnaissance of most of this river terrace to select an airstrip which would meet four requirements: (1) a length of at least 5000 feet and a width of 200 feet with suitable overrun, (2) approaches meeting Air Force standards, (3) relatively flat slope and micro-relief which would require a minimum amount of construction effort for an aircraft landing, and (4) adequate soil profile and soil strength for safe support of aircraft such as the C-124, C-97, or C-130 which might be used as the test aircraft. Since the approaches to almost any portion of the river terrace area would be excellent and since an adequate soil profile and strength was indicated in the characteristically gravelly soils throughout the area, the matter of selection was one of minimum construction effort versus adequate length.

The strip which was finally chosen is 5000 feet long and 200 feet wide; its approaches, using the standard minimum glide angle of 1:50, are unobstructed for at least 12 miles. The orientation is true North 27^{o} East, and the center is at 81^{o}41'N, 59^{o} 35'W. The terrace slopes gradually to the north, and the strip itself changes in elevation from south to north from 376 to 328 feet -- less than 1 foot in 100. The micro-relief consists of a few small lemming mounds, depressed polygon edges, and inter-laced relic drainage channels--none of which are greater than 6 inches in height and most of which are about 2 inches. The strip has three different surface soil conditions: (1) within polygons, (2) between polygons, and (3) in the relic drainage channels. Those areas within polygons cover the most area since the polygon feature so characteristic of permafrost regions is quite plainly visible throughout the entire terrace. However, its effect on the terrace and in the area of our airstrip is small as indicated by the slightly depressed polygon edges. The surface is studded with gravel having a predominant maximum size of 2 1/2 inches, and the surface soil is very dry. In areas within polygons the surface soil is quite loose, but that between polygons and in drainage channels is firm. There is little vegetation -- mostly scattered patches of Arctic willow.

Specific soils investigations conducted in the summer of 1958 in the area of the proposed airstrip were of three categories. First, five test pits in areas of different surface conditions were dug down to frozen ground to determine the soil

*Since the author was in Thule, Greenland at the time of the Planning Session, portions of his paper were given by Stanley M. Needleman, AFCRC, and by Alfred H. Joseph, U. S. Army Corps of Engineers.

profile, and soil samples were taken from them at various depths for sieve analyses, Atterberg limit tests, and moisture content determinations. Soil temperatures and depths to frozen ground were also noted. Second, approximately 2800 shearing strength readings were taken at 93 different locations over the entire strip and to various depths with both a Corps of Engineers Waterways Experiment Station cone penetrometer and an airfield cone penetrometer to determine the ability of the soil to resist a typical aircraft load. Third, numerous visual observations were made and noted throughout the time spent at the site, mainly to form an idea of the compaction characteristics of the soil from the effects of the jeep being driven over the strip and from the results of an improvised compaction test.

In general, these investigations revealed a uniform soil profile throughout the entire strip characterized by a quite loose silty gravel and sand mixture in the top 6 inches and a firm compact sandy gravel layer below that. Penetrometer readings indicated a fairly soft surface but a rapid increase in shearing strength with depth. At 3 inches the average equivalent CBR was 14.7. Rutting by the jeep after 40 trips down the centerline varied from none to 2 inches.

From the results of the 1958 work, it was determined that an aircraft landing could be safely made on the airstrip at Polaris Promontory. Typical operational aircraft require the following CBRs to make a landing on an unimproved natural soil surface -- for one coverage: KC-97, 12.0; C-124, 6.4; C-130, 5.3. For three coverages: KC-97, 14.0; C-124, 7.8; C-130, 6.3. A comparison of these values with the CBR rating of the site shows that the airstrip at Polaris could safely support any of these three aircraft without excessive rutting. 1959 plans for Polaris were made from this information, and it was decided that a field party would be set down on the Polaris airstrip on or about 4 August to complete the grading and marking of the strip and to effect a test landing with a heavy Air Force transport aircraft.

The 1959 summer field season began in the middle of June with most of the field party members at Thule, but it soon became evident that some of the phases of the Ice-Free Land Program were not going to materialize. As an alternate plan, it was suggested that a field party be sent into Polaris early, during the melt season. This plan had been desired by those directly connected with the project since its inception. It is obviously important to study a site in its worst condition, and such a state would exist in the spring just after the snows had melted and the surface soil was saturated.

