ABSTRACT

Frost Susceptibility Ratings and Pavement Structure Performance

by:

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A three year study of the relationships between flexible pavement performance, and design methods, materials properties and environmental factors was recently completed by the Alaska Department of Transportation and Public Facilities. One hundred and twenty older pavement sections from all climatic regions of the State were chosen for this investigation. Performance was characterized by measurements of fatigue or alligator cracking, rut depths and peak springtime deflection levels. Pavement structures were measured and sampled to a depth of \( \frac{1}{4} \) feet. Sample testing included gradations, Atterberg Limits, moisture contents and frost susceptibility related predictive factors. Additional information from previous frost heave testing programs was used to supplement the results of this performance study in formulating conclusions on the relationships between frost susceptibility indicators and performance.

Results of this study have indicated that low \(-0.075\)mm and \(-0.02\)mm particle size contents in unstabilized pavement structural layers may be the most important of the many factors which affect structural performance. Classifications and analysis of pavement layer soils and systems by the Corps of Engineers frost susceptibility system and the Reduced Subgrade Strength design method showed significant relationships with pavement performance in Alaska, while testing and design analysis using the Stabilometer R-value method was of no value in indicating relative performance levels.
INTRODUCTION

A major study to compare the field performance of Alaska's flexible highway pavements with the physical properties of the underlying aggregate and soil layers commenced in 1977 and was completed in 1980. A primary intent of this study was to evaluate the maximum fines contents which could be allowed at each depth without resulting in excessive thaw-weakening of the pavement system and premature fatigue failures of the overlying asphalt pavement. Soil layers were investigated from the bottom of the asphalt pavement to a depth of 4 1/2 feet.

The Alaska Department of Transportation and Public Facilities currently utilizes a combination of the Corps of Engineers "Reduced Subgrade Strength" design method and the Hveem "R-value" method for structural design of flexible roadway pavements (1), (2). Subgrade soils are classified for Frost Susceptibility Values (FSV), and minimum total pavement structure thicknesses are selected from design curves based on the Traffic Index (TI) and the soil FSV classifications of the subgrade.
soils. The thicknesses of the pavement and base course layers are then selected on the basis of R-value test data. If the reduced subgrade strength method were to be rigidly applied to all layers of the pavement system, all base and subbase soils to a depth of 12 to 18 inches beneath the pavement would be of Non-Frost Susceptible (NFS) classification, thereby effectively limiting the allowable percentage passing a #200 sieve to 5% or less after compaction. Specifications which permitted fines contents as high as 10 to 12% in past years have resulted in premature pavement failures from frost action and thaw-weakening within the base and subbase layers. Practicality, however, often dictates that fines contents higher than 5% be permitted in these layers.

Results of this study and of prior laboratory frost heave testing of base and subbase layers have led to a series of conclusions regarding the relationships between soil classifications and frost heave test results and pavement performance in various Alaskan environments.

SITE SELECTION AND CHARACTERIZATIONS

A total of 120 half mile to one mile long paved highway sections with unbound granular base layers were selected for study throughout the various climatic regions of Alaska. Roadway sections selected were those exhibiting either good long term performance and life, or clear evidence of premature fatigue-type distress. Emphasis in selections was placed on older pavements and resulted in an average pavement age of approximately fifteen years.
Each section selected was intensively measured for alligator or fatigue cracking and wheelpath rutting as these factors are considered to be the primary structural performance indicators (2), (3). Benkleman Beam deflection surveys were made weekly for one month after the start of spring thawing on each section, using the Asphalt Institute test procedure (4), to determine the degree of seasonal thaw-weakening. High springtime deflection levels which decrease during the summer season are considered to be the result of frost action within or beneath the pavement structure. Maximum deflection levels were used in this study to indicate the structural strength of each section (5).

To determine the properties of the pavement structures, two test pits were excavated to a depth of 4 1/2 feet in each study section and samples and thickness measurements were taken on each layer. Pavement cores were taken from wheelpath and non-wheelpath areas to determine thicknesses and to correct the surface rut measurements for the effects of pavement wear and displacement.

