ASPHALT CONCRETE PROPERTIES

AND

PERFORMANCE IN ALASKA

FINAL REPORT

by

Robert L. McHattie, P.E., Research Engineer

July 1981

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
DIVISION OF PLANNING AND PROGRAMMING
RESEARCH SECTION
2301 Peger Road
Fairbanks, Alaska 99701

in cooperation with

U.S. Department of Transportation
Federal Highway Administration

Technical Report Documentation Page

1. Report No. FHWA-AK-RD-82-2	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle "Asphalt Concrete Properties and Performance in Alaska"		5. Report Date July 1981
		6. Performing Organization Code
7. Author(s) Robert L. McHattie		8. Performing Organization Report No.
9. Performing Organization Name and Address Alaska DOTPF Research Section 2301 Peger Road Fairbanks, AK 99701		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. HPR F16162
12. Sponsoring Agency Name and Address Alaska Department of Transportation and PF Pouch Z Juneau, Alaska 99811		13. Type of Report and Period Covered Final Report
		14. Sponsoring Agency Code

15. Supplementary Notes
Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration

16. Abstract

This report examines asphalt pavement properties of 117 older highway sections within the State of Alaska. Principal research objectives included: 1) documentation of commonly measured physical properties of the asphalt concrete cores and extracted asphalt cement and 2) characterization of materials properties which provided the best long term pavement performance. Insufficient records existed to evaluate pavement performance on the basis of original properties or aging histories of the asphalt concrete. However, indications that aging progresses rapidly and generally attenuates after 6-8 years justified analyses utilizing aged-materials properties. All correlations and performance trends were therefore derived using aged-properties.

Results indicate that best long-term performance is obtained from asphaltic materials which retain softness and low tensile strength throughout the pavement's service life. Aged materials specifications are suggested in the report text which have provided optimum performance. It was concluded that asphalt cement should be subjected to an extended laboratory aging process prior to specification testing which would simulate 4-8 years of field weathering.

17. Key Words pavement structures, asphalt concrete, climatic factors, temperature susceptibility, fatigue cracking, thermal cracking, rut depth, indirect tensile test, pavement serviceability.	18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	208	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER I

INTRODUCTORY

INTRODUCTION

The design and construction of paved roads in Alaska is, for the most part, a post-World War II development. A program was initiated in 1948 by the Alaska Road Commission to upgrade the State's primary highway network, the first stage of which included paving of approximately 1000 miles of existing roadway. Research investigations of this era (1948-1950) were conducted by the Bureau of Public Roads (BPR) and oriented toward providing sufficient structural design strength to enable the roadway to withstand reasonable traffic use even during the critical spring thaw period (1). The intent of this early research effort was to provide an acceptable minimum granular soil thickness which would withstand the repeated truck loadings of more than one year's spring thaw. Recent investigations relating soil properties to pavement performance in Alaska have determined that the "quality" (desirability) of unbonded granular material is associated with some measure of frost susceptibility potential (2,3).

However, paved road performance depends not only on the quality of soils but also on the mechanical durability of the asphalt concrete layer. This report is intended then, to complement the study referred to above and published as "Pavement Structural Evaluation of Alaskan Highways," which primarily examined the performance aspects of unbound granular soil layers (2). Pavement sections evaluated during the course of this project were essentially the same as those utilized in the previous study and most of the pavement core sampling was in fact accomplished on the earlier project's funding.

The following investigation represents the first attempt, on a statewide scale, to relate asphalt concrete mix properties to existing roadway quality. A need for this investigation is underscored by traditionally high costs of construction materials and labor within Alaska. Although only about 2200 miles of paved highway presently exist within the state, the combined first-cost of construction, materials and maintenance are formidably equivalent to a much more extensive system. The scope of this report includes not only correlations to define best performing asphalt concrete materials but also deals with the variability in aged materials properties with location on the road as well as the asphalt aging process itself.

Objectives:

The primary objective of this study is to determine by direct and indirect correlative techniques, the probable cause-effect relationships which control the performance of a flexible pavement structure. The following questions served as a framework within which the performance evaluation procedure, materials sampling techniques and pavement section locations were chosen.

1) Why are the observed performances of apparently similar roadways so variable?

2) Which physical features of the asphalt concrete pavement layer appear to correspond with specific performance indicators such as cracking, patching and rutting?

3) What are the apparent effects of Alaskan climatic extremes on the performance qualities and aging characteristics of asphalt cement materials?

4) How do literature recommendations concerning ideal asphalt mix properties relate to observations from Alaskan field data?

5) Can examination of the relationships between materials properties and performance provide the basis for improved asphalt mix specifications?

Early test road investigations such as those conducted in 1950 by the Western Association of State Highway Officials (WASHO) and in 1958 to 1960 by the American Association of State Highway Officials (AASHO) provided a sound basis for evaluating the performance of in-service pavements (4,5,6,7). However, test roadways loaded and evaluated over a period of two or three years cannot duplicate the long term weathering accumulated by older in-service roadways. This project utilizes pavement rating techniques developed during the AASHO road test and later satellite studies to characterize pavements on the basis of specific recognized performance factors, specifically: cracking, patching and rutting.

Research involving in-service pavements and their constituent materials have been fairly rare in the highway research literature because they are expensive and require considerable project time and coordination to acquire the necessary data. Moreover, the large number of roadway sections used to form generalizations on an entire statewide system requires extensive and long term commitment of sample storage space and laboratory testing facilities. Direct benefits realized from this type of study, however, include a better pavement design and specification predicated on a more complete understanding of how available materials have actually responded to traffic and climate. An excellent example of an idealized pavement evaluation program is outlined by Yoder, et al (8).

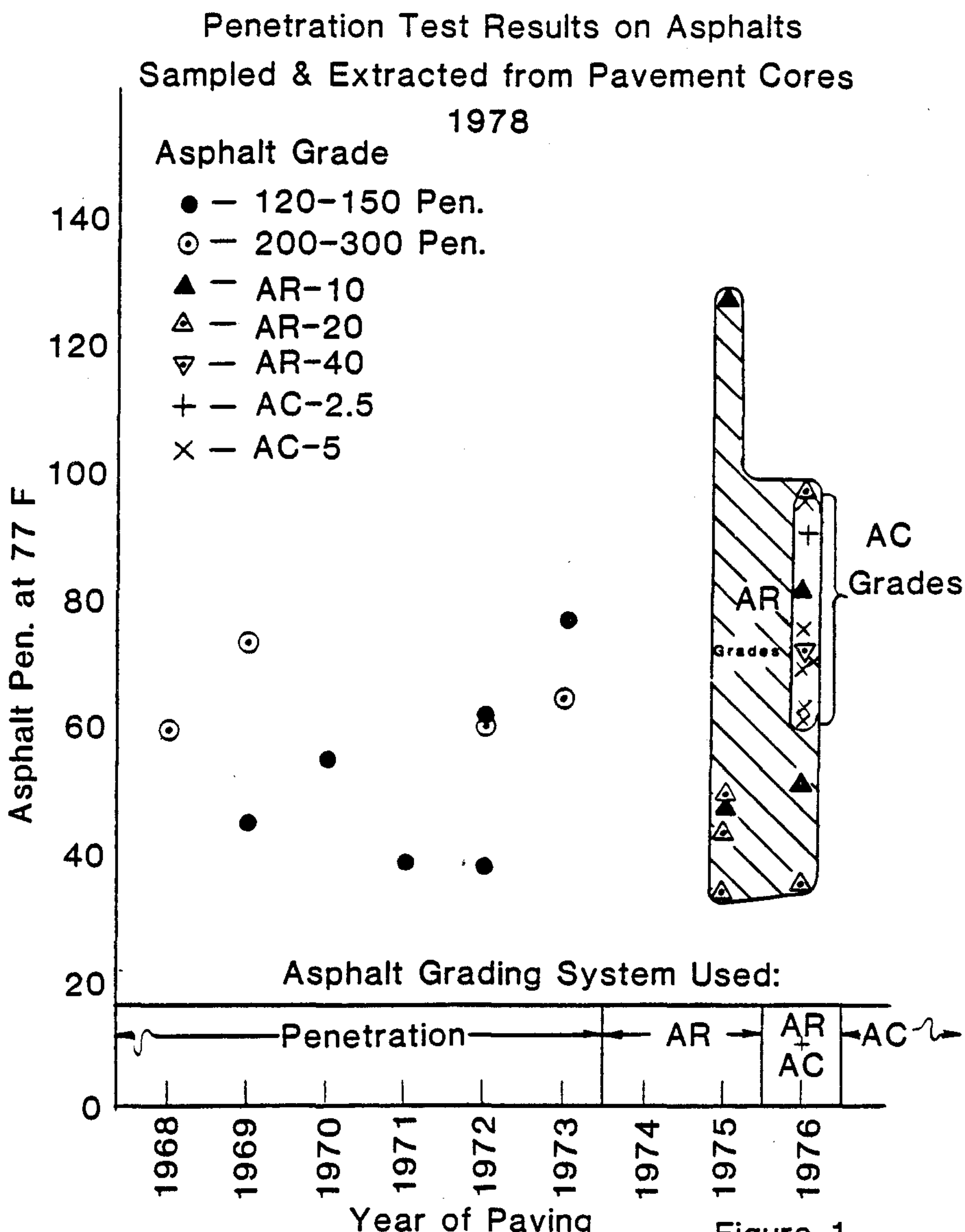
Historic Use of Paving Asphalts in Alaska:

The Pacific Coast Conference of User-Producers has been a primary voice behind the selection and application of paving asphalt specifications in the state of Alaska since the 1950s. Penetration graded asphalts were used within the state during the earliest days of paving. It was fairly standard procedure to use 200 -300 penetration grade material in the Interior as well as the more northerly portions of the South Central Region of Alaska, while 120-150 penetration was used in most other areas of the State (see map A). By January 1974, the entire west coast including Alaska had changed to AR (asphalt residue) grading, which characterized asphaltic materials on the basis of simulated "aged" properties, subsequent to the rolling thin film oven (RTFO) aging test. The AR10 and AR20 grade asphalts were used most extensively during this period which lasted for only about 2 years, although some AR40 based pavements were laid in the warmer areas of Southeastern Alaska. The AR graded asphalts unfortunately came into vogue at a bad time for the oil industry. The October 1973 Arab-Israeli war and consequent oil embargo necessitated fairly extensive modification of the then-existing base stock crude oil supply. Whether through basic chemistry changes in the asphalts, due to changing crude oil stocks, or simply from substitution of the new asphalt type, the AR graded asphalts fell to a position of low esteem in Alaska. Catch phrases developed during

1974-1975 within the then Department of Highways to indicate the thought that the asphalt had "lost its sticky" or "looked dead." General dissatisfaction with the AR system prompted a switch in 1976 to AC (asphalt cement) grading, a method of once again classifying viscosity on the basis of original, i.e., non-aged properties. This decision came about rapidly as AR grading materials were still being officially required in May 19th but by June 4, 1976, the specifications had changed to require AC designated asphalts. It is interesting to note that one of the State's major sources, Chevron, had consistantly supplied crude from the Cook Inlet field between 1968 and 1978 and was therefore unaffected by world affairs during the tightening of asphalt supplies. Since 1976, the practice has been to use AC 2.5 in the Interior Region except where very heavy traffic loads are anticipated. It is also used in the South Central Region except where heavy traffic is anticipated. AC 5 is generally used elsewhere within the state.

