PERFORMANCE OF A ROADWAY WITH A PEAT UNDERLAY OVER PERMAFROST

by

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### Performance of a Roadway with a Peat Underlay over Permafrost

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**Abstract:**
An experimental roadway section was constructed in 1973 near Fairbanks, Alaska, to evaluate the thermal benefits of four and five foot thicknesses of peat placed beneath a roadway cut section in permafrost. Results of temperature and settlement observations over a four year period following construction have been utilized to analyze the performance of these sections. Adjacent undisturbed forest and normal roadway sections were also analyzed for comparison purposes.

Observations through 1977 have shown much earlier total refreezing of the peat sections as compared to the normal roadway, and greater seasonal cooling of the underlying permafrost beneath the peat section.

Surface temperature observations have demonstrated that the roadway surface has an average temperature very similar to that of the undisturbed forest and that permafrost will be maintained at some equilibrium depth beneath the roadway.

Results of this four year study indicate that for climatic areas similar to Fairbanks, Alaska, a thickness of 2 ½ feet of consolidated peat placed beneath a four foot thick roadway fill will be adequate to prevent thawing into the permafrost underlying a paved highway. However, progressively deeper thawing beneath slope and ditch areas may still occur in spite of a peat underlay.

**Key Words:**
- Ground Temperature
- Heat Flow
- Permafrost
- Peat
- Roadway

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Performance of a Roadway with a Peat Underlay Over Permafrost

Abstract

An experimental roadway section was constructed in 1973 near Fairbanks, Alaska, to evaluate the thermal benefits of four and five foot thicknesses of peat placed beneath a roadway cut section in permafrost. Results of temperature and settlement observations over a four year period following construction have been utilized to analyze the performance of these sections. Adjacent undisturbed forest and normal roadway sections were also analyzed for comparison purposes.

Observations through 1977 have shown much earlier total refreezing of the peat sections as compared to the normal roadway, and greater seasonal cooling of the underlying permafrost beneath the peat section. Major settlements of the roadway over the peat have occurred and appear to be still progressing at the end of four years. These settlements resulted because the peat was installed in a frozen state and could not be permitted to thaw and consolidate prior to final pavement placement.

Surface temperature observations have demonstrated that the roadway surface has an average temperature very similar to that of the undisturbed forest and that permafrost will be maintained at some equilibrium depth beneath the roadway. However, the side slope and ditch areas warm significantly, resulting in progressively enlarged residual thaw zones in the underlying soils.

Results of this four year study indicate that for climatic areas similar to Fairbanks, Alaska, a thickness of 2 1/2 feet of consolidated peat placed beneath a four foot thick roadway fill will be adequate to prevent thawing into the permafrost underlying a paved highway. However, progressively deeper thawing beneath slope and ditch areas may still occur in spite of a peat underlay.
INTRODUCTION

In the zone of discontinuous permafrost, current roadway designs for ice-rich permafrost areas generally attempt only to provide sufficient overlays to support vehicle loadings during thaw of underlying ice deposits. Therefore, a considerable amount of differential settlement occurs which must be corrected by costly regrading or repaving. The thicknesses of granular overlay necessary to prevent thaw of underlying permafrost are so great as to be generally uneconomical in permafrost areas having average ground temperatures in the 28 to 32°F range.

Thaw of subsurface ice deposits becomes a particularly serious and costly problem when new roadway sections are constructed across previously undisturbed permafrost terrain. In such areas, every attempt is made to avoid disturbance to the ground surface layer of moss, grass and low shrubs, both by hand clearing of trees and brush, and by avoidance of cut sections. However, cut sections in ice-rich permafrost are sometimes unavoidable.

Under this study, a four year field investigation was made of the effectiveness of layers of peat installed beneath the normal pavement structural layers in a roadway cut section, for purposes of preventing or greatly retarding thaw of underlying ice-rich permafrost.

In Norway, both compacted peat layers and pre-compressed peat bales have been used extensively and successfully since 1903 as a soil replacement layer to control frost heaving beneath railways and roads (1). Studies made of these peat layers in recent years have shown little decay of the peat after up to fifty years of service (2). The peat was effective in retaining high moisture contents and therefore a high latent heat effect, even though installed in areas above the normal groundwater level. Because
of the lower ground temperature in permafrost regions, bacterial action leading to decay of peat should be negligible.

Wet peat typically has a frozen thermal conductivity nearly twice as high as when thawed. Thus a peat layer is much more quickly frozen than thawed, assuming temperature gradients of equal magnitude. Peat is therefore more suited to applications for preservation of permafrost than for usage for seasonal frost control. This favorable thermal behavior as a summer heat insulator and a winter heat conductor would be expected to result in lower temperatures in the underlying permafrost than in sections where peat is absent from the active layer.

OBJECTIVE

This study was designed to evaluate the benefits of incorporating a layer of peat beneath a roadway pavement system, for purposes of preventing thaw of underlying ice-rich permafrost in a roadway cut section. Information on climatological data, soil properties, surface and subsurface temperatures, and roadway elevation changes with time were obtained to permit theoretical thermal analysis of the results of the study.

SITE DESCRIPTION

The site chosen for this study is located near Mile 300 on the Richardson Highway, approximately 66 miles southeast of Fairbanks at 64° 16' North Latitude and 146° 30' West Longitude (Fig. 1). A cut of up to 30 feet in depth in frozen silt was required in this area for a new roadway segment constructed in 1972 and 1973.
Topography

The study section is located one mile north of and 250 feet above the Tanana River, in an area of rounded ridges and hills with gentle side slopes and wide valleys. The Tanana River is slowly eroding the bases of these hills, and small streams flowing to the Tanana have developed V-shaped valleys where they near the river. The study site is located on a gentle, northeast-facing slope of the Canyon Creek valley, where a cut section was required to carry the roadway down into the valley bottom located to the south of the study site.

Geology

The roadway cut section intersects a contact between a Pre-Cambrian schist bedrock and overlying silts of eolian origin. An active layer 1.5 to 2.5 feet in thickness, overlies the perennially frozen silt. The surface layer composed of organic material, roots, and moss ranges from 0.5 to 1.0 feet in thickness, and provides most of the natural insulation that protects and preserves the permafrost at this locality. Black spruce trees up to 6 inches in diameter and 20 feet in height, spaced 1 to 4 feet apart, provide dense year-around shade and reduce the thickness of insulating snow during the winter.

Silt soils form a variable mantle up to 33 feet in thickness overlying the irregular schist bedrock surface, and have been partially retransported to form thickened colluvial aprons on the middle and lower slopes. The silts encountered in the excavation ranged from dark gray to dark brown in color, and had a strong organic odor. Measured organic contents ranged from 3 to 7% by weight. Particle size analysis showed approximately 10% of the soil particles to be larger than .074mm (200 sieve) and 10% smaller than .01mm.
Silt Moisture Contents vs. Depth

Figure 2
Beneath the active layer the silt moisture contents ranged from 30 to 87% by weight of the dry soil, averaging 47% for 45 samples. Segregated ice was limited to occasional very small lenses and stringers. Moisture contents tended to decrease significantly with depth, as shown by Figure 2. All moistures were well above the Liquid Limits, which ranged from 23 to 30%.