Environmental factors were determined for each site, including climatological data such as mean annual temperature, precipitation, and mean freezing index (6), as well as age and cumulative traffic expressed as equivalent axle loadings. These factors were included in the study analysis to determine whether significant performance differences existed between similar pavement structures in warmer coastal environments and the colder dry interior regions of Alaska. Mean air temperatures ranged
from 22 to \(40^\circ\)F, freezing indices from 300 to 6000 \(^\circ\)F-days, and annual precipitation from 10 to 80 inches. Equivalent 18,000 lb. axle loadings at the time of site inspections varied from 20,000 to 860,000. Asphalt pavement thicknesses ranged from 1 to 4 inches, averaging 1.9 inches.

LABORATORY TESTING

All pavement structure soil samples were tested for particle size gradation and were classified under the Corps of Engineers Frost Susceptibility Classification System (1). Under this system based on original observations stated by A. Cassagrande (7), gravels having 3% or less of particles finer than .02mm are considered non-frost susceptible (NFS), while all other gravels and sandy gravels are placed in classes F-1 to F-4 in accordance with Figure 1.

Heave Rate Tests

Heave rate testing was performed on 41 base course and subbase samples, selected from study sections ranging from excellent to poor in performance. Heave test procedures used in this study have been developed by USA CRREL (8), (9) and modified in the Materials Laboratory of the Alaska Department of Transportation and Public Facilities over the past ten years, for evaluating the performance of soil stabilizing agents and for comparing the frost heave susceptibilities of base and subbase aggregates at differing gradations and fines contents. The testing procedure as used in this study involved the removal of the +3/4 inch particles and compaction of samples with a vibratory hammer in 6 inch diameter by 5½ inch high segmented ring molds, followed by sample saturation by
overnight soaking. Heave measurements are recorded while applying a fixed $+15^\circ$F air temperature above the samples for 72 hours and maintaining a $+40^\circ$F temperature beneath the samples (Figure 2). Samples are classified on the basis of the heave occurring between 48 and 72 hours after the start of freezing, during which time the freezing rate approximates $\frac{1}{2}$ inch per day.

A Heave Classification System which was originally developed for Corps of Engineers heave tests performed at a freezing rate of $\frac{1}{2}$ inch per day in tapered molds, is applied to the heave test results shown by Table 1.

<table>
<thead>
<tr>
<th>AVERAGE HEAVE RATE</th>
<th>HEAVE RATE CLASSIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>48 - 72 hrs. (mm/day)</td>
<td></td>
</tr>
<tr>
<td>0.0 - 0.5</td>
<td>Negligible</td>
</tr>
<tr>
<td>0.5 - 1.0</td>
<td>Very Low</td>
</tr>
<tr>
<td>1.0 - 2.0</td>
<td>Low</td>
</tr>
<tr>
<td>2.0 - 4.0</td>
<td>Medium</td>
</tr>
<tr>
<td>4.0 - 8.0</td>
<td>High</td>
</tr>
<tr>
<td>Greater Than 8.0</td>
<td>Very High</td>
</tr>
</tbody>
</table>

Stabilometer R-Value Testing

For evaluation of the Hveem R-value design method, 25 road sections were selected to cover the full range of distress severity, and samples from
each layer was tested to determine the Stabilometer R-values in accord-
ance with ASTM Test Method D-2844.

PERFORMANCE RELATIONSHIPS

Initial analyses to relate performance levels to soil properties at
various depths were made using a computerized multiple regression pro-
cedure developed by Kansas University as part of the Statistical Package
for Social Sciences (SPSS) program. The major dependent variables used
to describe the performance of each section were the percentage of
alligator cracking, the maximum deflection level and the average rut
depth. Although all possible soil property, layer thickness and environmental
parameters were included in stepwise multiple regression analyses, no
reasonable correlations were obtained between performance and any combination
of variables, in spite of the large number of sections (120) and the
large number of independent variables considered on each section (175).
Each new variable brought into the analysis often significantly affected
the regression coefficients of all other variables. As a result, this
approach was abandoned in favor of grouping pavement study sections on
the basis of similar levels of performance, and comparing average performance
levels of these groups with average material properties of each layer.
The soil properties at selected depths beneath the pavement of 3, 9, 18,
30, 42 and 54 inches were used in this analysis to simplify the comparisons
between different sections with different layer thicknesses.