Figure 1 is extracted from an Alaska DOTPF research report (presently awaiting publication) by John Henry titled "Pavement Performance Versus Asphalt Gradings." It shows the penetrations at 77°F on asphalts extracted from sample cores in 1978 for the various specification materials used in construction projects between 1968 and 1976.

Because of the possibility that recent variations in basic crude oil chemistry may have affected the aging properties of some asphalts, study sections were chosen almost entirely from pre-1974 construction. The asphalt materials being dealt with in this investigation are, therefore, the older penetration grade types. Also, this selection process allowed the investigation of pavements, many of which were old enough to have reached their originally intended service life expectancy.



Penetration Test Results on Asphalts
Sampled & Extracted from Pavement Cores
1978
Asphalt Grade
● — 120-150 Pen.
⊙ — 200-300 Pen.
▲ — AR-10
△ — AR-20
▽ — AR-40
+ — AC-2.5
× — AC-5
Asphalt Pen. at 77 F
140
120
100
80
60
40
20
0
AR
Grades
AC
Grades
Asphalt Grading System Used:
Penetration
AR
AR
+
AC
AC
1968
1969
1970
1971
1972
1973
1974
1975
1976
Year of Paving

Figure 1

CHAPTER II

DATA ACQUISITION AND TESTING METHODS

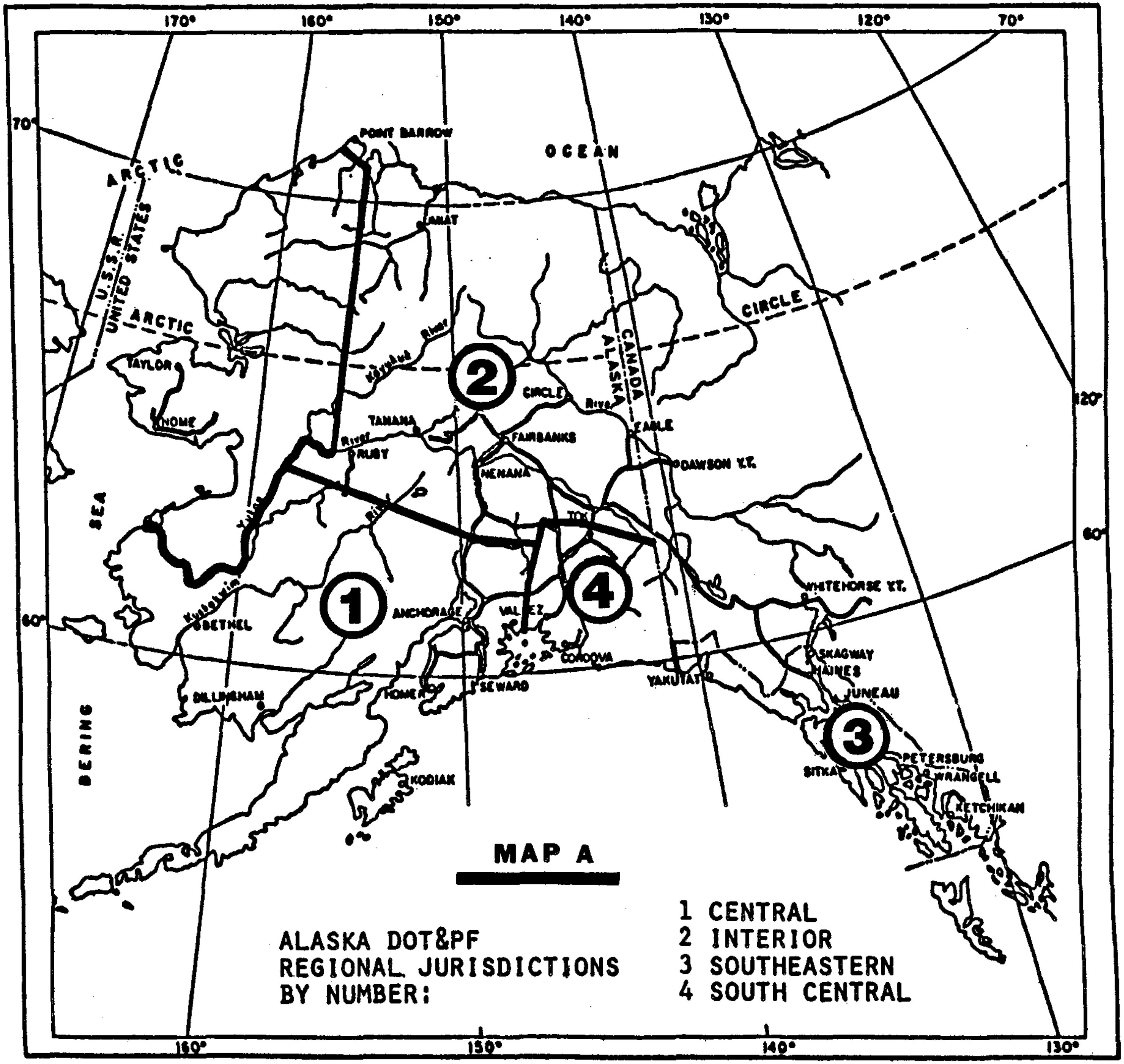
Field Sampling:

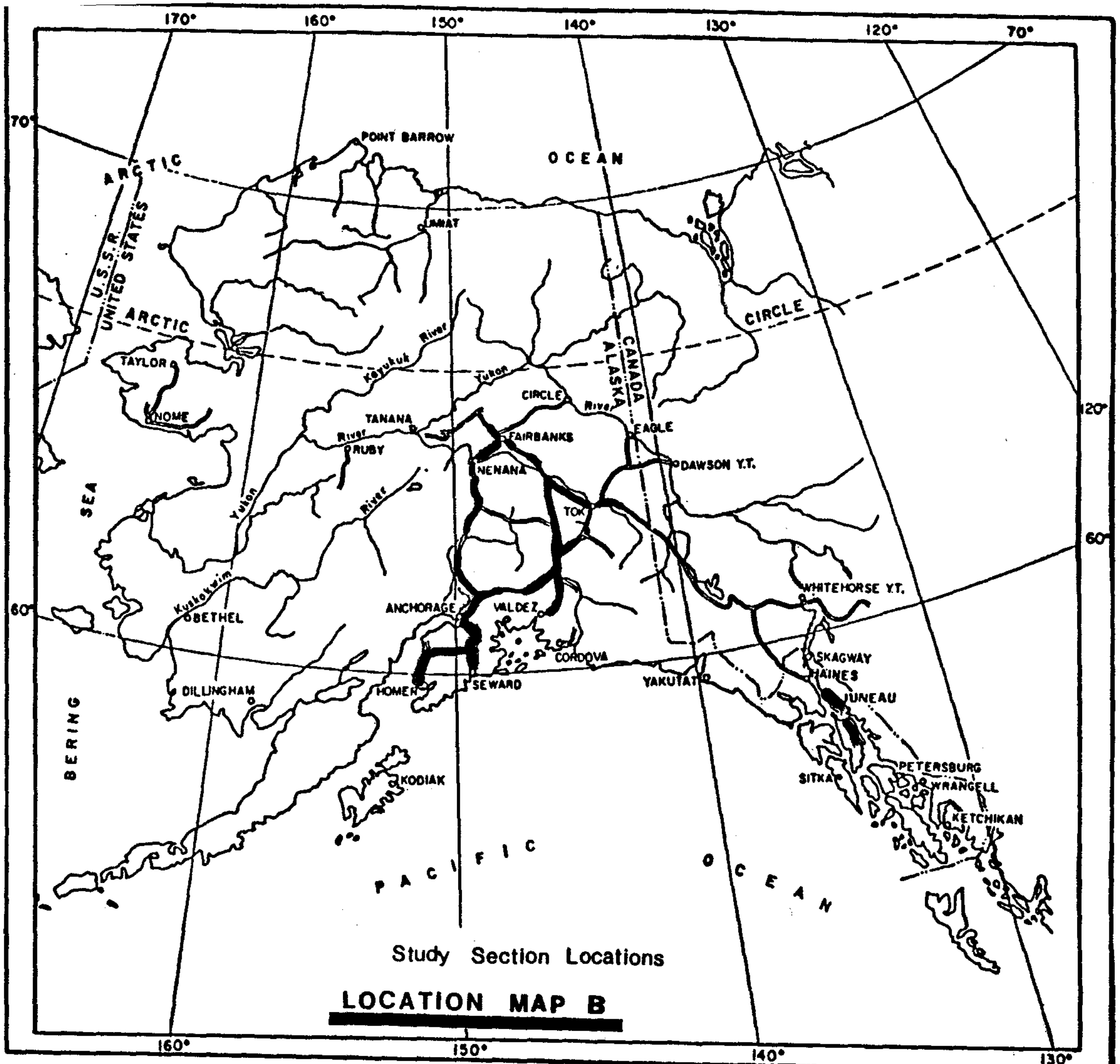
In order to provide a significant pavement sampling which represented the most important ranges of weather, traffic and construction types, 120 roadway sections were selected for investigation. The general requirements used in the selection of study sections were as follows:

1. Construction characteristics of the section should be reasonably uniform along its total length in both cross section and material type.
2. Low fills or cut sections were the preferred cross section type.
3. The environmental setting should remain uniform throughout a given section. This would include:
   (a) traffic loading
   (b) sunlight and wind exposure
   (c) drainage quality

Uniformity of construction and environment is required to insure that a relatively few sample locations would adequately represent the entire study section. Low fills and cut sections usually allowed the maximum soil sampling depth (54") to penetrate into the foundation materials. This minimized the unknown effects of embankment height and unsampled soil layers. Using these criteria, sections were chosen from within the four major Alaskan Highway regions (map A). The distribution and description of the sections are listed in Appendix A.