The bedrock underlying the study site is a quartz-mica schist, which is perennially frozen to an unknown depth. The schist is extremely weathered near its upper surface, with frozen moisture contents ranging from 16 to 22% in six samples.

Persistent supra-permafrost water flows were noted throughout most of the thawing season at the west end of the study site, and caused a generally saturated condition in the south side roadway ditch area.

Climate

The climate of the area is typical of the continental climate of interior Alaska. Winters are cold and dry, with warm, relatively dry summers. Air temperatures at this site average slightly lower and wind velocities slightly higher than in Fairbanks, the closest location having long-term weather records. The mean annual site air temperature is approximately 25°F, with seasonal extremes near +95°F and -50°F. Annual precipitation averages approximately 12 inches, with 70 inches of total snowfall. The snow cover generally starts to form in late September, reaches a maximum of approximately 27 inches in February, and thaws during April.

From the Fairbanks Weather Bureau records compiled since 1931, the average annual freezing and thawing indices were approximately -5550 and +3300 °F days, respectively.
PROJECT DESCRIPTION

The site selected for the peat study area was located between Stations 3246+30 and 3252+17 on the Silver Fox to Canyon Creek roadway reconstruction, Project Number F-062-4(30). The roadway profile required a cut section in the area where foundation soils were frozen silts with very high moisture contents, as previously described.

Design Considerations

A source of peat was located 5.1 miles from the test site, adjacent to the Richardson Highway near Birch Lake. This site was a frozen peat bog formed by shoreline advancement around a small pond, and was selected since no thawed peat sources were available.

Calculations of seasonal thaw depths for design of the study sections were based on the "Modified Berggren" calculation approach, as described in Army Technical Manual TM-5-852-6(Ret.1). Assumptions were made of a final 125% equilibrium moisture content after the peat had thawed and consolidated, and a percentage of unfrozen moisture of 40%, which would remain in the peat at subfreezing temperatures (3). Calculations indicated the maximum seasonal thaw depths to be between 2.0 and 3.4 feet in a consolidated peat, when covered by a 5 foot gravel layer and an asphalt pavement. For peat placed in an initially frozen state, it was apparent that consolidation of the peat would occur in the portion thawed during each summer. Samples from the peat source indicated that initial thaw and consolidation of this peat would result in approximately a 40% decrease in thickness under a loading of 5 feet of fill. Since consolidation would result in considerable loss of moisture and thus reduce the latent heat effect of the peat, the depth of thaw would increase annually for several
years until equilibrium was reached.

Placement of the peat in an initially thawed condition would have permitted essentially all of the consolidation to occur during construction, and would have avoided the progressively deeper thawing and resultant settlements mentioned above. However, since the peat from the frozen source was the only material available, and since the costs of progressively excavating and stockpiling peat from this source as it thawed were considered to be too high, the decision was made to excavate and place the peat in the frozen state, and to initially place only a thin granular overlay above the peat to carry traffic. With minimal cover, the peat layer was expected to fully thaw and consolidate during the first summer after placement, and within the construction period. Following the first thaw and the subsequent winter refreeze, the embankment would be raised to final grade. The insulating effect of the additional fill would then prevent deeper thawing during subsequent years. This approach required that sufficient peat thickness be placed so that the thickness after initial thaw and consolidation would still be adequate to prevent thawing of the underlying permafrost. Frozen peat layer thicknesses of four and five feet were selected, to give consolidated thicknesses of approximately 2.4 and 3.0 feet.

For comparison purposes, a 100 foot long section at the start of the cut was to be excavated to a depth of nine feet, similar to the four foot peat section, but was to be built to final grade with only a granular fill material. Calculations of thaw depths in granular fills, which are very sensitive to the fill moisture contents, indicated the maximum thaw depth to be in the vicinity of 15 feet in gravels without a peat underlay.

In addition to presenting a site for studies of peat underlay
performance, this cut section presented the opportunity for observing the stability of cut slopes in high moisture content silts without segregated ice. The cut slopes were intentionally designed with very steep (3/4 horizontal : 1 vertical) slopes, and with 16 foot wide flat-bottom ditches to provide storage room in the event of cut slope failures.

Instrumentation System Design

A system consisting of 192 thermocouples and 12 thermistors was designed to permit periodic monitoring of thaw depths and changes in subsurface temperatures. This system combined the advantages of a very high level of accuracy of thermistors with the low cost and reliability of thermocouples. Three cross sections located in the center of the control and four and five foot peat areas were selected for instrumentation. One undisturbed forest location, at 88 feet left of centerline Station 3250, was selected to be instrumented for comparison purposes. To provide an exact depth reference at the contact between fill materials and the bottom of the subcut, three strings of 12 thermocouples each were to be placed horizontally prior to backfilling of the subcut. The remaining composite thermocouple and thermistor strings were to be placed in vertical borings at centerline, mid-slope, and mid-ditch locations.

To permit direct measurements of the consolidation of the peat layers, four composite settlement plates were specified to be located beneath the left and right shoulders in the 4 and 5 foot peat sections. These installations each consisted of three plywood bases with pipe floor flanges and vertical pipe risers attached, with pipe sizes of 3/4, 1 1/2, and 3 inches to permit the top and middle plates to settle vertically with respect to the bottom plate (Fig. 6). This permits thickness changes in the top and bottom halves of the peat layers to be measured separately, and also permits
measurements of the thaw-consolidation occurring beneath the bottom of the subcut.

To complete the instrumentation system, provisions were made for installing a weather station adjacent to the site, with battery operated recorders to continuously measure air temperatures at a 5 foot height, and also pavement and side-slope soil temperatures at a depth of one inch beneath the surface.

**Contract Specifications**

Specification requirements applied to construction of the study sections were as follows:

1. Hand clearing of trees and brush was required to 20 and 15 feet back of the top of cut slopes to the right and left of the roadway centerline, respectively.

2. Above, one 190 foot long section of the high cut slope to the right of centerline, the organic mat was to be reinforced with a experimental wire mesh blanket to prevent the mat from tearing and sliding down the cut face during thaw.

3. The cut excavation and peat placement operations were to be completed between October 15 and December 31, to prevent thaw while working the cut.

4. All costs of the peat excavation and placement, and other related work, were to be bid as a lump sum. The experimental wire mesh blanket was also bid as a lump sum.