Comparisons between the three primary performance factors, namely fatigue
or "alligator" cracking, rut depths and peak spring Benkleman Beam
deflection levels indicated very good correlations between these variables
(Figures 3 and 4). For this reason, generalized comparisons between
materials properties and performance could be made on the basis of
relationships with maximum spring deflection level or with alligator
cracking expressed as a percentage of the total length of the wheel paths.
Unless otherwise noted, all references to deflection levels made herein
will refer to the maximum or "peak" springtime Benkleman Beam deflection,
calculated as the average of eleven tests on each section plus twice the
standard deviation of those tests.

Performance Versus -#200 Sieve and -.02mm Contents

Fines (-#200 sieve) and -.02mm size fractions are generally used as the
primary indicators of frost susceptibility, with fines content specifica-
tions most often used to control frost susceptibility in pavement layers,
due to the ease of testing. To evaluate the effects of fines contents
on deflection levels and alligator cracking, study sections were grouped
into six deflection level ranges and into four alligator cracking ranges.
Average fines for each group were then determined for the six depths
mentioned above and plots prepared as shown by Figures 5 and 6. Best
fit lines on these plots were then used to determine the average fines
contents at each depth corresponding to the selected deflection levels
of .020, .030, and .040 and .050 inches, and to alligator cracking
levels of 0, 10, 25 and 50%. These values were then used to prepare
Figures 7 and 8, summarizing the observed general relationships between
deflection and alligator cracking levels and -#200 contents.
As a second indicator of the effects of increasing fines contents on reduced roadway strength during the thaw-weakening period, five roadway sections were selected as having progressively increasing fines contents in the base course layer, with cleaner soils underlying the base to at least ½ feet. In these cases, the base course represents the most frost susceptible layer in the pavement system. All sections of this series showed seasonal deflection histories which had very rapid thaw-weakening and rapid strength recovery, followed by low summertime deflection levels. Figure 9 shows the peak spring deflection levels for these sections plotted against the -#200 contents of the base course, and demonstrates the detrimental effects of increased fines contents on pavement structural performance.

Correlations between performance factors and -0.02mm contents were similar to, but not quite as strong as those with the -#200 contents, in spite of the fact that the -0.02mm particle size is a significantly better predictor of frost heave rates under laboratory conditions (7). The ratio of % -#200 to % - #40 particle sizes, termed the dust ratio, also had a significant relationship with performance. No other particle size or shape factors were observed to significantly affect performance.

The average soil properties associated with those sections having no alligator cracking were very similar to those associated with maximum deflection levels of 0.020 inches and best performance. The percentages finer than #200 and .02mm and dust ratio (P200/P40) values at various depths which were associated with these performance levels are shown by Table 2.
Table 2. Average Soil Properties for Best Performance Sections

<table>
<thead>
<tr>
<th>DEPTH (INCHES)</th>
<th>-#200 (%)</th>
<th>-.02mm (%)</th>
<th>DUST RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>6</td>
<td>3</td>
<td>.28</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>3</td>
<td>.30</td>
</tr>
<tr>
<td>12</td>
<td>7</td>
<td>3</td>
<td>.32</td>
</tr>
<tr>
<td>24</td>
<td>9</td>
<td>6</td>
<td>.35</td>
</tr>
<tr>
<td>48</td>
<td>12</td>
<td>6</td>
<td>.40</td>
</tr>
</tbody>
</table>

For pavements having poor performance as indicated by 50% combined average wheelpath alligator cracking or 0.060 inch average maximum deflection levels, the related average P200, P.02 and P200/P40 values were shown by Table 3.

Table 3. Average Soil Properties for Poor Performance Sections

<table>
<thead>
<tr>
<th>DEPTH (INCHES)</th>
<th>-#200 (%)</th>
<th>-.02mm (%)</th>
<th>DUST RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>11</td>
<td>7</td>
<td>.42</td>
</tr>
<tr>
<td>6</td>
<td>11</td>
<td>7</td>
<td>.44</td>
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<td>12</td>
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<td>7</td>
<td>.46</td>
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<tr>
<td>24</td>
<td>15</td>
<td>8</td>
<td>.52</td>
</tr>
<tr>
<td>48</td>
<td>19</td>
<td>8</td>
<td>.63</td>
</tr>
</tbody>
</table>
From these observations, the detrimental effects of increasing fines and 
and -0.02mm contents on performance is obvious; however, the significance 
of soil properties at the greater depths listed above could not be de-
termined from this study since this was not a controlled experiment 
where single layer properties could be varied while holding all other 
factors constant. Inspection of the soils data indicated that due to 
geological factors controlling soil distribution, high fines contents at 
depths of two to four feet related to a higher probability that base and 
subbase layers would also be high in fines.