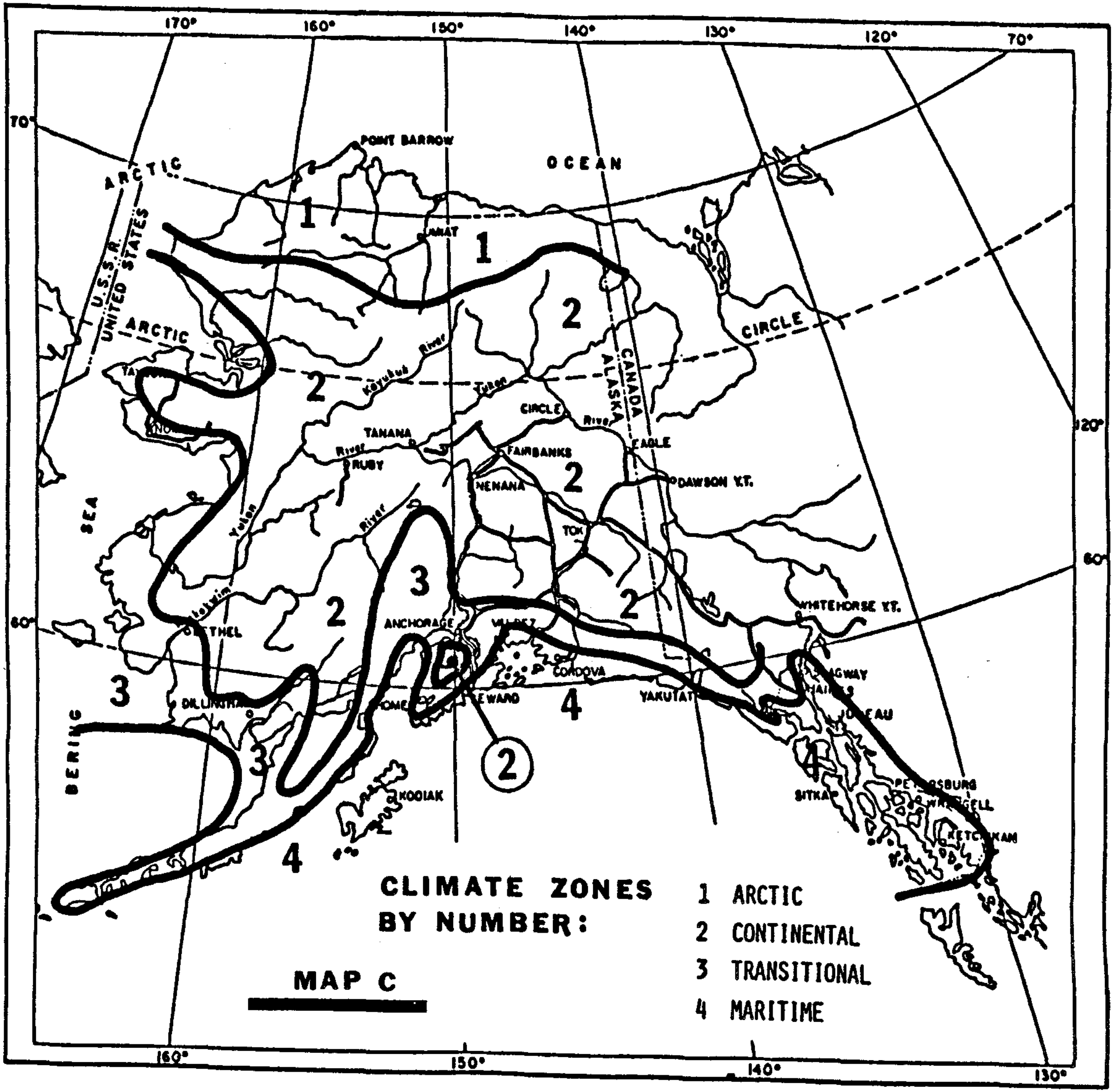
Of the 120 pavement study sections initially chosen for general performance evaluation, 117 were utilized by the author in this


MAP A
ALASKA DOT&PF
REGIONAL JURISDICTIONS
BY NUMBER:
1 CENTRAL
2 INTERIOR
3 SOUTHEASTERN
4 SOUTH CENTRAL
POINT BARROW
OCEAN
ARCTIC
ARCTIC CIRCLE
U.S.S.R.
UNITED STATES
CANADA
ALASKA
BERING SEA
TAYLOR
NOME
TANANA
RUBY
CIRCLE
FAIRBANKS
EAGLE
DAWSON Y.T.
NENANA
TOK
WHITEHORSE Y.T.
ANCHORAGE
VALDEZ
CORDOVA
BETHEL
DILLINGHAM
HOMER
SEWARD
YAKUTAT
SKAGWAY
HAINES
JUNEAU
SITKA
PETERSBURG
WRANGELL
KETCHIKAN
KODIAK



Study Section Locations

LOCATION MAP B


CLIMATE ZONES
BY NUMBER:
1 ARCTIC
2 CONTINENTAL
3 TRANSITIONAL
4 MARITIME
MAP C
ARCTIC
OCEAN
BERING
SEA
U.S.S.R.
UNITED STATES
CANADA
ALASKA
ARCTIC CIRCLE
POINT BARROW
CIRCLE
TANANA
RUBY
FAIRBANKS
NENANA
EAGLE
DAWSON Y.T.
TOK
BETHEL
ANCHORAGE
VALDEZ
CORDOVA
YAKUTAT
WHITEHORSE Y.T.
KODIAK
SITKA
PETERSBURG
KETCHIKAN
Yukon
River
170°
160°
150°
140°
130°
120°
70°
60°

investigation of asphalt materials related performance. Of the 117 sections, 47 were located in the Interior Region, 27 in the Southcentral Region, 8 in the Southeast Region and 35 in the Central Region. Climatic variability was considered to have been well sampled because all regions except the Southeastern Region are contiguous and the study sections were distributed in a fairly uniform manner.

The following reference maps indicate the general distribution of sections along the paved highway system (B) and the recognized climatic zones within Alaska (C)(9).

Field sampling began in 1977 which was to provide a generally useful data base for subsequent studies of pavement structure performance. Data collection at that time included springtime Benklemen Beam deflections material samples and surface condition ratings. Asphalt concrete cores had originally been obtained in 1977 so that all aspects of the general data bank would represent contemporaneous measurement. These materials were stored under laboratory temperature and humidity conditions until undergoing testing as part of this study in 1979. A scarcity of materials and construction records on the asphalt grades originally used in these sections, especially for projects before 1959 (statehood), necessitated that performance correlations be based on the properties of asphalts extracted from the pavement cores, rather then on original properties.

Sample locations were selected to best represent the average range of observed performance throughout each study section. Two locations were chosen within each study section to represent pavement performance for the typical best and the typical worst conditions. Only one location was sampled for those sections showing an extremely small variation in surface quality. It should be stressed that the terms "worst" and "best," when used to describe differences within a given section, were only relative terms. The study sections were initially selected on the basis of their uniform condition.

Asphalt concrete sampling was accomplished by means of a small gasoline powered, trailer mounted drill rig with a 6" diameter core barrel attachment. Sets of four adjacent core samples were taken, representing materials from centerline, shoulder and both wheel paths.

Pavement Rating Procedures:

A pavement rating technique was specially developed by the Alaska D.O.T. for the purpose of pavement research. It incorporates methods derived from a variety of literature sources and describes pavement distress in terms of cracking, rut depth and patching. Longitudinal surface variations (measured as road roughness) is part of the rating method but was not used as a performance criterion during this study due to the abundance of bumps created by factors obviously not related to the pavement, such as thaw-consolidation of permafrost. The rating method as described in Appendix B examines the following recognized distress indicators:

Fatigue or "Alligator" Cracking - forms as polygonal blocks which somewhat resemble the skin of an alligator. Individual blocks typically can range in size from 1 to more than 24 inches in longest dimension. Fatigue cracking was measured as 0-100 percent individually in each wheelpath, and is reported as the sum total of both wheelpaths combined, therefore ranging from 0-200%.

Wheelpath Rutting - occurs as depressions within the wheelpath which are parallel to the centerline. These features average about 0.20 inches in depth on most Alaskan roads but can range to 1 inch or more. Rut depth is measured by means of a dial indicator and $5\frac{1}{2}$ foot straight edge. It is averaged for each study section from 11 randomly selected locations in each wheelpath, 22 measurements per section.

Thermal Cracking - is perhaps the most frequently occurring distress feature on Alaskan pavements. Two basic forms considered in this report are:

Miscellaneous thermal (map) cracks - usually form as a randomly oriented interconnected net of fractures of width lesss than 1/8", affecting only the asphalt concrete surface. The geometric patterns created by map cracking are usually much larger than those exhibited as a result of traffic related fatigue, and intercrack spacing can range up to 10-20 feet. The reader is referred to figure 2, Apendix B for a pictorial representation of typical thermal and longitudinal crack types. Individual crack segments are very often oriented either longitudinal or transverse to the centerline, which results in a commonly observed pattern of orthogonal squares and rectangles. Map cracks as mentioned previously are mostly hairline features and can exist unnoticed by the driving public. Ironically, they tend to be made most noticeable as a result of careful maintenance sealing which outlines and widens the appearance of the cracks and may also induce small but noticeable bumps felt or heard by the motorist. Because of it's random nature, it is difficult to quantify map cracking. In this study, map cracking is measured by counting intersections with one roadwidth transverse line and one equal length longitudinal line at 11 randomly selected individual locations within each study section (see fig. 2, Appendix B). Cracks intersecting transverse grid lines are by definition "miscellaneous transverse thermal cracks" while those intersecting longitudinal grid lines are termed "miscellaneous longitudinal thermal cracks." The reader should note that these cracks are characterized by the grid line which is crossed and not by the orientation of the crack segment per se.