Copies of Contract Specifications and plan details pertinent to test section construction are included in Appendix A.
CONSTRUCTION OPERATIONS

Construction in the test area began July 9, 1972, with the hand clearing of the trees and brush between Stations 3233+00 and 3261+00. On October 16, 1972, the stripping of the moss and excavation of the ice-rich silt began. The silt was first ripped with D-9 Caterpillar tractors equipped with single rippers and then loaded with 641 scrapers for haul to a waste area. The subexcavation of the silt and the transition to the bedrock cut were completed by October 27, 1972. Temperatures during the construction period were ideal, remaining below 32°F even during mid-day. Only minor surficial thawing of the south facing silt slope occurred prior to winter.

The designated source of peat backfill, 5.1 miles distant and adjacent to the highway at 'L' Station 2980, (M.S. 624-155-2), was first stripped of the covering of grass tussocks. The underlying frozen peat was ripped in three directions to permit loading into 641 and 651 scrapers. Some minor selective excavation was required to avoid segregated silt and ice deposits. The scrapers then hauled the frozen peat to the study site where one D-8 and two D-9 cats spread the frozen peat chunks and partially broke them up. A sheepsfoot roller was used to further break up and compact the peat in uniform layers approximately 12 inches in thickness.

A total of 5,243 cubic yards of frozen peat was placed, with a 4 foot thickness from Station 3248+10 to 3249+80 and a 5 foot thickness from 3250+00 to 3251+65, transitioning into the bedrock foundation at Station 3253+00. Because of a surveying error the silt between Station 3251+00 and 3251+65 was excavated too deeply, causing the granular overlay above the 5 foot peat section to be 1 to 2 feet thicker than planned. The total cost of
excavating, hauling, placing and compacting the peat was paid for at the contract lump sum price of $35,000.

As the peat layer was built up, the telescoping settlement plates were placed at four locations, with one plate at the base of the peat, one at the middle elevation, and one on top of the peat. After the completion of placement operations, the peat sections were covered with a layer of decomposed granite fill (grus) from three to four feet in thickness to carry traffic loading during the subsequent season of thawing and consolidation. By November 1, 1972, the first year's embankment work had been completed, and normal traffic was routed over the unpaved sections during the 1972-73 winter. Figures 3 to 6 show cross section, plan, and profile views of the sections as constructed through the fall of 1972.

Work resumed on the study sections on June 24, 1973, with the embankment raised to final subgrade profile with alluvial gravel, followed by placement of 6 inches of subbase and 4.5 inches of base course. The 1.5 inch thick asphalt concrete pavement was completed by July 24, 1973. The earlier than scheduled test section completion was necessary to avoid delays to the contractor since the remainder of this 15.5 mile project was completed approximately one year ahead of schedule. This early completion of the embankment over the peat underlays, still mostly frozen in July of 1973, proved to have very excessive settlements since the initial thaw and consolidation stage for the peat layer did not occur during the project construction as originally planned.
CROSS SECTION  Sta. 3250+62

Undisturbed Ground

T.C. No. 4

Finished Grade

3.3' Selected Material (Granitic)

5.0' Pile

T.C. No. 3

Figure 4
- Thermocouple Strings
- Settlement Plates

DETAIL OF SETTLEMENT PLATES

- Pipe Cap
- Stacked Iron Pipes
- Pipe Flanges
- Top of Peat
- Center of Peat Layer
- 3/4" Plywood (24" x 24")
- Frozen Silt
EMBANKMENT SOILS

Peat Layer

The peat utilized on this project was apparently formed as the result of advancing shoreline deposition around the margins of a small pond, located approximately 5 feet above and 400 feet distant from Birch Lake. Test holes showed several peat layers up to 6 feet in thickness, separated by thin layers of gray silt with occasional layers or masses of pure ice. The peat varied between coarse and fine fibrous in appearance, with moisture contents ranging from 124 to 300% of the dry weight and organic contents from 39 to 54% by dry weight.

After compaction two density tests were performed, and indicated a compacted wet density of approximately 59 pcf. Five thaw-consolidation tests were run on samples of the compacted peat and indicated that under a loading of five to six feet of fill the peat would compress to an average of 56% of the initial frozen thickness. Moisture contents of the peat samples after consolidation ranged from 81 to 133% and averaged 95%.

Decomposed Granite

The source of this material, which was utilized as the initial backfill layer over the peat and as fill in the control section, was a borrow pit located in a highly weathered granite outcrop adjacent to the roadway approximately three miles west of the study area. The granite was decomposed to an arkosic sand and gravel, geologically termed "grus." Under the action of equipment, this material broke down to a grading roughly similar to a well graded fine gravel.
Gravel

The remaining embankment and pavement system layers came from an alluvial gravel source located at the edge of the Tanana River floodplain near Birch Lake, an 8 mile haul distance from the study site.

Observed field densities, moisture contents, and estimated thermal conductivities of all embankment materials are shown by Table 1.

<table>
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<tr>
<th>Materials</th>
<th>Avg. Dry Density (pcf)</th>
<th>Moisture Average (%)</th>
<th>Moisture Range (%)</th>
<th>Thermal Conductivities BTU/ft-hr-°F* K Frozen K Thawed</th>
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<tr>
<td>Base Course Crushed Gravel</td>
<td>145.0</td>
<td>4.5</td>
<td>3 - 6</td>
<td>2.2 2.1</td>
</tr>
<tr>
<td>Subbase Crushed Gravel</td>
<td>152.7</td>
<td>4.0</td>
<td>2 - 5</td>
<td>2.4 2.3</td>
</tr>
<tr>
<td>Select Fill Clean Gravel</td>
<td>145.0</td>
<td>4.5</td>
<td>4 - 5</td>
<td>2.2 2.1</td>
</tr>
<tr>
<td>Common Fill Decomposed Granite</td>
<td>128.7</td>
<td>6.7</td>
<td>3 - 9</td>
<td>1.6 1.6</td>
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<tr>
<td>Peat Layer As Placed</td>
<td>19.3</td>
<td>204</td>
<td>124-299</td>
<td>0.52</td>
</tr>
<tr>
<td>Peat Layer After Consolidation</td>
<td>33.9</td>
<td>95</td>
<td>81-133</td>
<td>0.60 0.30</td>
</tr>
</tbody>
</table>

*Note: Thermal Properties taken from Kersten, "Laboratory Research for the Determination of the Thermal Properties of Soils (4)."
Subsurface Temperature Indicators

The thermal performances of the two peat underlay sections are compared with the adjacent roadway control section and with an undisturbed ground area through a system of 3 horizontal and 12 vertical strings, each having 12 thermocouples. Additional thermistor and thermocouple pairs, which were physically taped together, were also installed at the bottom ends of the twelve vertical thermocouple strings to permit very accurate temperature observations at the maximum depths drilled. This system allowed use of the deep thermocouples as the thermocouple reference junction in lieu of an ice bath reference, with the temperature of this reference junction being determined by the adjacent thermistor reading.