On 6 July, David Craven, a field assistant from the Arctic Institute of North America, and myself were flown in a C-54 from Thule to Alert where we were picked up by Bradley Air Services of Ottawa, Canada. The pilot, Mr. Wellde Phipps, had a single-engine Piper Super Cub equipped with over-sized low-pressure balloon tires to enable him to land on the softest of surfaces, and, although he chose the worst spot in the entire 15 square miles of flatland on which to set down, he made the landings and takeoffs without any difficulty.

The objectives we hoped to attain during our early visit were to explore as many of the numerous flat areas which exist on the lowland of the promontory as we could and to investigate the soil conditions of the 1958 site as affected by the excessive moisture from the melting snow, primarily loss of strength. It was unfortunately

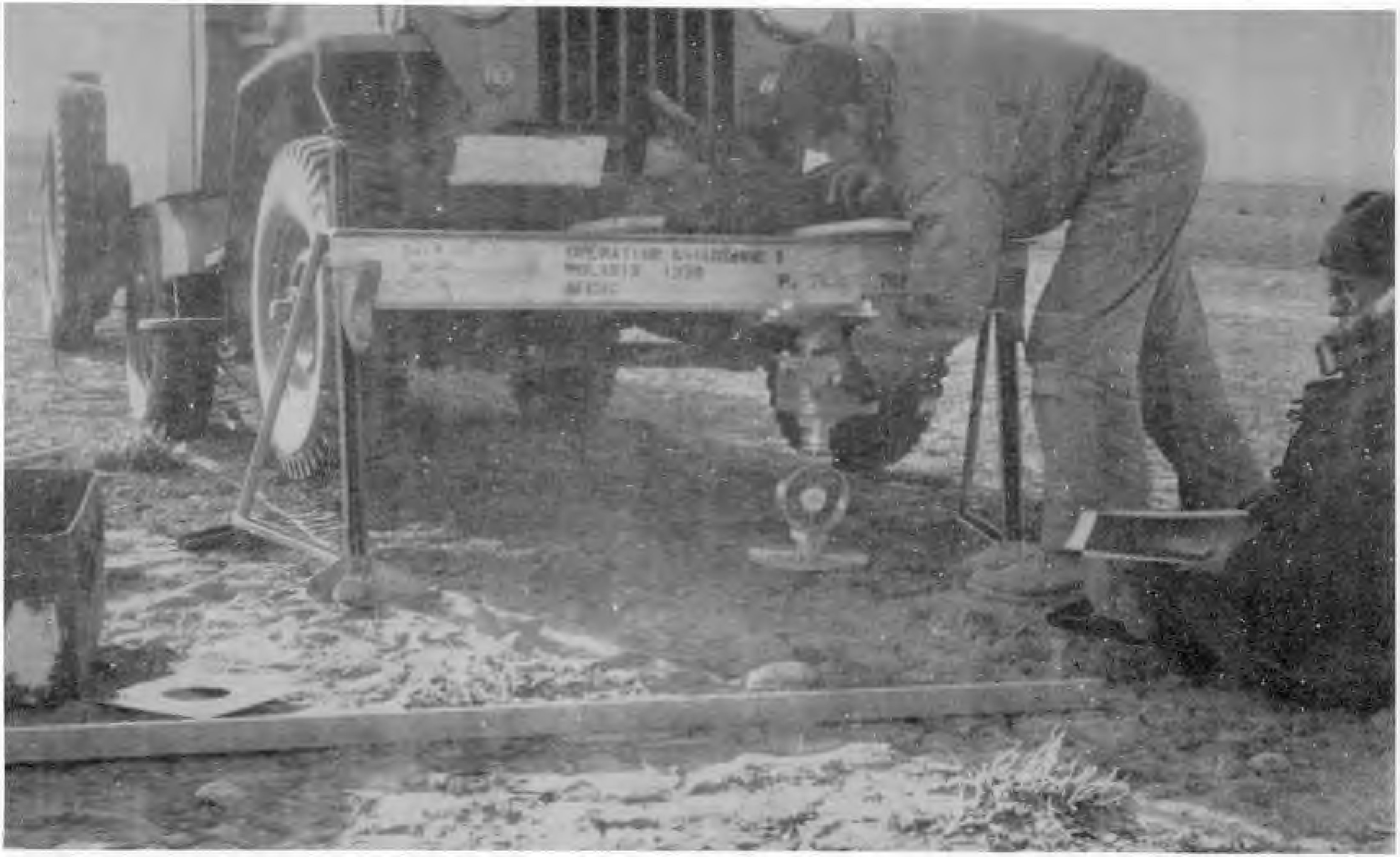

Fig. 1. CBR test being performed in the field at Polaris Promontory. The jeep is being used as reaction.

impossible to get to the Polaris site to observe the entire period of melt. When we landed, all the snow had disappeared; but I believe we arrived very shortly after the last of the surface water had drained away and I am quite sure we saw the strip in its most saturated condition.