Major transverse cracks - cross the entire width of the roadway at approximately 90° to the centerline, and constitute the rythymic "tire thumpers" which are familiar to most drivers. In Alaska, these features are frequently characterized as extending in depth many inches into the soil layers of the road structure and laterally past the edge of pavement. Interval spacing ranges from 40-300 feet throughout the state and individual crack widths vary with yearly temperature fluctuations, occasionally as much as 1 inch or more (1). Large seasonal width variations and spalling due to continual wheel impacts assures the necessity for a yearly maintenance effort, even on roadways which are otherwise problem-free. Major transverse cracks are easily seen at highway speeds, and are reported on a number-per-mile basis.

Longitudinal Cracks - run more or less parallel to the road's centerline and are subdivided into 3 types depending on location and severity. These features are grouped together as a class on the basis of physical similarity rather than mechanism of origin and are included with thermal cracking in Appendix B only because of the similar way they are counted. Longitudinal cracking is catagorized in the following way:

Regular type - found anywhere on the road surface except within 1 foot of the pavement edge.

Spalled type - found anywhere except within 1 foot of the pavement edge. These represent a more advanced state of surface distress where several closely spaced longitudinal cracks form a zone.

Edge type - longitudinal crack types, either spalled or not, which form within a foot of the pavement edge.

Major longitudinal cracks are counted as they intersect transverse grid lines at each of the 11 grid locations within a study section. It is the discretion of the rater which differentiates between map cracking and major longitudinal cracks, as grid intersections are being counted.

Patching - indicates the level of maintenance effort which has been required on a given road section. Care was taken to select study areas where patching would tend to indicate traffic related cracking rather than failure due to subgrade settlements. Patching was measured as two morphological types: pothole and full, or lane width patches. The two basic patching types are differentiated as follows:

Major (full width) patching - is that type which covers at least one full lane width and is usually as long, i.e., parallel to centerline as it is wide. Pothole patches are counted individually and reported on a number per mile basis. Major patching is summed in terms of total accumulated length through the study section and then reported as patch length per mile.

Testing:

Laboratory test procedures used in this project are described on Table 1:

Table 1

Description of Test	Units of Test Results	Test Method Source
thickness of pavement	inches	non standard test, used standard 6" caliper at 3 locations on each sample
quantitative extraction of asphalt cement	N/A	AASHTO T-164 Alaska Test Method T-16
gradation of aggregate	% finer than	AASHTO T-27
abson recovery asphalt content w/ash correction	% of aggregate	AASHTO T170-73
absolute viscosity @ 140°F	poises	AASHTO T-202
penetration @ 77°F	tenths of mm (dmm)	AASHTO T-49-78
penetration @ 39.2°F	tenths of mm (dmm)	AASHTO T-49-78
(indirect) tensile strength	psi	non standard method, see text
in-place density (SSD)	lbs/cu. ft.	Alaska Test Method T-18
maximum density	lbs/cu.ft.	procedure was modified by J.A. Waddell from ASTM C-70-72 and AASHTO T142-74

Except for the indirect tensile test and penetration @ 39.2^{o}, analyses were chosen to investigate properties which are presently recognized in standard specifications used by the State of Alaska for cement/asphalt concrete classification and quality control. Mechanistic design properties such as elastic modulus and creep compliance were disregarded during this study because the State of Alaska presently has no way of obtaining this data without the use of outside lab facilities and Alaskan design methods presently do not utilize these properties.

A majority of the materials testing was performed by the Alaska DOTPF Research laboratory at Fairbanks although some assistance was supplied by Interior Region personnel and facilities. Information concerning laboratory test results and surface ratings for each roadway section can be obtained on special request from the Alaskan Office of Research and Development in computer tape/card formats or as a raw data printout.

Environmental Considerations:

Factors which appear to control the longevity and character of surface distress can be generalized into 2 types:

1. properties of construction material type and placement methods
2. externally active elements of climate, vehicular loading and age

Climate, surface loading and age are the prime constituents of "environment."

In effect, all aspects of the environment could be thought of in terms of vehicle load. For example, an older road surface would tend to suffer more than a fresh asphalt concrete pavement from a single pass of a given loading because of brittleness imparted through accumulated fatigue and age hardening. Climate variations affect pavement durability by modifying, sometimes to a high degree, basic mechanical qualities of the construction materials. Such conditions as strong sunlight, heavy precipitation, severe freezing, and extreme temperature variation may act individually or combine to accelerate pavement deterioration. Certain wavelengths of sunlight are known to promote photo-oxidation, for instance, and heat produced by unreflected solar radiation also causes a continual loss of low level volitiles from the asphalt cement (10). Infiltration of surface water into the asphalt concrete is considered to be one of the more acute problems associated with short term damage.(11)

In asphalt concrete types which have high permeabilities, the presence of water in interstitial voids can lead to loss of asphalt -aggregate bonding resulting in stripping. This type of process will usually lead to surface ravelling and general weakening followed by early failure of the pavement surface.

Soil layers are also adversely affected by the entrance of surface water, with increasing pore pressures resulting in decreasing support strength. In terms of overall pavement support, however, the most critical increase in moisture is from the upward migration of water during freezing, controlled by the frost heave susceptibility of the soil layers themselves. Northern Alaska roadways are subjected to freezing conditions in excess of 5,000 degree-days which often lead to active layer (freeze-thaw) depths of up to 15 feet in dry soils. The pavement structure usually gains considerable strength during continued freezing; but freezing also provides the driving potential through which ground moisture migrates into frost susceptible soil layers. Resulting moisture levels can greatly exceed dry-soil saturation limits in some soil types and lead to weak support with characteristic high surface deflections upon thaw. As in most processes which are active in determining the overall performance of a pavement system, loss of soil support interacts with a poor quality asphalt material by means of a sort of "degenerative feedback." Poor soil support can allow load related surface deflections which are quickly destructive to poor quality asphalts or badly constructed pavements. The problem can become rapidly progressive as early cracking allows easier entry of surface water, thereby reducing soil support, which in turn promotes additional cracking, resulting in an accelerated pavement distress. Within the scope of this report a concentrated effort is made to account for the effects of environment on asphalt concrete properties and to determine the best asphalt materials and paving mixtures for use within Alaska.

Transverse cracking is another feature commonly associated with environment and is especially severe in areas of the state having high annual/diurnal temperature variations. This type of crack typically extends the width of the roadway and may involve just the asphalt surface, or in many cases, can extend several feet into the roadway structure. In addition to acting as a driving annoyance, major transverse cracks also provide an inlet for surface water and can therefore contribute to a number of secondary problems associated with high moisture content soils.

Another distress feature ascribed primarily to severe temperature variation is the formation of thermal "map" cracking. When present, this type of crack usually occurs over the entire surface of the roadway, a characteristic which is common to most climate associated damage types.

Environmental data used in this report were extracted from the work of Hartman and Johnson (9) published as "Environmental Atlas of Alaska." This is a standard reference for design work and site evaluation in Alaska and is relied on heavily because of the scarcity of weather recording stations near specific project locations. The climatic factors assumed to be significant variables included:

1. mean precipitation
2. mean snowfall
3. mean annual temperature
4. degree-days freezing
5. average number of wet days per year
6. seasonal temperature variation
7. daily temperature variation

Vehicle loading, for the purpose of this study, is analyzed in the form of Equivalent Axle Loadings (EAL). EAL represents the load damage potential of actual traffic in terms of total passages by a standard weight vehicle. Alaska presently normalizes mixed traffic volumes to 18,000 pound axle loadings for the calculation of EAL. This relationship is exemplified by the following:

The approximate expression for the relative damage potential of a given load is (12):

$$F = (A/S)^4$$

where: F= damage factor compared with a standard load

S= standardized maximum axle load (18K in Alaska)

A= actual axle loading being considered

This relationship is depicted in Figure 2.

The variable of pavement age is related to pavement distress from both environmental and traffic factors as it constitutes the "time of action" through which damage accumulates. Studies have usually shown, therefore, that a combination of pavement age and other environmental factors are better predictors of performance than pavement age alone.

DAMAGE FACTOR EQUIVALENCY
IN TERMS OF STANDARD 18,000 POUND LOADINGS (EAL)

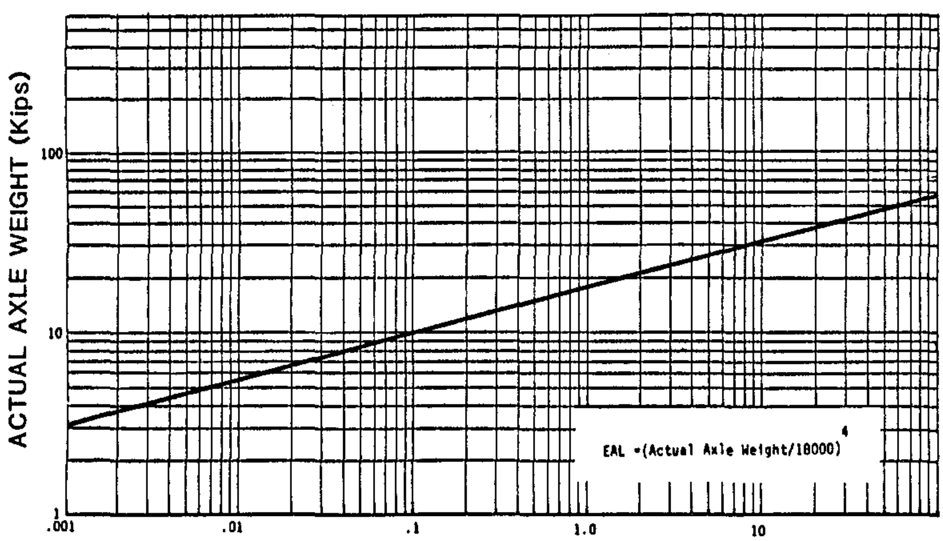


Figure 2

CHAPTER III

DATA ANALYSIS METHODS

Data Analysis Techniques:

Data collected for this project was analyzed on the University of Alaska's Honeywell computer using computational subroutines from the Statistical Package for Social Sciences (SPSS). This is a generalized system containing a large variety of statistical methods allowing easy processing of the project data. The table below lists the variables used in these analyses:

Environmental Variables:

Region	Mean Precipitation
Climate Zone	Mean Snowfall
Mean Temperature	Degree Days Freezing
Wet days/Year	Degree Days Thawing
Average Diurnal Temp. Variation	Age
Average Season Temp. Variation	Traffic EAL

Performance Variables:

Thermal (Map) Cracking	Full Width Patching
Major Transverse Cracks	Longitudinal Cracks
Rut Depth	Alligator Cracking

Asphalt Concrete Material Variables:

Asphalt Cement Content

Viscosity

Penetration

In-Place Density

Maximum Density

Aggregate Gradation

Tensile Strength

Miscellaneous:

Pavement Thickness

Data analysis was of two general types and consisted of 1) descriptive statistics and 2) correlative studies.