Thermocouples were fabricated from Leeds and Northrup (L&N) special accuracy grade copper-constantan thermocouple wire, using L&N crimp on "Quik-Tip" connectors. The individual thermocouple lead wires were taped together at intervals in the portions to be installed vertically on borings, while the horizontal portions were encased in black 3/4" I.D. flexible polyethylene water piping, for protection against abrasion. Lead wires were terminated in electrical switch boxes mounted on 4" X 4" wood posts on the roadway shoulders. At this point, the copper leads from the uppermost 12 thermocouples were connected through 12 position single pole L&N rotary switches, while the constantan leads from each of these thermocouples were joined together in common. The common constantan and switched copper sides were then wired to the constantan and copper sides of a plug jack to permit plug-in field connections with the readout device.

This system avoided the possible problems of added thermocouple
junction effects which could have resulted from switching constantan leads through a copper switch, but problems progressively developed from "ground loops" through the soil around the thermocouples because of the common constantan connections. As a result, indicated temperatures became increasingly erratic with time on these interconnected thermocouples and after four years of usage in this mode, all thermocouples were rewired to eliminate the common connection, the single pole switches being replaced with "Stackpole" brand double pole switches. This eliminated the common connection and resultant ground loop problem, since both copper and constantan legs are switched at the same time. The possible problems from thermocouple effects in switching a constantan lead through a copper switch have been successfully minimized by placing insulation around the rotary switch to keep both the "in" and "out" terminals at the same temperature.

Thermistors used as accurate deep temperature references are of the glass-encapsulated type, and were obtained from and calibrated by the U.S. Army Cold Regions and Engineering Laboratory. In the vicinity of 32°F, these thermistors have a resistance coefficient of approximately 300 ohms per °F and can be read in the field to an accuracy of better than one ohm. Performance has been excellent, with no failures over the five years since installation.

Installation Operations

The first installation of temperature instrumentation was made in late October of 1972, when the three horizontal thermocouple strings were placed at the bottom of the silt cut, labeled strings TC 1, 2, & 3, (Fig. 5 & 6). These strings were installed just before the control section granitic fill and the two thicknesses of peat were placed. Special care was taken to
prevent damage to the protective tube around the thermocouple wires by placing the tube on the silt and covering it with hand-placed fill material before the rest of the fill was pushed on top.

On November 17, 1972, the undisturbed ground string was placed after augering a 6 inch diameter hole to a depth of 31 feet, at 85 feet left of centerline Station 3250. The remainder of the vertical strings were placed between May 9 and June 14, 1973, in holes augered with a 6 inch solid auger using a Mobile Drill B-38 drilling rig. After drilling the instrumentation holes to the desired depths, which ranged from 12 to 35 feet below the top of the silt foundation soils, the thermocouple strings were weighted with two to three pound stones and lowered into the holes. The lower portion of each hole was backfilled with dry concrete mortar sand up to a depth of two to three feet below the top of the frozen silt. Above this level the backfill consisted of soil cuttings from the auger hole. Water problems were encountered in holes located in the right ditch, which was saturated by snowmelt runoff and by water from a small spring located just up grade from the test sections. To prevent this water from saturating the sand backfill in the permafrost portion of each hole, two layers of bentonite pellets were placed in each hole near the top of the permafrost zone. Figures 7 to 9 show the as-built cross sections of the completed construction, with instrumentation details.

Temperature observations indicated that in the permafrost zones all backfill materials had refrozen and essentially regained the temperature of the surrounding soils within 30 days after string placement.

**Temperature Measurements**

Subsurface temperature measurements were taken monthly through the term of this study. Three different measurement devices have been utilized.
Readings from the time of string installation until December of 1974 were taken with a L&N Model 8686 potentiometer for thermocouples and an L&N portable wheatstone bridge for thermistors. From December of 1974 to March of 1977, both thermocouple and thermistor readings were taken with a Data Precision Model 3500 digital multimeter having a sensitivity of 1 microvolt and 1 ohm. This unit provided accuracy better than the previous equipment, with increased speed of reading since no manual nulling was required. However, it did require the use of an AC power supply provided by a DC/AC inverter mounted in a car. In April of 1977, the Data Precision unit was replaced with a Hewlett-Packard Model 3465B battery powered digital multimeter, which presented additional stability of readings since its more stable power supply avoided some electrical noise and static problems caused by the electrical interconnection with an automobile through the DC/AC inverter. Electrically shielded thermocouple extension leads from the instrument to the switch boxes have also proven beneficial.

The thermocouple reference junction utilized for thermocouple readings must be at an exactly known temperature. For the first 2 1/2 years of this study the deepest thermocouple on each string was used as the reference junction and its temperature was obtained from the adjacent thermistor. This method avoided the need to make up and maintain an ice bath reference. A change to a double insulated ice bath reference was made in December of 1975 to improve accuracy further, and this reference has been utilized since that time. This procedure also permits monthly comparisons between indicated temperatures at the deep locations from the paired thermocouples and thermistors, and has indicated the accuracy of the thermocouple readings to be consistently better than 0.3°F.
Air and Surface Temperatures

On-site air temperatures are obtained by a battery operated recorder of the remote-reading 3-pen type, with the air temperature probe located in a white painted Weather Bureau-type thermometer shelter. Maximum and minimum temperatures over the monthly period between chart changes are also checked by U.S.W.B. calibrated maximum and minimum thermometers. The two additional probes are located beneath the roadway pavement and at 1 inch beneath the side slope soil surface, to record pavement and soil temperatures. The recorder housing was mounted in the embankment side slope so that the snowcover provides some insulation from low winter air temperatures. Accuracy of these recorders were checked annually by field recalibrating the probes with a large ice bath, and appears to be better than 2°F.

Settlement Measurements

Four telescoping plate-type settlement platforms were used to measure thickness changes in the peat layers, and also to measure the settlements resulting from thaw beneath the peat layers. Measurements were periodically made between the three extension pipes in each settlement platform assembly to determine relative settlements. In addition, the elevation of the top plate was determined by level surveys.

A bench mark was established on the left side rock bench cut at roadway Station 3251+50, which consisted of a 3/4" X 6' iron pipe driven to refusal into the very soft and highly weathered bedrock. However, because of the initially frozen state and high moisture content of this bedrock, settlements of the bench mark occurred during thawing and periodic bench mark elevation adjustments were required.

In addition to the settlement platforms, a pavement surface elevation
grid was established covering the area of the study section and the adjacent normal roadway segments, with points on centerline and at 10 and 19 feet right and left of centerline. These pavement elevation points were resurveyed at approximately monthly intervals during the first year after construction and once to twice yearly since that time.

AIR AND SURFACE TEMPERATURE OBSERVATIONS

Annual temperature and snowfall records are summarized by Table 2.