The five test pits dug in 1958 were re-dug and investigated for soil temperatures and moisture content at various depths and the depths to frozen ground. This was done immediately upon arrival while the strip was still wet and again in early August after the strip had dried to the condition in which it had been observed the previous summer. Moisture content samples were also taken at random for comparison with each other and to determine the portions of the strip which were most affected by the excessive moisture. The shearing strength of the soil was also investigated at two different times in order to determine the loss and recovery of the strength of the soil. The airfield cone penetrometer was used exclusively, and approximately 3000 readings were obtained, one group upon arrival at the strip while it was still wet and a second after the strip had dried. Notes were continually kept on visual observations of the condition of the surface of the airstrip and of the river from the time before the melt started to the time when conditions were the same as observed in 1958. Periods of important changes, such as ice breakup, melting of the snow, high water, and surface drainage were recorded. It was possible to observe these conditions before our arrival because we were able to fly over the area at low altitudes at three different times before 6 July. Meteorological data were gathered during our six-week stay on Polaris, and readings of the barometric pressure, maximum and minimum temperatures, and relative humidity, observations of sky conditions, cloud type and coverage, precipitation, and wind speed and direction were noted. In our search for additional possible airstrip sites, three separate hikes were taken into the western, central, and southern portions of the lowland. Not all of the flatlands were observed, but an attempt was made to visit those with the most promise of success.

On 7 August the original 1959 plans were implemented, and the main party arrived from Thule via the Coast Guard icebreaker WESTWIND. Their objective was to complete the grading and marking of the airstrip and to effect a test landing. A snow blade mounted on the front of the jeep had been used in the summer of 1958 to do most of the required grading, and an Allis-Chalmers industrial-type tractor equipped with a dozer blade was used in the summer of 1959 to complete the job. There was little actual grading to be accomplished, and it was necessary only to knock the tops off the larger lemming mounds and to smooth out areas where polygon edges were depressed more than 2 inches. Both vehicles used -- the jeep last year and the tractor in 1959 -- were transported from the ship to the shore of Polaris Bay by an amphibious landing craft and then driven overland approximately 25 miles to the main camp. A little difficulty was experienced each year along the overland routes, especially on soft stream banks; but with a few shovels and some good hard manual labor, we proved that, with a moderate amount of caution, vehicles such as these can be used in ice-free land areas.

Upon completion of the grading and dragging operations, specially designed markers were installed along the sidelines and extended centerline of the airstrip, and on 15 August a C-130 from Hanscom field, piloted by Capt. Bob Terry, came up from Thule. Three test landings and takeoffs were made to prove conclusively the suitability of the Polaris airstrip to support aircraft activities.

The first test landing was actually an air evacuation mission. The Danish member of the party became extremely ill early the morning of the 13th and had to be taken on board the WESTWIND to receive the proper medical care. His case was diagnosed as acute appendicitis. The first landing, then, was to evacuate the Dane. The C-130 came back in the afternoon of the 15th and made two more landings and takeoffs, and all the personnel and most of the equipment were taken out on the third takeoff. A cache of food, fuel, and camping equipment was left in a tent for the next visitors.

Results of the 1959 investigations show that the airstrip at Polaris could not safely be used by other than light aircraft for the 2 to 3 week period in June and July when the snow melts, the resulting water drains from the area, and the surface soil dries to a moisture content compatible with the strength required for an aircraft landing. After this period, the strip is dry and strong enough to support heavy aircraft, and since there appears to be very little rainfall during the summer the strip probably remains in a dry condition until the beginning of the winter. Snow undoubtedly covers the strip all winter and the soil remains frozen until the snow begins to melt the following summer.