It was important early in the study to determine if Alaskan climate zone differences affected the aging of asphalt cement to a degree requiring a completely independent data analyses within each major zone. Figures 3 and 4 show a series of comparisons between frequency distributions of viscosities and penetrations from extracted asphalt cements taken from Continental, Transitional and Maritime zones. The similar shaped curves tend to indicate that aging processes have similarly affected the extracted asphalt viscosity properties regardless of climate zone. For this reason and the statistical advantage of increased sample size, it was decided that subsequent analyses would proceed without attempting to stratify data groups according to climate zone.

The following forms of analytical approach were utilized during the course of data evaluation:

Figure 3

FREQUENCY DISTRIBUTION OF EXTRACTED OIL PROPERTIES WITHIN SPECIFIC CLIMATIC ZONES

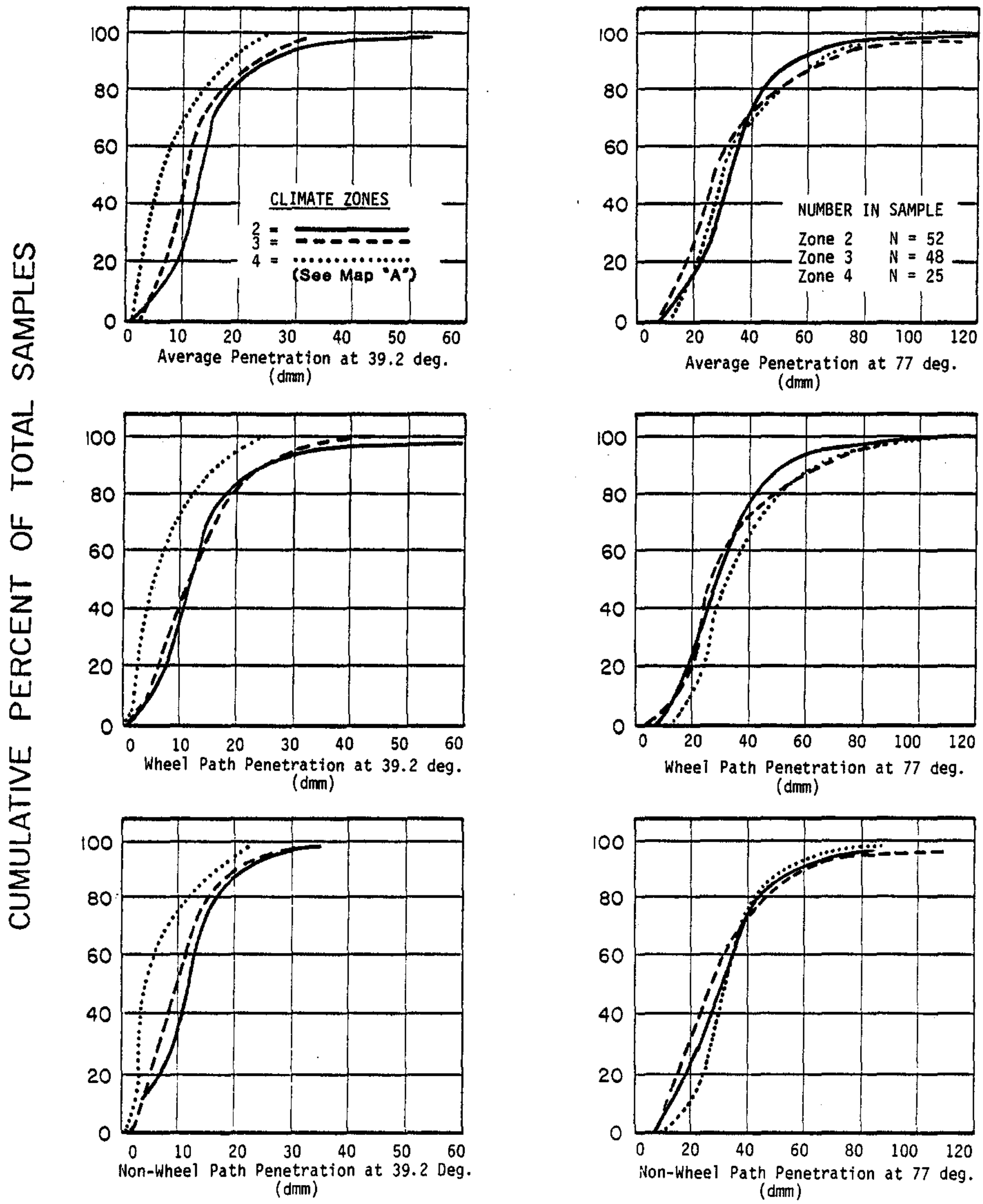
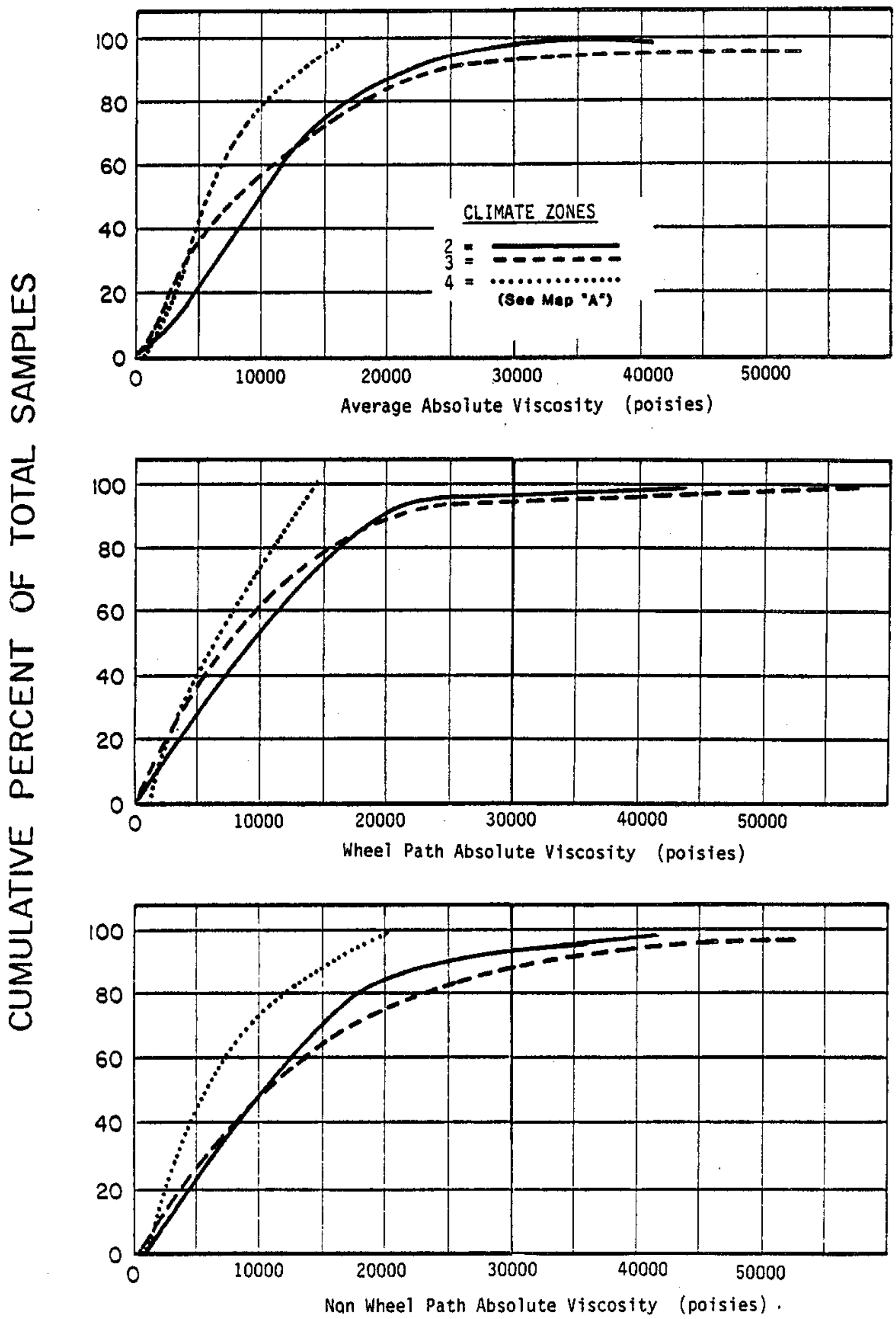


Figure 4

FREQUENCY DISTRIBUTION OF EXTRACTED OIL PROPERTIES WITHIN SPECIFIC CLIMATIC ZONES



1) Single Variable Descriptive Statistics

2) Bivarient Scatter Plots

3) Pearson Correlations

4) Partial Correlations

5) Regression Analysis

6) Trend lines Based on Points Representing Data Group Averages

Data analysis began with a determination of the basic distributional characteristics of the important variables. Appendix C includes a series of cumulative distribution plots for each variable utilized in this study.

Bivarient scatter plots are a rudimentary but valuable source for investigating the interrelationship of one variable with another. It is a good method to detect correlations and also to examine the nature of data point "flyers" which may need attention before a more advanced form of correlation process is used.

A basic objective of this study was to define relationships between asphalt concrete properties and existing (present) distress levels of the pavement surface. Scatter plots of performance versus material property variables usually revealed faint trends which, for practical purposes were as well defined by a linear as by a non-linear trend line. Because linearity was assumed, it was decided to use Pearson product-moment type correlation coefficients as a guide to the strength of statistical interrelationships. Pearson's "r" can range from -1 to +1 and is a standard method of defining the strength of relationship between the two variables where -1 or +1 indicates respectively perfect inverse or positive correlation while 0 would indicate no correlation. A detailed description of the calculation and interpretation of correlation coefficients can be found in most basic statistics textbooks.

In addition to the examination of normal correlation coefficients a method was also necessary for evaluating the degree of functional control exerted by external variables. This is done statistically by means of partial-correlation analysis. Partial correlation provides a means by which the coefficient of correlation (r—value) can be adjusted for the effects of external control variables. In concept, partial-correlation allows bivarient relationships to be derived as if the data had actually been stratified into similar groups before analysis. The most pointed example of data stratification which might have ideally been used in this study would be the individual evaluation of data groups gathered within each definable climate area. It may properly be argued that the validity of the study would have been enhanced by consideration of stratified data but the overriding problem remains one of an economically tolerable sample size.