Table 2  
<table>
<thead>
<tr>
<th>Year &amp; Season</th>
<th>Yearly Avg. (°F)</th>
<th>Thawing Index (°F)</th>
<th>Freezing Index (°F)</th>
<th>Snowfall* Total Inches</th>
<th>Factor** (%)</th>
<th>Season Lengths</th>
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<td>62</td>
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<td>3100</td>
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</table>

* Snowfall data from Eielson A.F.B., located 30 miles northwest of site.  ** Distribution factor is percentage of winter snowfall prior to January
Site air temperatures have averaged 24.1 °F during the five year period covered by this study. Air freezing and thawing indices have averaged -5496 and 2870 °F days, respectively.

Surface temperatures and their relationships to air temperatures are presented by Table 3. The "N" factors calculated for these freezing and thawing seasons refer to the mathematical ratios between ground and air freezing and thawing indices, as utilized in the "Modified Berggren" calculation approach (3). Average air and surface temperatures, calculated over consecutive seasons of freezing and thawing, are also presented in Table 3. These data indicate the average air, pavement surface, and side slope surface temperatures over the 2 1/2 year term of measurements to be 23.8, 30.1, and 37.2°F, respectively.

Table 3. SURFACE AND AIR TEMPERATURE RELATIONSHIPS

<table>
<thead>
<tr>
<th>Year &amp; Season</th>
<th>Freezing or Thawing Indices (°F-days)</th>
<th>'N-Factor'</th>
<th>Average Temperature for Winter &amp; Summer</th>
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<td>Pavement</td>
<td>Side Slope</td>
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<tr>
<td>74-75 Winter</td>
<td>-6410</td>
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<td>-1800</td>
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<td>1975 Summer</td>
<td>2650</td>
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<td>3600</td>
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<tr>
<td>75-76 Winter</td>
<td>-6500</td>
<td>-5600</td>
<td>-1800</td>
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<tr>
<td>1976 Summer</td>
<td>2980</td>
<td>4900</td>
<td>4100</td>
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<tr>
<td>76-77 Winter</td>
<td>-3900</td>
<td>-4400</td>
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The surface temperature data for the 1976-77 winter does not correspond to the previous winters in that the average winter pavement temperatures indicated were consistently lower than the indicated air temperatures. However, similar temperature relationships were observed at other air-pavement temperature recording sites in the Fairbanks area, and are apparently the result of the many unusual warm air masses which passed over interior Alaska during that winter. Similar observations are commonly made in Norway and Sweden (5). The abnormally cold side slope temperatures were primarily the result of a lack of snow cover early in the winter, a lower than normal annual snow cover, and removal of snow in the study area by high winds. This is confirmed by the fact that temperatures beneath the adjacent undisturbed ground indicated lower temperatures as a result of the 1976-77 winter than in any of the four prior winters.
SUBSURFACE TEMPERATURE OBSERVATIONS

Roadway Areas

The potential long term performance of the peat underlays is best judged by inspection of subsurface temperatures and temperature trends. One means of representing ground temperatures from vertical thermocouple strings is provided by plotting at each depth the maximum and minimum temperatures observed during a full season of thawing and refreezing. These plots, termed "temperature envelopes", were plotted with respect to depth as referenced to the bottom of the subcut. Temperature envelopes for the control and the peat sections are presented by Figures 10 to 12. These figures indicate that greater cooling has occurred beneath the peat sections during all three winters studied. Note also that during the abnormally warm 1976-77 winter the control (non-peat) area did not totally refreeze, leaving a thickness of nearly one foot of unfrozen silt beneath the roadway centerline. With this one exception, all road centerline temperature observations have indicated full annual refreezing. Temperature measurements at the thirty foot depth indicate little or no wintertime cooling of the permafrost beneath the control section roadway compared to significant cooling occurring beneath the peat underlay areas. These data also show progressively deeper summer thawing, regardless of treatment, indicating that thermal equilibrium has not been reached in the first 5 years after construction.

Ditch and Undisturbed Areas

Temperature envelopes beneath the undisturbed forest site and a typical roadway ditch area location in the 4' peat section are shown by Figures 13 and 14. By comparison to the undisturbed site, all centerline sections demonstrate much greater seasonal warming and seasonal cooling. The ditch
Temperature - °F

Legend:

- 1973 SUMMER & 73-74 WINTER
- 1975 SUMMER & 75-76 WINTER
- 1977 SUMMER & 76-77 WINTER

4' PEAT SECTION - \( \frac{C}{L} \)
MAXIMUM & MINIMUM TEMPERATURES

Figure 11
Temperature - °F

Depth - Feet

Legend:

- 1973 SUMMER &
  73-74 WINTER
- 1975 SUMMER &
  75-76 WINTER
- 1977 SUMMER &
  76-77 WINTER

5' PEAT SECTION - ζ
MAXIMUM & MINIMUM TEMPERATURES

Figure 12
Legend:

- 1973 SUMMER & 73-74 WINTER
- 1975 SUMMER & 75-76 WINTER
- 1977 SUMMER & 76-77 WINTER

4' PEAT SECTION - RIGHT DITCH
MAXIMUM & MINIMUM TEMPERATURES

Figure 14
area has experienced no wintertime cooling because the heavy snow cover in
the ditch areas prevented full refreezing of the ditch bottom soils during
all five years of observations. Progressively deeper annual thawing beneath
the ditches, combined with a lack of annual refreezing, has resulted in
residual thaw zones beneath the ditch bottoms of from three to five feet in
thickness.

Seasonal Temperature Lags

The times at which the temperature extremes are observed at various
depths are presented for the three roadway centerline areas by Figures 15 to
17. As can be seen from these figures, the time differences between maximum
and minimum air and ground temperatures, termed the "seasonal lag", differ
very little between the different treatments. Times of maximum temperatures
are particularly difficult to determine near the top of the permafrost since
temperatures in this region change very little between August and the time
of complete refreezing of the active layer, sometime between December and
February. This uncertainty causes the apparent spread in the times of
maximum temperatures, as indicated on these figures.

Temperature Trends at Depths below 30 feet

The effectiveness of utilizing peat in the "active layer" or seasonally
thawed zone as a means of preserving the permafrost in the subgrade soils,
is indicated by examination of temperature trends at depths of 30 feet or
greater. Figure 18 presents a comparison of indicated temperatures from
reference thermistors located at the bottoms of the three centerline
thermocouple strings and at the bottom of the undisturbed ground string.