On 24 June a flight was made over the area and the site was generally covered with snow. The jeep, tent, and some of the flags which had been left the summer before could be seen easily, and since the snow was drifted around the jeep to a height of 2 or 2 1/2 feet, it is assumed that the depth of snow over the entire area was perhaps 1 to 1 1/2 feet. A few bare patches of ground were visible. On 1 July, the snow was melting and the coverage was less than 50%. Only ridges of snow running in an east-west direction remained, and there was quite a bit of water at the north (lower) end. On 2 July only 25% of the ground was covered and drainage streams braided the entire site. Pools of standing water existed, but most of the raised polygons seemed clear of water and dry. The entire length of the jeep track made in 1958 along the centerline of the strip was visible, so the effects of water action can not have been too great. There was no standing or running surface water when we arrived at the site on 6 July, but the area was quite moist. The first penetrometer readings were taken and the pits reinvestigated at this time. On 24 July the strip had dried to its 1958 condition and the second set of penetrometer readings and pit investigations were made.

The surface soils were extremely moist and soft on 9 July just after the melt. Soils within polygons had moisture contents approaching the plastic limit in the top 3 inches, and soils between polygons in the top 6 inches. Soils in the drainage channels had moisture contents exceeding the liquid limit in the top 6 to 9 inches. In all cases, the moisture content dropped rapidly in depths below these moist top layers.

Plots of the recovery of shearing strength for the various types of soil show that the drainage channel areas have the highest percentage of recovery. Conversely, these soils would also show the greatest loss of strength with the addition of excessive moisture. Strength recovery generally decreased with depth, with the greatest recovery for polygon soils taking place in the top 3 inches and for drainage channel soils in the top 6 inches. The loss and subsequent recovery of shearing strength of these soils took place between 24 June and 24 July.

A lightweight field CBR kit had been brought along, and several tests were conducted using the jeep or the tractor as the reaction. The data obtained tended to substantiate the previous year's findings of a fairly soft surface but a rapid increase in strength with depth. However, not enough points could be tested to use the data conclusively.

Moisture in the soil at Polaris can be helpful or detrimental. A slight amount, 5% or perhaps a little more, in the fine-grained surface soils increases strength. This is evident in the areas between polygons where more moisture exists in the same type of soil as is found within polygons, and the strength of the soil between polygons is noticeably greater. Too much moisture decreases the strength so that the soil is very weak. This effect is particularly noticeable in a silty soil with very little cohesion such as at Polaris. Not only does the soil have virtually no strength when its moisture content is above the plastic limit, but also it breaks down very rapidly with the addition of moisture while approaching the plastic limit from its natural moisture content. The point at which more moisture would decrease rather than increase the strength is very critical for the type of soil found at the surface at Polaris. In the bottom layers of soil, however, excessive moisture would not have much of an effect, since these gravelly soils have a high degree of porosity and any moisture which accumulates in this layer drains off easily.

The search for additional possible airstrip sites on the lowland of the promontory was not very successful. A 200 by 3000 foot strip of doubtful strength was laid out and investigated in the western portion, but this area was not up to expectations. The only other area of promise which was visited is upstream along the river on the same side and on the same terrace as the main strip and approximately 3 miles southeast of it. However, no site visited approached the main strip in length and strength. Many flat areas exist on the promontory, and our hikes did not by any means cover all of them. Therefore, it is quite possible that there is another satisfactory 200 by 5000 foot strip in the area. In any case, the many flat areas in the surrounding regions increase the potential of the main strip.

The test landings were a complete success. Landings and takeoffs were made in both directions, and the entire strip was tested in some way by the landing, taxiing, or takeoff of the aircraft. The gross weight of the C-130 was 90,000 lbs, and the tire pressures were 55 psi. With these governing factors, a CBR of 4.5 was required for one coverage. The deepest ruts were 6 inches, but they occurred in just a few isolated areas in drainage channels, and the majority of the deeper ruts were no more than 4 inches. The moist gravelly areas between polygons did not rut at all, and an average rut depth is estimated at 1 to 2 inches. The three-inch snowfall which we had the day before the test landings was undoubtedly beneficial. Two inches remained on the strip at the time of the landing; this acted as a cushion for the aircraft once it made its initial impact. In addition, there might have been a slight increase in the strength of the soil at the surface due to the addition of moisture from the melting snow. These effects would be slight, of course, and could be ignored in the final determination of the absolute strength of the Polaris airstrip. The depth of rutting is the important factor, and this figure was very satisfactory to all of us on the project, including the pilot who is the most important judge.