Partial-correlation performs the function of artifical stratifications of the data by selected variables in a statistical rather than a literal manner. The basic formula used for generating the partial-correlation coefficient is:

$$r_{ij.k} = \frac{r_{ij} - (r_{ik})(r_{jk})}{\sqrt{1 - r_{ik}^2}\ \sqrt{1 - r_{jk}^2}}$$

where: r_{ijk} = correlation coefficient between variable i and variable j while controlling for variable k

r_{ij} = correlation coefficient between variables i and j

r_{ik} = correlation coefficient between variables i and k

r_{jk} = correlation coefficient between variables j and k

This formula can be extended to consider more than one control variable by replacing the simple bivarient correlation coefficients on the right side of the equation with succeedingly higher order partial-correlation coefficients. In this way, the formula can be made to compute higher and higher order coefficients of the type ...

$r_{ij.klmnop...}$

where the control variables are klmnop etc. etc.

Multiple regression analysis formed the next step in the analytical process. High speed computers have made the activity of generation of regression equations deceptively simple and rapid. This approach has apparently been viewed by many researchers as an analytical panacea, able to magically convert large masses of raw field data into meaningful design equations. One must in reality be extremely cautious in the application of formulae generated from regression techniques and must guard against the temptation to overuse the method itself.

Regression analysis as accomplished for this report, provides several potentially useful items of information. A regression equation is constructed of the form:

$$y=ax_1,+bx_2+cx_3+dx_4....+ \text{constant}$$

where y = user designated dependent variable

a,b,c,d = regression equation coefficients

x_1,x_2,x_3,x_4 = user designated independent variables

The analysis also provides information on the significance level of the equation, the confidence which may be placed in the significance level and the expected standard error of prediction of "y".

As mentioned earlier, a companion study (2) was concerned with the relationships between structural soil layers and surface performance. Multiple regression was tried in an attempt to delineate the most important variables from an exceptionally large number which typified a system of six soil "layer" locations. The results proved ambiguous and confusing to the extent that multiple regression analysis was duly dropped as an evaluative tool. On the other hand, this study is concentrated toward the variables describing only a single layer of material and the multiple regression approach was re-examined.

In order to eliminate all but the most highly significant variables in the generation of regression equations, a stepwise linear analysis was utilized. Since the stepwise linear regression technique is covered in a number of advanced statistical texts, only a brief explanation will be offered. The process provides a means by which the most significant independent variables are selected from a number of available choices. In the first step, the independent variable with the highest r-value is brought into the equation and the statistical significance is evaluated. At each succeeding step in the analysis, one new variable is added, a new regression equation is derived and statistical significance is re-evaluated. the process is terminated when a minimum acceptable significance ("F") level is obtained. The application of this technique to pavement studies is discussed further by Fromm and Phang (13). A separate regression equation was derived using each of the principal distress indicators as a dependent variable. The analysis is discussed later in this report, but was directed more toward identifying the relative importance of independent variables than providing anything akin to design equations.

Another form of analysis was used in order to generate bivarient trend lines while suppressing the effects of other (external) controlling variables. It was assumed that regardless of the control exerted by extraneous variables, a specific average level of performance could be typified by a characteristic range in a specific materials property. In order to perform what shall be termed "group-data analysis" the following method was used. A selected performance variable was examined as to its numerical range and frequency distribution characteristics. The total sample is then subdivided into non-overlapping groups of ascending value. If the frequency distribution tends to be continuous, then the subgroups (cells) were selected so that each was approximately of equal size. If, on the other hand, a variable appeared to be strongly bounded or "bunched" with natural subgroupings strongly indicated, then the sample cells reflected this tendency.

The average value was determined for both the dependent and independent variable within each individual sample group; and this constituted an x-y coordinate location, i.e., a "grouped-data" point. When all grouped-data points are plotted, a trend line can be established which represents the average variable interdependence. The use of grouped-data points in defining trends differs from more conventional methods such as regression analysis in one fairly obvious respect. While the normal form of least squares analysis minimizes residuals (predictive error) between the regression line and all data points, the grouped-data method allows each trend defining point to be independent of all others.

The following list indicates the interval breakdown of performance variables as used in grouped-data analysis:

NON-THERMAL PAVEMENT DISTRESS

1) Alligator Cracking:

   0%, 1-5%, 6-20%, $>$ 20%

2) Rut Depth (inches):

   0-0.120, 0.121-0.158, 0.159-0.227, $>$ 0.227

3) Full Width Patching (ft/mile):

   0-19, 20-250, 251-706, $>$ 706

THERMAL CRACKING

4.) Major Transverse Cracks (#/mile):

0-32, 33-52, 53-70, >70

Map Cracking (counted as number per section at 11 selected locations per section*)

5) Miscellaneous Thermal Cracks Crossing a Transverse Gridline:

0, 1-2, 3-8, 9-24

6) Miscellaneous Thermal Cracks Crossing a Longitudinal Gridline:

0, 1-2, 3-9, 10-48

THERMAL/NON-THERMAL PAVEMENT DISTRESS

(counted as number/selection on 11 grid locations*)

7) Regular Longitudinal Cracks:

0, 1-8, 9-16

8) Edge Longitudinal Cracks:

0, 1-2, 3-15

*see Appendix (B) for details of performance rating procedures.

CHAPTER IV

SPECIAL TESTING

- THE INDIRECT TENSILE

TEST

The Indirect Tensile Test:

The indirect tensile test, as described by R. Lottman, was utilized to determine the tensile strength properties of Alaskan asphalt concrete materials.

In his report (11), Lottman had proposed a tensile strength ratio (TSR) of saturated versus nonsaturated materials as a basis for assigning moisture damage potential to a given asphalt concrete mix. It was thought that this concept might be worth investigation because moisture in the asphalt concrete had not previously been evaluated as a source of performance deterioration in Alaskan pavements. In addition to investigating the possibility of moisture damage susceptibility, it was also useful to establish a data base of asphalt concrete tensile strength which could be directly correlated with performance variables in the same manner as any other materials property. The tensile testing device as constructed for this project utilized a Tinius Olsen Universal Testing Machine capable of maximum loadings at 5,000 + pounds and a strain rate suggested by Lottman, i.e., used 0.150 inches per minute at 73°F test temperature. The core sample was held in place by an aluminum allignment frame and load was applied through flat loading strips.

Test Theory and Procedure:

Maupin and Freeman (14) recount the history of indirect tensile testing from its early use on cylindrical concrete specimans. The method of applying tensile stress is termed indirect because the cylindrical sample is actually loaded in compression along a diametrical plane by means of two opposing load heads. A method of vertical compressive load application and resulting horizontal tensile stress distribution is shown on figure 5.

The assumptions used to generate the theoretical value of σ_{xmax} include (15)

1. point compressional loading
2. validity of Hooke's law
3. homogeneity of test speciman

The test method described by Lottman (11) accounts for these assumptions in the following ways.

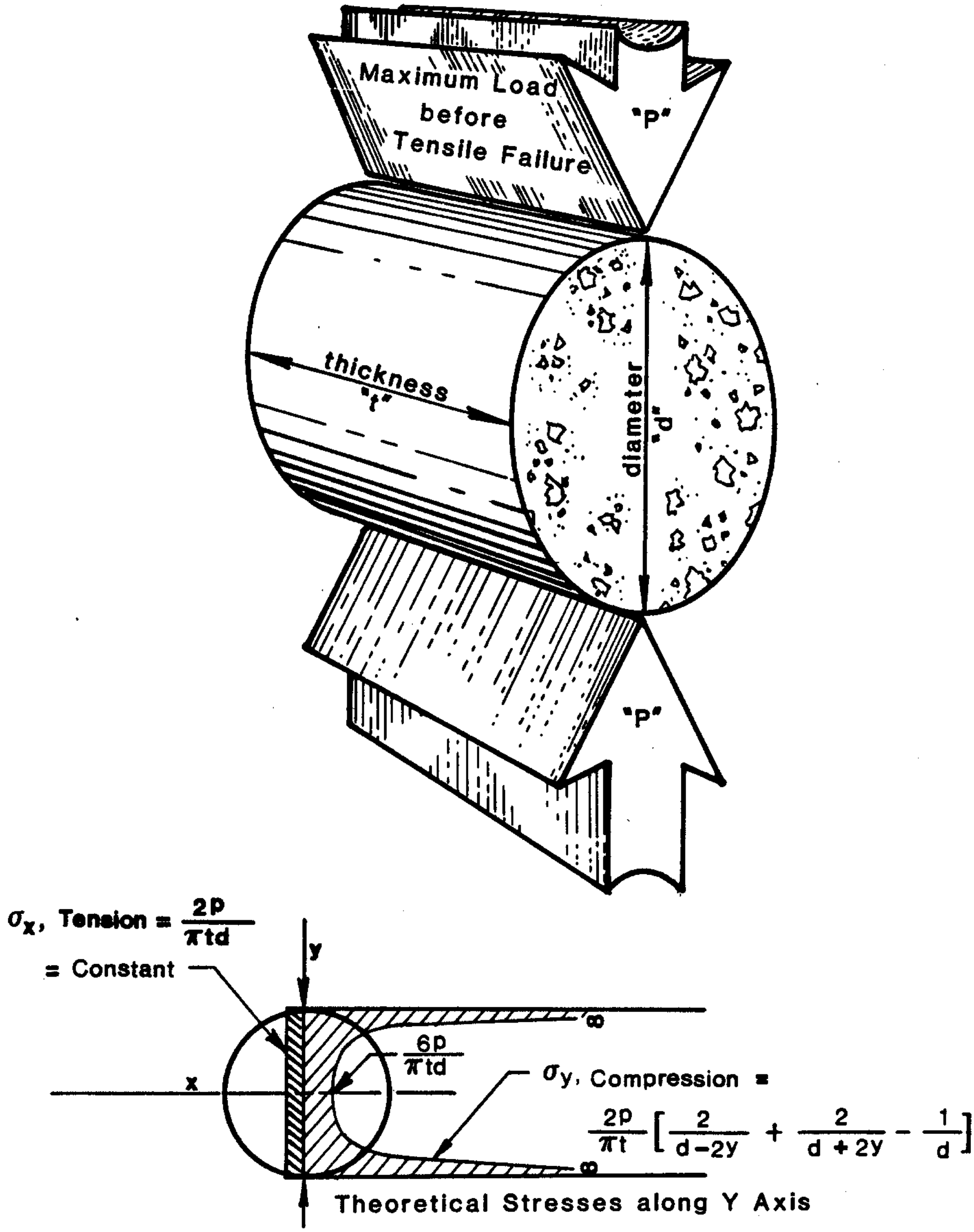
1. The formula is adjusted from $2P/\pi td$ to $1.93\ P/\pi td$, resulting in a somewhat lower calculated tensile strength because of minor flattening at the point of load application

2. Hooke's law is assumed valid if the compressional load is applied at a fairly rapid rate.

3. Only uncracked pavement cores in apparently good condition were selected for testing and homegeneity was therefore assumed.