Performance Versus Soil FSV Classifications

After first grouping the soils at the six depths mentioned above by 
similar FSV values, the average maximum deflection values for each FSV 
group and depth were calculated and plotted in Figure 10. The following 
observations were made from inspection of these relationships:

1. Non-frost-susceptible (F = 0) soils showed slight performance 
advantages over higher frost susceptibility classes.

2. No significant performance differences are apparent between 
F-1 and F-2 classes. This may be due primarily to the organiza-
tion of the Frost Class Chart (Figure 1), where, for instance, 
early identical gravels with a content of 4% finer than the 
-0.02mm size may be assigned to an F-1 class (gravel) or to an 
F-2 class (sandy gravel).

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3. FSV classes F-3 and F-4 at depths of up to 42 inches relate to significantly higher deflection levels than the lower FSV classes. Performance differences between the F-3 and F-4 classes appear insignificant.

4. Overall, the FSV classification system appears only weakly related to pavement deflection levels.

Similar plots between FSV groups and alligator cracking percentages (Figure 11) show even more erratic relationships. In this plot, NFS soil layers show major benefits in reduced alligator cracking to a depth of approximately 3 feet, while differences in alligator cracking between F-1, 2, 3 and 4 classes are erratic and appear non-significant. In contrast to the intent of the classification system that higher values represent the worst frost susceptibility, this plot could be used to indicate that F-2 soils may represent the worst classification.

The effect of FSV class on rut depth (Figure 12) is similar to that observed for alligator cracking except that NFS soils do not exhibit such a decisive performance advantage in the upper 18 inches.

In general, it was not demonstrated that the existence of a particular FSV class at a given depth can serve as a basis for confident performance prediction because all layers contribute to performance. NFS material is, however, most strongly indicated for use in the base and subbase layers. In view of the favorable performance expectations attached to low deflection levels, this study indicates the use of NFS materials to be of benefit even at depths to 30 inches.
A second approach to evaluating the frost susceptibility classification system involved the study of the frost overlay deficiencies of the actual study section pavement structures. Under Alaska's present pavement structure design procedure (1), the minimum overlays of gravels of better frost classification over subgrades of various FSV classes are determined from Figure 13. The Traffic Index (TI) is determined from the number of equivalent 18 kip axle loading by Figure 14.

Additional frost overlay (FSV) thickness requirements were derived by examining the design overlay thickness required by Figure 13 for each soil layer to a maximum depth of 54 inches. The actual thickness of the overlying layers was subtracted from the design requirement for the layer being considered and the remainder, if any, was termed the frost overlay deficit for that layer. The largest net deficit for all layers in a given pavement structure was then defined as the additional FSV overlay requirement. Of all 120 road sections studied, only eight were found to require no additional overlay according to the reduced subgrade strength design method. By far, the most common overlay deficit was in the range of 10 to 15 inches and was required over an F-1 or F-2 soil type. The practice observed prior to 1977 of allowing fines contents in base and subbase materials of up to 10 or 12% accounts for many of the indicated overlay deficiencies.

Following the determinations of the additional FSV overlay requirements, the relationships between this factor and the pavement distress factors
were investigated by grouping data into grouped-data points as shown by Figure 15, demonstrating significant correlations between performance and FSV overlay deficiencies.

The Mays Ride Meter data plot versus the additional overlay requirement is especially significant because ride meter roughness levels could not be correlated directly to the fines content or frost class associated with any individual soil layer. The plot in Figure 15 of EAL versus additional overlay requirement verifies the absence of spurious correlations which may have resulted from traffic or age related trends.

In summary, analysis of the FSV design method indicated general correlations between performance and overlay requirements. The presently used FSV overlay design chart (Figure 13) may be overly conservative by 15 to 18 inches of overlay for average conditions, since performance did not significantly deteriorate until pavement structures became deficient by more than this amount. However, some conservatism is necessary to allow for worst conditions.