Temperatures as shown by Figure 18, indicate a definite seasonal
cooling effect in both peat areas for all winters except the abnormally warm
SEASONAL THAW ZONE
Summer, 1977

GRANULAR FILL

SILT

MINIMUM TEMPERATURES
MAXIMUM TEMPERATURES

Legend:
O—MIN. FROM 1973-74 WINTER
& MAX. FROM 1973 SUMMER
X—MIN. FROM 1975-76 WINTER
& MAX. FROM 1975 SUMMER
△—MAX. FROM 1977 SUMMER

DATES OF SEASONAL MIN. & MAX. TEMPERATURE VERSUS DEPTH CENTERLINE ON CONTROL SECTION - STATION 3247+07.5

Figure 15
Fig. 7. Dates of seasonal min. & max. temperature versus depth centerline on 4' peat section – station 3249 +00.
DATES OF SEASONAL MIN. & MAX. TEMPERATURE VERSUS DEPTH CENTERLINE ON 5' PEAT SECTION – STATION 3250+59.5

Figure 17
1976-77 winter, with the 4' peat section showing a slightly greater cooling effect than the 5' peat section. This is apparently the result of the thinner granular overlay above the 4' peat section which results in earlier complete refreezing of the peat each winter. Cooling of the permafrost at depth obviously cannot occur until all overlying soils have refrozen and cooled to well below 32°F. The permafrost beneath the control section, by comparison, has exhibited a slight but continuous warming trend with the exception of very minor cooling from the winter of 1973-74.

The very warm 1976-77 winter resulted in a warming trend beneath all roadway sections, since total refreezing occurred very late in the winter in the case of the peat underlay sections and did not occur at all beneath the control section. The undisturbed site, however, experienced a greater cooling effect than in any previous year, as a result of the abnormal lack of snow cover during this winter; a factor having no effect on the cleared roadway sections.

These temperature data indicate that the most favorable location for a peat roadway underlay is close to the surface, since earlier full refreezing will result. However, because of the low strength and high elasticity properties of peats, granulay overlays on the order of three to four feet are generally considered the minimum for adequate pavement performance.

Heat Flow Analysis

The thermal performance of the different roadway sections analyzed in this study can be compared by studying the heat flow conditions into and out of the permafrost underlying each study section. Thermocouple temperature gradients were analyzed after selecting pairs of thermocouples beneath the road centerline which had two feet of vertical separation and which were both located within the permafrost just beneath the depth of maximum thaw.
Since the soil between these thermocouple pairs always remains frozen and varies little in temperature, it can be assumed to have a constant thermal conductivity. When the upper thermocouple of a given pair is at a higher temperature than the lower, heat is flowing into and warming the underlying permafrost. The temperature gradients, calculated in °F per foot, are labeled positive (+) for heat gain. Conversely, negative (−) temperature gradients indicate heat flow out of the permafrost and net heat loss.

Temperature gradients for the three different roadway sections and for the 4' peat area ditch section are presented by Figure 19. The most obvious difference between the peat and control areas, as seen from this plot, is that no cooling of the permafrost occurred beneath the control section during the 1976–77 or 1977–78 winters. This corresponded with the 1977 development of the residual thaw zone beneath the control section. Both peat sections showed some cooling even during the extremely warm 1976–77 winter. By contrast, the adjacent ditch area showed no wintertime cooling of the underlying permafrost during the full term of this study.

Cumulative heat flows were calculated in BTU per month per square foot of ground area, using an assumed thermal conductivity of 1.2 (BTU/ft·hr·°F), which was estimated from soil moisture and density data (4). These data, presented by Table 4, represent the net areas beneath the curves of heat flow versus time (Fig.19); and clearly demonstrate the thermal benefits of the peat layers in increased annual cooling of the underlying permafrost.
TEMPERATURE VARIATIONS OF DEEP THERMISTORS WITH TIME

Legend:
- △ 5' PEAT ON ♂ AT -42'
- ○ 4' PEAT ON ♂ AT -40'
- × CONTROL, ON ♂ AT -44'
- ⬤ UNDISTURBED FOREST AT -30'

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<td>31.0</td>
<td>30.8</td>
<td>30.6</td>
<td>30.4</td>
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</table>

Figure 18
MONTHLY TEMPERATURE GRADIENTS INDICATING HEAT GAIN OR LOSS IN PERMAFROST BENEATH ROADWAY

Figure 19
<table>
<thead>
<tr>
<th></th>
<th>Control C</th>
<th>4' Peat C</th>
<th>5' Peat C</th>
<th>4' Peat Ditch</th>
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</thead>
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<td>+650</td>
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<td>-4810</td>
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Seasonal Thaw Depths

Maximum seasonal thaw depths beneath the paved roadway sections generally occur in late September or October. These depths are determined from thermocouple temperature data as the position of the 32°F isotherm. In ditch, side slope, and undisturbed ground areas, depths of thawing are measured annually in late September by hand probing with 1/2" diameter steel rods. Thaw depths for the three instrumented cross sections are presented by Figures 20 to 22, as determined during 1973, 1975, and 1977. Depths of thaw in 1974 and 1976 were intermediate between the adjacent plotted years and were omitted for the sake of clarity. Surface elevation changes which occurred at these locations after pavement placement, as a result of thaw
MAXIMUM THAW DEPTHS
Control Section
Station 3247+10

Figure 20
MAXIMUM THAW DEPTHS
4' Peat Section
Station 3249+00

Figure 21
MAXIMUM THAW DEPTHS
5' Peat Section
Station 3250+62

Figure 22
and consolidation of the peat layers or the underlying permafrost, are also shown by these figures. With the possible exception of soils beneath the pavement area of the 5' peat section, all sections show annual deepening of the thaw zone beneath road and ditch areas. However, there was certainly some effect from the abnormally warm 1976-77 winter on this observed progression of thawing and it is possible that an equilibrium thaw depth has been reached beneath the cleared roadway areas, shown to have mean annual surface temperatures well below 32°F.

Residual Thaw Zones

As indicated by Table 3, the roadway side slopes, as well as the adjacent ditch areas, had an average annual surface temperature of approximately 37°F during the term of this study, 13°F above the average air temperature for the same period. This extreme warming is the result of the unvegetated gravel surfaces being exposed to the warming effects of the summer sun, followed by an insulating snowcover during the winter. The effect of the warmer surface temperatures in these areas has been to thaw more deeply each summer than the maximum depth of refreezing. This has created residual thaw zones or "taliks" beneath the ditches and lower side slope areas. Figures 23 to 25 show the extent of these thawed zones at the end of the 1976-77 winter. Since these taliks warm quickly after summer thawing of the overlying seasonal frost layer, progressively deeper annual thawing of the underlying permafrost occurs. This ultimately results in continuing settlements in the ditch and side slope areas after the paved roadway has reached its equilibrium thaw depth, and often causes longitudinal cracking of the outer portions of the roadway.
RESIDUAL THAW ZONE
WINTER, 1976-77
Control Section
Station 3247+10

Figure 23
Figure 24

RESIDUAL THAW ZONES
WINTER, 1976 - 77
4' Peat Section
Station 3249+00
RESIDUAL THAW ZONES
WINTER, 1976-77
5' Peat Section
Station 3250+62

Figure 25
SETTLEMENT OBSERVATIONS

Because the final roadway pavement was placed prior to fully thawing and consolidating the peat, a measure necessary to avoid costly delays to the roadway contractor, major settlements have occurred throughout the study area. Settlements which occurred across the three instrumented cross sections between pavement completion, in July of 1973, and observations in September of 1978 are shown in Figures 20 to 22 as the change in surface elevations.