Figure 5

Sketch of Load Application and Theoretical Stress Distribution in a Diametrically Loaded Asphalt Core Sample



The test procedure included, whenever possible, the selection of four pavement cores from each study section. Two of these were subjected to vacuum saturation as described by Lottman and the remaining two were tested without pre-conditioning. Because of the poor condition of many asphalt concrete cores, it was not possible to choose samples in such a way as to differentiate between wheelpath and nonwheelpath locations. Each sample was loaded to failure at an approximate test temperature of $73^{\circ}F$ and a constant strain rate of 0.150 inches per minute in the direction of compressive loading.

Preliminary Findings Concerning Results of Indirect Tensile Testing:

Tensile strength ratio (TSR) values below 0.8 were suggested by Lottman to indicate those materials which have been critically susceptible to moisture damage.

where: $TSR=(\sigma_{max\ saturated}/\sigma_{max\ dry})$

An examination of figure (6) reveals a tendency which would be considered curious in view of most previous research work. Most data points indicate saturated tensile strengths which are above the critical line of y=0.8x and in fact many actually indicate strength <u>increases</u> in going from the dry to saturated condition. About half of all asphalt concrete sample sets indicated apparent increases in tensile strength upon saturation. Effectively, 50% of the samples appeared to gain strength while 26% fell into the range indicative of moisture damage. Figure (6) also indicates that no test result (saturated or dry) exceeded a 140 psi tensile strength. Cumulative curves (see Appendix C) indicate that only about 5% of the samples tested exhibited tensile strengths above approximately 80 psi.

A regression equation was calculated to describe the relationship between saturated and dry samples and is given as:

saturated tensile strength = (.607)(dry tensile strength)+19.9

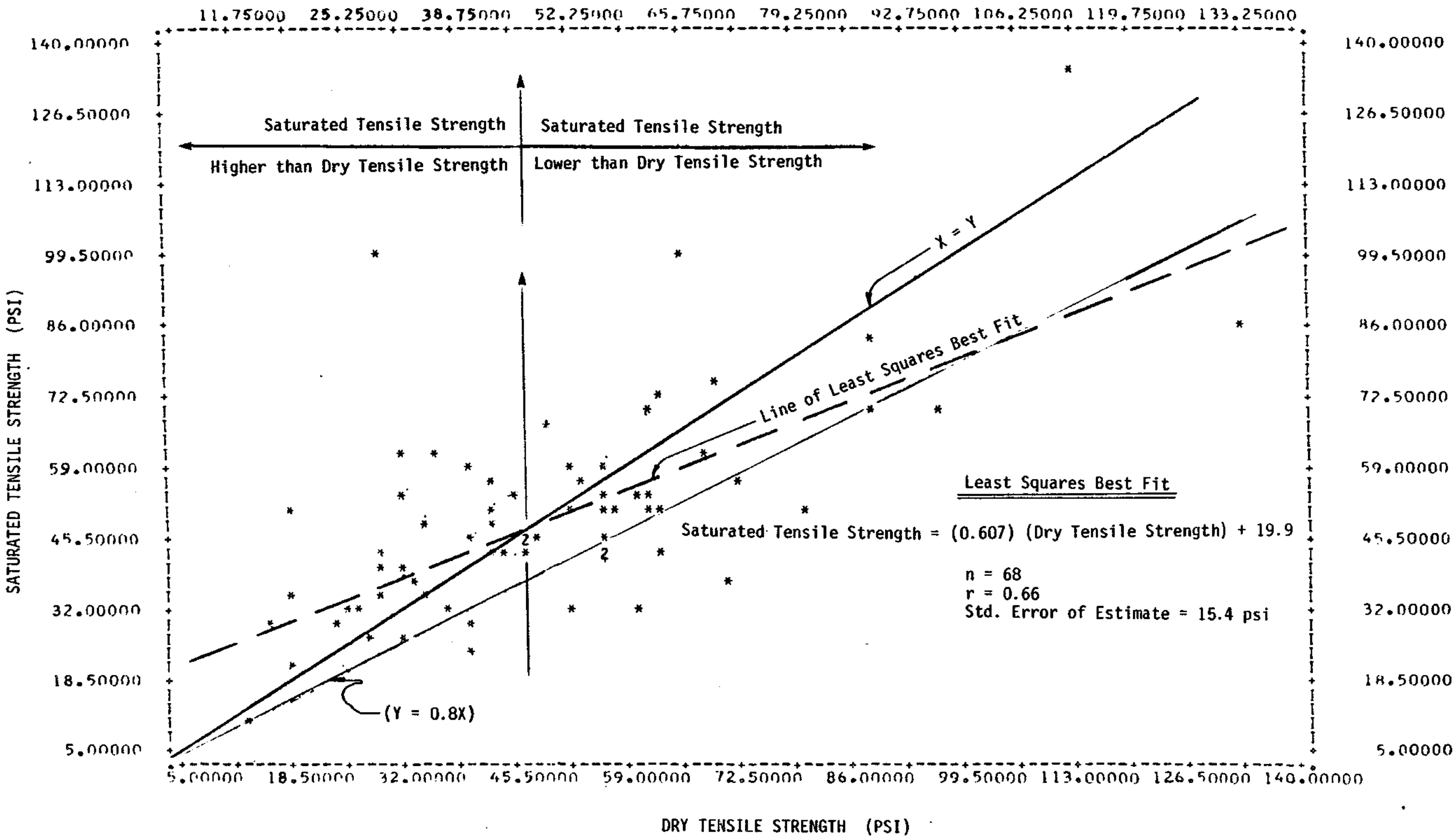
r=.66

std. error of est. = 15.4 psi

The low r–value of .66 indicates that the equation would have a low predictive ability although the trend line is nevertheless informational. The calculated trend line indicates a slight tendency for dry strengths to become relatively higher than corresponding saturated values at generally higher ranges. It could be assumed therefore from the regression results and an anomalous tendency to gain structural strength with saturation, that the data may have been more in line with previous researchers if Alaskan asphalt concrete materials had been of generally higher strength.

Saturated and dry values of tensile strength are treated throughout this report as basic material properties in correlations with pavement performance variables.

Figure 6



Saturated Tensile Strength
Higher than Dry Tensile Strength
Saturated Tensile Strength
Lower than Dry Tensile Strength
X = Y
Line of Least Squares Best Fit
(Y = 0.8X)
Least Squares Best Fit
Saturated Tensile Strength = (0.607) (Dry Tensile Strength) + 19.9
n = 68
r = 0.66
Std. Error of Estimate = 15.4 psi
SATURATED TENSILE STRENGTH (PSI)
DRY TENSILE STRENGTH (PSI)
11.75000 25.25000 38.75000 52.25000 65.75000 79.25000 92.75000 106.25000 119.75000 133.25000
5.00000 18.50000 32.00000 45.50000 59.00000 72.50000 86.00000 99.50000 113.00000 126.50000 140.00000
140.00000
126.50000
113.00000
99.50000
86.00000
72.50000
59.00000
45.50000
32.00000
18.50000
5.00000

CHAPTER V

- ANALYSIS OF DATA -

MATERIALS DESCRIPTIONS

ANALYSIS OF DATA

In order to fulfill the principal objectives of this study, it was necessary to explore and quantitatively define relationships between asphalt concrete properties and observed pavement performance. It was also important to determine the degree to which environmental conditions affected changes in specification asphalt cements with the passage of time. For the sake of efficient and logical presentation, the following material is divided into subject headings which represent specific catagories of analysis.

Single Variable Frequency Distributions:

All important variables describing environment performance and material type are presented in the form of cumulative frequency plots in Appendix C. With this information, it is possible to understand the characteristics of range, variation and central tendency which is associated with existing paved roads in Alaska. Descriptions are given in text form to point out the more salient features of each variable.

A more or less normal (Gaussian) distribution is implied unless stated otherwise and characteristic features such as flatness, peakedness or skew is noted as a comment. A measure of dispersion of values about the mean is given by the coefficient of variation included for each variable. This parameter is defined as follows:

coefficient of variation = (S/X)

where: s = sample standard deviation

X = sample mean

An advantage is gained in examining the coefficient of variation instead of the standard deviation because it tends to cancel the effects of scale size when dispersions of different types of variables are compared.

Data ranges which are given below are the values which lie between approximately the $2\frac{1}{2}$ and $97\frac{1}{2}$ percentile levels in order to suppress the influence of flyers in the following descriptions.

Environment:

1) Pavement age (years)-

mean 14 n = 117 median 12

range 3 - 25 coeff of var. 0.51

comments: The distribution of pavement age is very "flat." Sections were chosen so that any one age range would not be weighted too heavily.

2) Traffic (EAL)-

mean 175,000 n = 117 median 109,900

range 20,000 - 700,000 coeff of var. 0.99

comments: Distribution is not normal. Lower values (< 300,000) are by far the most heavily represented.

3) Traffic (TI)-

mean 7.0 n = 117 median 6.9

range 5.4 - 8.5 coeff. of var. 0.12

comments: The mathematical transform of EAL to TI creates an almost normalized distribution.

4) Mean Precipitation (inches)-

mean 30 n = 117 median 20

range 10 - 74 coeff. of var. 0.83

comments: Strongly bounded at 10 inches, the distribution reflects smaller sampling in Southeastern Alaska.

5) Mean snowfall (inches) -

mean 92 n = 117 median 70

range 20 - 200 coeff. of var. 0.59

comments: An almost flat distribution

6) Mean temperature (^{o}F)-

mean 30 n = 117 median 28

range 23 - 38 coeff. of var. 0.17

comments: The flat distribution begins to tail-out, i.e., skew slightly toward temperatures above freezing.