**Heave Rates Versus FSV Classifications and Fines Contents**

Relationships between FSV and laboratory heave rates for 41 tests on samples in the NFS, F-1 and F-2 classes are shown by Figure 16. This plot shows direct increases in the average heave rates with increased FSV classification number, but the range of heave rates also increases with class, making the FSV class system a relatively poor predictor of laboratory heave rate.
The relationship of soil fines contents to laboratory heave rate was also investigated. Predictive equations derived using least squares linear regression analysis are as follows:

\[
\text{Heave Rate } \text{mm/day} = (0.36) (\% - 200) + 0.38
\]

\[
\text{Heave Rate } \text{mm/day} = (1.02) (\% - 0.02\text{mm}) - 1.01
\]

The coefficient of determination or \( R^2 \) values were 0.86 for both equations. These equations provide significant correlations between fines and heave rate and indicate the generalized rate of change of heave rate as fines increase. However, no combination of soil gradation factors could be found which predicted the heave rates with reasonable accuracy.

Previous heave test programs performed by the Alaska Department of Transportation and Public Facilities in relatively clean gravels used for pavement system subbase and base course layers have demonstrated relatively uniform increases in heave rate with increases in percentages of particles smaller than .075mm (−#200 sieve) and .02mm. Figure 17 shows the changes in heave rate which occurred when a base course aggregate having identical gradations in the +#40 sieve portions was heave tested with five different −#200 and −.02mm contents. Test programs on aggregates from several different construction projects have repeated this comparison between heave rates and varying fines contents.

All heave test runs using varying fines contents with the same gravel fraction have shown direct relationships between increases in −.02mm
and -#200 sieve contents and heave rate, with some significant heave occurring at fines contents higher than 1 to 2%. Data show that the - .02mm particle size percentage is a better indicator of heave rate for aggregates from different sources than is the - .075mm (-#200) particle size. However, neither size fraction can be used to accurately predict heave rates.

Performance Versus Heave Rate

Heave test samples analyzed in this test program represented base and subbase materials from 27 pavement study sections ranging from good to poor in performance. Figure 18A depicts by quartile plots the range of heave rates measured on samples from various depths between 0 and 30 inches. The position of the median lines indicate that about half of the sampled soils at each depth had heave rates of less than 3mm per day.

In preparing Figure 18, the 27 study sections having heave test data available were grouped into three categories of different degrees of alligator cracking, three of rut depth and four of deflection levels. For each category, the average related sample heave rates at depths of 3, 9, 18 and 30 inches were determined and plotted on Figures 18B, C and D, respectively.

An inspection of each plot indicates only a rough relationship of lower heave rates to lower distress levels. For all three distress types, heave rates at 9 and 18 inches appear to be the most consistent indicators of performance. It is interesting to note that low alligator
cracking, low deflection levels (<0.025") and minimal rut depths (<.1") were associated with heave rates of less than 2 to 3mm/day, while worst case levels were erratically predicted by heave rates greater than 3 to 4mm/day. By the heave rate classification system described in Table 1, heave rate classifications of "negligible" to "low" related to good performance, while the "medium" to "high" classes did not perform well.

Specifications Based on Frost Heave Testing

Earlier (unpublished) Alaska Department of Transportation and Public Facilities studies of certain base and subbase layers which had resulted in very rapid fatigue failures of pavements; have shown that heave rates in excess of 3mm per day, resulting from -.02mm and #200 sieve contents of greater than 8% and 13%, respectively, were totally unacceptable under wet coastal climatic conditions. Heave rates of 2mm per day or less under the testing procedure previously described appeared to result in acceptable pavement layer performance. On the basis of these early studies, maximum #200 sieve contents of base and subbase layers are currently specified at 0 to 6% in an attempt to prevent frost action from causing excessive thaw-weakening of the pavement system layers. With normal aggregate sources, this assures that -.02mm particle contents will not exceed approximately 4%.

Laboratory heave rate criteria have not been incorporated into any form of pavement structural design method or project specification to this time. However, heave rate differences between different aggregates would appear to relate more directly to structural performance during
the springtime thaw-weakening period than the simple FCV classification system. Higher laboratory heave rates result from increased moisture gain upon freezing, and would be expected to result in increased and prolonged strength losses upon thawing. Further and more intensive field studies are necessary to provide a basis for pavement structure design based on frost heave testing.

Performance Versus R-Value Test Data

Attempts were made to relate observed pavement performance to soil sample R-values, based on data collected from 25 study section locations covering a wide range of distress severity.

Figure 19 indicates the average R-values at selected depths associated with various levels of distress. These data were prepared and analyzed in the same manner as described for Figure 18. A decrease in minimum observed R-values with depth is obvious for each performance factor. Interestingly, however, poor performance appears to be associated with the highest average R-values at each depth location noted. No systematic relationship is indicated between performance and the R-values associated with any depth.