Settlement Platform data, (Fig. 26), show the elevation changes of the top and mid-point of the peat layers since the time of placement in a fully frozen condition in October of 1972. These data indicate that no significant settlements have occurred at the settlement plates placed at the contact between the bottom of the peat and the top of the frozen silt subgrade, while major settlements have occurred within the peat layers.

Longitudinal settlement profiles taken from periodic elevation surveys along the roadway centerline are presented by Figure 27. Data from the 1977 summer are not available because of heavy levelling patches placed over this area by maintenance personnel. These settlement data indicate that progressive settlements are still occurring in both the peat and control sections, with greater annual settlements occurring beneath the peat sections.

Results of pavement surface and peat layer settlement plate data for all sections are summarized as follows:
SETTLEMENT PROFILES ALONG CENTERLINE

Figure 27
Control Section

1) Settlements commenced shortly after the July 1973 pavement placement, as a result of the thawing of permafrost foundation soils beneath the 10 foot thick roadway fill section, and averaged 0.20 feet by October 3, 1973.

2) Settlements averaged 0.52 feet by the end of 1976.

3) Centerline settlements were 14% greater than at 19 feet left and right (north and south) of centerline.

4) Shoulder settlements were nearly identical on north and south shoulders.

4' Peat Section

1) Settlements were occurring rapidly at the time of pavement placement, due to initial thaw of the peat, and averaged 0.40 feet by October, 1973.

2) Settlements averaged 0.85 feet by October 15, 1974 and increased to 1.20 feet by the end of 1976.

3) Centerline and north shoulder settlements were approximately 15% greater than at the south shoulder.

4) Thawing reached the mid-point of the peat layer during September of 1973 and to the bottom of the peat by September of 1977, by which time the original 4' peat layer had consolidated to a 2.0 foot thickness.

5' Peat Section

1) Settlements were occurring rapidly at the time of pavement placement in July of 1973 and averaged 0.42 feet by October of that
year.
2) Settlements averaged 0.87 feet by October 15, 1974, and 1.3 feet by the end of 1976.
3) Centerline settlements were 8% greater than at the north and south shoulders.
4) Thawing reached the mid-point of the peat layer during September of 1973, and had progressed to a depth of 4.3 feet below the original top of the peat by September of 1977.
5) At the end of 1977, the seasonally thawed peat layer had consolidated to a thickness of 2.3 feet with 0.8 feet of frozen peat remaining beneath the seasonally thawed zone.
6) Settlement plates showed no significant frost heaving of the peat layers during the annual refreezing.
7) The top half of the peat layer exhibited an additional 9% decrease in thickness during the second thawing cycle in 1974, and a further 7% thickness decrease during the thaws of 1975 through 1977.

CUT SLOPE STABILITY

In the design stage it was anticipated that cut slope failures might occur upon thawing. Therefore, wide bottomed ditches were provided and provisions were also made for anchoring wire mesh to the overlying vegetative mat to reinforce it. However, these cut slopes, in frozen silts at moisture contents averaging around 45%, have proven very stable. The only slumping which has occurred has been very minor, and was confined to an area where surface runoff saturated the north facing cut slope in the vicinity of Station 52. The north-facing slope apparently attained thermal equilibrium
rather quickly, thawing to a depth of 4.0 to 4.5 feet each summer and fully refreezing each winter. This thermal stability is aided by the steep slopes, which do not accumulate snow. The south-facing slopes were much lower in height, receive more solar radiation and snow cover, and have experienced deeper and more progressive thawing than those facing north.

SUMMARY AND CONCLUSIONS

Four and five foot thicknesses of frozen peat were placed beneath the pavement structure in a roadway cut section in perenially frozen silts in 1973. This test installation was made to investigate the thermal benefits of peat in preserving permafrost beneath a roadway in the discontinuous permafrost region of Alaska. Temperature, thaw depth, and settlement observations were made on these sections at regular intervals from 1973 through 1977.

Because the frozen peat was not permitted to fully thaw and consolidate prior to final pavement placement, annual thawing and drainage of the excess moisture from the peat have resulted in annual settlements of the roadway surface and a slow progression toward thermal equilibrium beneath the roadway surface. Data indicate that annual increases in the depth to the permafrost table were still occurring at the end of the fourth year after construction. Continued observations will be necessary over several additional years to determine the final state of thermal equilibrium of these sections.

Temperatures at various depths beneath the roadway surface have demonstrated that the peat layer annually refreezes much more quickly than the soils beneath an adjacent normal roadway. The permafrost underlying the
peat is cooled significantly each winter, while that underlying the normal roadway has experienced only progressive warming during the term of the study. Therefore, the peat has a significant thermal benefit in preserving permafrost beneath roadways.

In the roadway ditch areas the exposed gravel surface, combined with the winter insulating snow cover, have prevented any full depth annual refreezing. Therefore, progressively enlarging residual thaw zones have developed beneath the ditches. Peat underlays beneath the ditches have had a negligible effect in preventing this thawing.

The roadway test section having a final thickness of 2.3 feet of consolidated peat beneath a 5 foot thick granular overlay has been adequate to prevent annual thawing from reaching into the underlying permafrost. In the adjacent normal roadway area, thawing has occurred annually beneath a 10 foot thickness of granular fill.
IMPLEMENTATION RECOMMENDATIONS

The following conclusions of this study should be applied to roadway design and maintenance operations in areas of discontinuous permafrost:

1) Peat underlays can be effectively utilized beneath paved roadways to prevent thawing of the underlying permafrost. For climatic conditions similar to those of the Fairbanks area, a minimum thickness of 2.5 feet of consolidated peat is required beneath a 4 foot thickness of granular fill material to prevent thawing into the underlying permafrost. This will require an adequate source of thawed peat, and the peat must be pre-consolidated by a surcharge during construction, to minimize long-term secondary consolidation.

2) The installation of a compacted, frozen, unconsolidated peat layer beneath a roadway is not recommended. Very large initial surface settlements, on the order of 50% of the peat thickness, must be expected upon thawing. An additional 10 to 20% consolidation of the peat during subsequent freeze-thaw cycles should also be expected.

3) Wide, exposed, unvegetated roadway side slopes and wide ditch areas should be avoided in ice-rich permafrost areas. The surface areas created by these features have very high mean annual surface temperatures, and result in progressive long term thawing of the underlying permafrost.