An analytical approach was then taken more closely paralleling the actual design usage of the R-value test. Each of the 25 sections was examined to see if the as-built construction satisfied the overall design overlay requirement. Overlay deficits in terms of additional
asphalt pavement thickness ranged from 0" to 3.5" and are plotted as group average data points in Figure 20. Equivalent additional gravel base thickness requirements would be approximately twice these values, based on a gravel equivalent factor of 2.0 for asphalt concrete pavements. No definable relationships are shown which correlate overlay deficit with any of the three principal performance variables of rut depth, alligator cracking or deflection.

The absence of any relationships between R-value test results and pavement performance in Alaska is considered to be the effect of overriding frost-susceptibility considerations controlling the design procedure. As indicated by Figure 21, progressively increasing the fines content of a base or subbase aggregate will not result in any decline in the R-values until the fines content exceeds 12 to 14%. However, at fines contents above 6 to 10%, base and subbase aggregates may become extremely susceptible to frost heave and thaw-weakening, in spite of high R-values.

SUMMARY

Analyses were made to determine the critical factors in good pavement performance, based on 120 roadway sections on which the pavement structures were measured, sampled, tested and classified for frost susceptibility. This study was confined to flexible pavements between 1 and 4 inches in thickness, with unbound granular bases. It must be realized that this was not a controlled experiment; i.e., no one variable could be altered while holding all others constant. For this reason, the effects of a single factor could not be absolutely determined under specific conditions.
The primary factors omitted from this study were the relative densities and elastic properties of the pavement structure layers, and quantifications of ground water availability to support frost action. In spite of multiple regression analyses of 175 material, dimensional and environmental factors pertinent to performance of 120 study sections, no empirical equation could be derived to predict the relative performance levels of different pavement structures with reasonable accuracy.

CONCLUSIONS

1. From regression analyses of the material and environmental factors commonly related to good performance of flexible pavement structures in Alaska, the most important factors in good performance were low percentages of -#200 sieve (fines) and -.02mm particles in the base and subbase layers.

2. Best performance is related to maximum base and subbase fines contents of 6% and to maximum -.02 contents of 3%. Poor performance predominates when base and subbase fines reach 11%, and when -.02mm contents reach 7% in these layers.

3. Soil Frost Susceptibility ratings of the pavement structural layers by the Corps of Engineers (FSV) classification system are only weakly related to pavement performance. Performance differences between the F-1 and F-2 classes were found to be nearly insignificant, and differences between F-3 and F-4 classes were likewise small. Soil fines percentages therefore should be considered for direct use as a design parameter for frost areas, instead of the FSV classification system.

4. The Hveem Stabilometer R-value test is not a useful indicator of relative pavement structure performance for frost areas because it
does not indicate differences between soils of low and high frost susceptibility. Modifications to the moisture conditioning phase of this test, such as the addition of a frost heave stage, should be considered to make the R-value test more representative of structural performance in frost areas.

5. Laboratory heave test results indicated the best pavement performance to be related to heave rates in base and subbase layers of less than 3 mm per day, as determined by freezing samples in segmented ring molds at approximately \( \frac{1}{4} \) inch per day under testing procedures described herein.

ACKNOWLEDGEMENTS

The authors wish to express appreciation to the many people whose efforts contributed to this paper, and in particular to Materials Engineers Dan Herman, Jerry Roach, Paul Misterek and Ray Miller for assistance in sampling, soil analysis and deflection testing operations. This research work was accomplished in cooperation with the Federal Highway Administration, U.S. Department of Transportation. The contents of this paper reflect the views of the authors and not necessarily those of the State of Alaska or the Federal Highway Administration.
REFERENCES


ALASKA DEPT. OF TRANSPORTATION & PUBLIC FACILITIES

FROST CLASS CHART

LESS THAN 50% - #200
COARSE GRAINED SOIL

TOTAL SAMPLE
-3"

MORE THAN 50% - #200
FINE GRAINED SOIL

%3" TO +#4 IS LARGER

GRAVEL

GRavelLY SOIL

% #4 TO +#200 IS LARGER

SAND

<table>
<thead>
<tr>
<th>COARSE</th>
<th>MEDIUM</th>
<th>FINE</th>
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<tbody>
<tr>
<td>4-10</td>
<td>10-40</td>
<td>40-200</td>
</tr>
<tr>
<td>IS LARGER</td>
<td>IS LARGER</td>
<td>IS LARGER</td>
</tr>
</tbody>
</table>