4) Roadway cut-slopes to 30 feet in height may be cut nearly vertical in silt permafrost having moisture contents as high as 60% without resulting in thaw-related slope failures, provided that thawing rates are not excessive at the time of construction.
5) Failure to maintain roads free of snow will adversely affect the thermal stability of roads in the discontinuous permafrost zone, and perpetually ongoing thaw-related settlements may result in ice-rich terrain. Roadway surfaces maintained clear of snow in wintertime may have yearly average surface temperatures very similar to the adjacent undisturbed forest areas.

6) Periodic wintertime removal of snow from slopes and ditches should be considered in areas where continuing maintenance problems are anticipated from slope and ditch area thawing into underlying permafrost.
ACKNOWLEDGEMENTS

The Alaska Department of Transportation gratefully acknowledges the cooperation of the Federal Highway Administration in funding this project under the Highway Planning and Research Program. Project construction records and elevation surveys were provided through the efforts of Mr. Orlin Entzel, Project Engineer. Field temperature observations and temperature records have been primarily obtained by Mr. Richard Jurick, Electronics Technician.
REFERENCES

(1) Skaven-Haug, S. "Protection against Frost Heaving on the Norwegian Railways" Geotechnique, Sept, 1959


(4) Kersten, M. "Laboratory Research for the Determination of the Thermal Properties of Soils" 1949, Engineering Experiment Station, University of Minnesota

(5) Heirsted, S. "Thermal Climate Regime on Road and Ground Surface" 1975 Frost I Jord NR10


(9) Wilson, H. "Construction of a Highway Test Section on Permafrost" CRREL Technical Note
APPENDIX A

203-3.04 Construction of Embankment with Moisture and Density Control.

Add the following: All embankment except rock and the Test Section, shall be constructed with moisture and density control.

Add the following:

203-3.07 Test Section. An insulating layer of peat will be placed between station 3247 + 30 and 3252 + 56+, and a wire mesh blanket for erosion control will be placed at the top of the cut slope on the right between stations 3250 + 00 and 3251 + 90, as detailed on the plans.

1. Roadway excavation, placing and compaction of peat, and placing and compaction of selected material, between stations 3246 + 30 and 3252 + 56+, shall be carried out only during the period October 15 to December 31.

The peat shall be obtained from Material Sources 624-155-2, and shall be frozen when excavated and placed. Peat shall contain no admixed silt or masses of ice, but may contain trees smaller than 1 inch in diameter, and grass and moss ground cover. The peat shall be placed in 12" maximum lifts and immediately compacted with a 10-ton sheep's foot roller, or equivalent equipment, as approved by the Engineer, for a minimum of 1/2 hour per 100 cubic yards of placed volume.

The selected material shall be compacted in accordance with subsection 203-3.05.

Water draining into the silt cut shall be controlled by pumping or other means, and shall not be allowed to accumulate in either ditch.

Instrument Placement. Between Stations "0" 3246 + 30 and "1" 3251 + 65 the Department will install instrumentation within and beneath the roadway and ditches to evaluate the performance of the Test Section. Installation of instrumentation will be done before and during placement of the peat layer. Monitoring installations will be located off to the side of the roadway to minimize interference with construction operations, with the exception of six settlement monitoring pipes to be located in the roadway shoulder areas. There will be no payment for delay of or interference with the Contractor's operations due to this instrumentation and monitoring. The Contractor is hereby notified of such instrumentation placement and will be responsible for repair or replacement of any instrumentation damaged by him during construction, at no additional expense to the State.

The Contractor shall conduct his operations in such a manner that, upon completion of the work described above, the work area will be readily accessible to the State's snow removal equipment.
After initial thaw settlement in the peat layer is complete, expected to about July 15, the selected Material in place over peat shall be compacted by rolling 1 hour per station. Any additional selected material required shall then be placed and compacted in accordance with subsection 203-3.04

2. Drainage of the above area, through the rock; cut ahead, shall be established as rapidly as practicable.

3. The wire mesh blanket shall be placed on and secured to the organic ground cover as soon as practicable after hand clearing of the area between stations 3250 + 00 Rt. and 3251 + 90 Rt.

Wire mesh and anchor wire shall conform to the requirements of subsections 710-2.08 and 710-2.09, respectively.

203-4.01 Method of Measurement.

Add the following:

10. Spread existing road shall be measured along the staked centerline by the station unit, complete and accepted.

11. Obliterate existing road shall be measured along the staked centerline by the station unit, complete and accepted.

12. Pre-splitting. This work will be measured using the two-dimensional method, to determine the area of the cut-face surface, in square yard units, pre-split in accordance with this Special Provision.

SPECIAL PROVISIONS
Project F-062-A(30)
Silver Fox to Canyon Creek
203-5.01 Basis of Payment. In the penultimate paragraph change the word "Designated" to read, State Furnished.

Add the following: Pre-Splitting shall be paid for at the contract unit price per square yard of cut-face surface. Pre-Splitting shall include all work involved in drilling, stemming, loading and detonating and shall be full compensation for furnishing all labor, materials, tools, equipment, and incidentals, completed as specified.

Test Section(Peat) shall be paid for at the contract lump sum price, which payment shall include all work involved in furnishing, hauling, placing and compacting frozen peat and dewatering the ditches, as required.

Test Section(Wire Mesh) shall be paid for at the contract lump sum price, which payment shall include all work involved in furnishing and installation of wire mesh for erosion control.

Selected material obtained from approved material sources shall be measured and paid for under Item 203(5B).

Add the following Pay Items:

<table>
<thead>
<tr>
<th>Pay Item No.</th>
<th>Pay Item</th>
<th>Pay Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>203(12)</td>
<td>Spread existing roadway</td>
<td>Station</td>
</tr>
<tr>
<td>203(13)</td>
<td>Obliterate existing roadway</td>
<td>Station</td>
</tr>
<tr>
<td>203(16)</td>
<td>Pre-Splitting</td>
<td>Station</td>
</tr>
<tr>
<td>203(17A)</td>
<td>Test Section(Peat)</td>
<td>Square Yard</td>
</tr>
<tr>
<td>203(17B)</td>
<td>Test Section(Wire Mesh)</td>
<td>Lump Sum</td>
</tr>
</tbody>
</table>

Delete the last paragraph.
STATE OF ALASKA
DEPARTMENT OF HIGHWAYS

PLAN AND PROFILE
PROPOSED HIGHWAY PROJECT
F-062-4(30)
SILVER FOX TO CANYON CREEK
GRADING, DRAINAGE
HOT ASPHALT PAVEMENT

INFORMATION ONLY
MAY NOT BE USED FOR BID

PROJECT SUMMARY
WIDTH OF SUBGRADE 44 FT.
WIDTH OF SURFACING 40 FT.
LENGTH OF GRADING 5,818.83 FT. = 9.356 MI.
LENGTH OF PROJECT 81,605.93 FT. = 15.456 MI.

DESIGN DESIGNATION
ADT (1972) 500
ADT (1969) 1400
DIV 250
D 40-60 %
T 7 %
V 60 M.P.H.