%0.02mm FSV

0-3 NFS
4-10 F1
10-20 F2
OVER 20 F3

SILT

FSV
F4

CLAY

P.I. FSV
OVER 12 F3
UNDER 12 F4

VERY FINE SILTY SAND MORE THAN
12% - #200

%0.02mm FSV

UNDER 15 F3
OVER 15 F4
INTERIOR DIAGRAM OF HEAVE TEST CABINET

FIGURE 2
RELATIONSHIPS BETWEEN DEFLECTION AND ALLIGATORING

○ Ave. % Alligatoring Outer Wheel Path (A₀)
☐ Ave. % Alligatoring Inner + Outer Wheel Paths (Aₛ)

\[
A₀ = 0.009 (δ^{1.96}); \quad R^2 = 0.99
\]

\[
Aₛ = 0.032 (δ^{1.73}); \quad R^2 = 0.97
\]
RELATIONSHIPS BETWEEN RUT DEPTH AND ALLIGATOR CRACKING

\[
R \cdot A_s \left/ \left( 27.01 + 2.55 \ A_s \right) \right. \\
R^2 = 0.96
\]

Figure 4

AVERAGE RUT DEPTH (INCHES)

% ALLIGATOR CRACKING
(inner + outer wheel paths)
RELATIONSHIPS BETWEEN CUMULATIVE % PASSING #200 SIEVE AND AVERAGE DEFLECTION + 2 STD. DEV. \((\bar{e}_a)\) AT VARIOUS DEPTHS

DEPTH of SOIL (INCHES)

CUMULATIVE % PASSING No. 200 SIEVE

\((\bar{e}_a) = 0.050\)

\((\bar{e}_a) = 0.030\)

\((\bar{e}_a) = 0.020\)

\((\bar{e}_a) = 0.040\)

FIGURE 7
VARIATION in AVERAGE ALLOWABLE FINES WITH INCREASING DEPTH and ALLIGATOR CRACKING

Figure 8

Depth of Soil (inches)

Cumulative % Passing No. 200

6  8  10  12  14  16  18  20  21

60% Alligator Cracking; Average E.A.I. = 163,000
50% Average Pavement Age = 11 years; Average E.A.I. = 140,324
40% 25%
MAXIMUM DEFLECTIONS
BY BENKLEMAN BEAM
VERSUS
FINES CONTENTS OF BASE

[For Roadways Having Lower
Fines Contents in Subbase
and Subgrade]

% - # 200 SIEVE IN BASE COURSE

FIGURE 9
Figure 10
FIGURE 11
FIGURE 12
RELATIONSHIP BETWEEN E.A.L. & T.I.

\[ T.I. = 9.0 \left( \frac{E.A.L_{18k}}{10^6} \right)^{0.119} \]

FIGURE 14
ADDITIONAL OVERLAY REQUIREMENT VERSUS PERFORMANCE

FIGURE 15
QUARTILE PLOT FOR 48-72 HR. HEAVE RATE (cm/day)

Data from 41 samples of Alaskan Base Course & Subbase Materials obtained from statewide locations.

Figure 16
SAMPLE HEAVE VS. ELAPSED TIME
SAMPLES IN SEGMENTED RING MOLDS

ELAPSED TIME

(HOURS)

0 10 20 30 40 50 60 70 80 90

HEAVE (INCHES)

0 0.100 0.200 0.300 0.400 0.500 0.600

Figure 17

15% - 200
(Sample E)

12.5% - 200
(Sample D)

10% - 200
(Sample C)

6.5% - 200
(Sample B)

3% - 200
(Sample A)
ADDITIONAL ASPHALT CONCRETE OVERLAY REQUIREMENT FROM R-VALUE DESIGN METHOD

Figure 20

- % Alligator Cracking vs. Additional Asphalt Overlay (inches)
- Rut Depth (inches)
- Deflection + 2 Std. Dev. (inches) vs. Additional Asphalt Overlay (inches)
FIGURE NO. 21
R-VALUE VERSUS % PASSING # 200
FOR ALL GRAVEL TESTS - 1976