7) Freezing potential (degree days freezing)-

mean 3600 n = 117 median 4300

range 300 - 5,600 coeff. of var. 0.52

comments: A fairly flat distribution with marked tendency toward values between 4,000 and 5,500 degree days.

8) Wet days per year (# of days)-

mean 59 n = 117 median 45

range 30 - 105 coeff. of var. 0.41

comments: Bimodal for values between 30-50 and 80-100 with the bulk of sections lying on the lower group.

9) Seasonal temperature variation (^{o}F)-

mean 28 n = 117 median 31

range 14 - 36 coeff. of var. 0.28

comments: Some tendency for grouping of values between 30 and 36 degrees.

10) Average diurnal variation (^{o}F)-

mean 18 n = 117 median 19

range 10 - 21 coeff. of var. 0.18

comments: A fairly normal distribution but with most sections grouped above 15 degrees.

Performance Variables:

1) Major transverse cracks (# per mile)-

mean 53 n = 117 median 52

range 0 - 105 coeff. of var. 0.53

comments: Fairly well distributed with slight skewing to higher values of 100 cracks per mile or more.

2) Pot hole patches (# per mile)-

mean 4 n = 117 median 0

range 0 - 25 coeff. of var. 3.98

comments: Non-normal distribution, strongly bounded at 0 and skewed.

3) Full width patching (feet per mile)-

mean 169 n = 117 median 0

range 0 - 1200 coeff. of var. 2.47

comments: Non-normal distribution, strongly bounded at 0 and skewed.

4) Inner wheel path alligator cracking-

(total % in inner wheelpath) -

mean 6.2 n = 117 median 0.3

range 0-55 coeff. of var. 2.94

comments: Non-normal distribution, strongly bounded at 0 and skewed.

5) Outer wheelpath alligator cracking (total % in outer wheel-path)-

mean 10.5 n = 117 median 0.5

range 0 - 75 coeff. of var. 2.21

comments: Non-normal distribution, strongly bounded at 0 and skewed.

6) Alligator cracking in both wheelpaths

(total % summed from both inner and outer wheelpaths)-

mean 16.7 n = 117 median 1.1

range 0 - 150 coeff. of var. 2.40

comments: Non-normal distribution, strongly bounded at 0 and skewed.

7) Average rut depth (inches)-

mean 0.191 n = 117 median 0.158

range 0 - .8 coeff. of var. 0.62

comments: A fairly normal distribution but skewed toward high values above --0.300 inch

8) Regular longitudinal cracks (# per section)-

mean 3.7 n = 117 median 1.3

range 0 - 13 coeff. of var. 1.22

comments: Non-normal distribution, strongly bounded at 0.

9) Longitudinal edge cracks (# per section)-

mean 1.7 n = 117 median 0.4

range 0 - 10 coeff. of var. 1.65

comments: Non-normal distribution, strongly bounded at 0.

10) Miscellaneous thermal cracks (transverse) (# per section)-

mean 5.2 n = 117 median 2.4

range 0 - 20 coeff. of var. 1.19

comments: Non-normal distribution, strongly bounded at 0 and skewed.

11) Miscellaneous thermal cracks (longitudinal)(# per section)-

mean 4.2 n = 117 median 0.4

range 0 - 30 coeff. of var. 1.93

comments: Non-normal distribution, strongly bounded at 0 and skewed.

Variables Describing the Asphalt Concrete:

1) Pavement thickness of top layer in wheelpath (inches)-

mean 1.73 n = 117 median 1.67

range 0.90 - 2.70 coeff. of var. 0.24

comments: normal distribution

2) Total pavement thickness in wheelpath (inches) -

mean 1.81 n = 117 median 1.68

range 0.90 - 3.00 coeff. of var. 0.32

comments: normal distribution

3) Pavement thickness of top layer, non-wheelpath (inches)-

mean 1.90 n = 114 median 1.74

range 0.90 - 3.50 coeff. of var. 0.34

comments: Normal distribution

4) Total pavement thickness, non-wheelpath (inches)-

mean 1.90 n = 114 median 1.74

range 0.90 - 3.50 coeff. of var. 0.33

comments: normal distribution

5) Wheelpath void content (% of total mix)-

mean 6.9 n = 114 median 6.8

range 2.3 - 12.4 coeff. of var. 0.34

comments: Normal distribution

6) Non-wheelpath void content (% of total mix)-

mean 7.9 n = 112 median 8.0

range 2.6 - 12.6 coeff. of var. 0.31

comments: Normal distribution

7) Maximum theoretical density (lb/cu.ft.)-

mean 157.8 n = 112 median 157.9

range 151.5 - 163.5 coeff. of var. 0.02

comments: Normal distribution

8) S.S.D. density in wheelpaths (lb/cu.ft)-

mean 146.8 n = 113 median 146.6

range 137.5 - 153.5 coeff of var. 0.

comments: Normal distribution

9) S.S.D. density, non-wheelpath (lb/cu.ft.)-

mean 145.2 n = 113 median 145.2

range 138.5 - 153.0 coeff. of var 0.

comments: Normal distribution

10) Average bitumin content (as % of aggregate)-

mean 5.4 n = 117 median 5.4

range 3.6 - 7.4 coeff. of var. 0.17

comments: Normal distribution

11) Tensile strength, dry specimen (psi) -

mean 47 n = 82 median 43

range 14-90 coeff. of var. 0.46

comments: A fairly normal distribution but skewed to values greater than 75 psi

12) Tensile strength, saturated specimen (psi) -

mean 50 n = 68 median 47

range 13 - 100 coeff. of var. 0.41

comments: a fairly normal distribution but skewed to values greater than 75 psi

13) Penetration at 39.2°F in wheelpath (dmm)-

mean 14 n = 113 median 12

range 2 - 29 coeff. of var. 0.70

comments: skewed to values above 75 dmm

14) Penetration at 39.2°F, non-wheelpath (dmm)-

mean 12 n = 112 median 11

range 2 - 26 coeff. of var. 0.59

comments: skewed to values above 20 dmm.

15) Penetration at 77°F in wheelpath (dmm)-

mean 37 n = 112 median 29

range 10 - 87 coeff. of var. 0.65

comments: skewed to values above 50 dmm.

16) Penetration at 77°F, non-wheelpath (dmm)-

mean 33 n = 112 median 30

range 10 - 70 coeff. of var. 0.49

comments: skewed to values above 55 dmm.

17) Absolute viscosity in wheelpath (poises)-

mean 10,200 n = 117 median 8,400

range 500 - 30,000

comments: Skewed to values above 20,000 poises.

18) Absolute viscosity, non-wheelpath (poises)-

mean 11,900 n = 115 median 9,300

range 1,500 - 36,000 coeff. of var. 0.85

comments: Skewed to values above 20,000 poises.

19) Aggregate gradation (% finer than 3/8 inch)-

mean 79 n = 117 median 80

range 64 - 94 coeff. of var. 0.08

comments: Skewed to values above 90%

20) Aggregate gradation (% finer than #4 sieve)-

mean 56 n = 117 median 56

range 44 - 69 coeff. of var. 0.10

comments: Skewed to values above 65%

21) Aggregate gradation (% finer than #10 sieve)-

mean 40 n = 117 median 39

range 29 - 50 coeff. of var. 0.11

comments:Normal distribution

22) Aggregate gradation (% finer than #40 sieve)-

mean 21 n = 117 median 20

range 14 - 39 coeff. of var. 0.24

comments: Skewed to values above 30%

23) Aggregate gradation (% finer than #200 sieve)-

mean 7 n = 117 median 7

range 4 - 11 coeff. of var. 0.24

comments: Normal distribution

Three catagories of variables have been described: 1) environment, i.e., climate and traffic, 2) pavement performance indicators and 3) material properties. Pavement performance and material properties are represented by accurate field and laboratory measurements made specifically for each study section. Environmental descriptors unfortunately may not reflect localized conditions in more than a generalized way because they were estimated by means of interpolation and extrapolation. The following list suggests several reasons why climate and traffic data is only approximate:

1. Interpolations used to describe weather variables are based on environmental atlas data and may not exactly reflect localized differences.

2. Traffic counters are widely spaced. Local traffic differences might have been significant.

3. EAL is calculated using estimated "truck factors" based on

infrequent total traffic counts.

4. Some "backwards" extrapolation was required in order to estimate total life EAL on roads built before accurate traffic figures were kept.

The distribution of variables was controlled by the physical extent of the state's paved road system and a philosophy that study sections should be located at least every 20 miles along rural highway segments. Sections were chosen to statistically favor high performance levels as only about 50% of the locations show significant cracking or rut depths greater than 0.150 inches. This type of weighting factor was introduced to insure that project findings would be most strongly influenced by data associated with pavements in good, rather than poor condition. In other words, conclusions are based more on what seems to have worked rather than on what did not. Heavy weighting of good performance is indicated on the cumulative plots by bounded values, e.g., at zero percent cracking and by skewing (tailing) of data toward values representing poorer pavement condition.

The Asphalt Concrete Material:

This section will examine the aging of asphaltic materials and compare the lateral variation in properties found between wheelpath and non-wheelpath areas. It will also develop a correlation between some of the commonly measured properties which are used to specify and typify asphaltic paving materials. Relationships are developed in the following subject areas:

1) Variations of asphalt concrete properties with time and traffic
2) comparisons between variables describing asphaltic materials
3) comparisons of wheelpath properties with non-wheelpath properties
4) comparison of asphalt mix properties and the total % voids

Figure 7 indicates the apparent time variations in absolute viscosity and penetration. Samples have been categorized as coming from north or south areas of the state. Northern areas include mostly the Interior Region of the Alaska D.O.T., almost entirely within the continental climatic zone and typified by at least 3500 degree-days of freezing. Penetration grade asphalts of 200-300 grade were used most frequently on these sections. The line labeled as southern Alaska represents sections from within the transitional and maritime environments where 120-150 penetration grade asphalts were originally used. Data used to construct the trend lines was selected from roads more than 7 years old in order to insure that only penetration grade asphalts would be considered. Lines were then projected back to time zero by assuming the material's average properties after the mixing process. These average properties were approximated by referring to Rolling Thin Film Oven (RTFO) residue specifications for similar viscosity original asphalts. Wheelpaths tend to show somewhat less

THE AGING PROCESS OF ASPHALT CEMENT IN ALASKA - APPARENT BEST FIT LINES

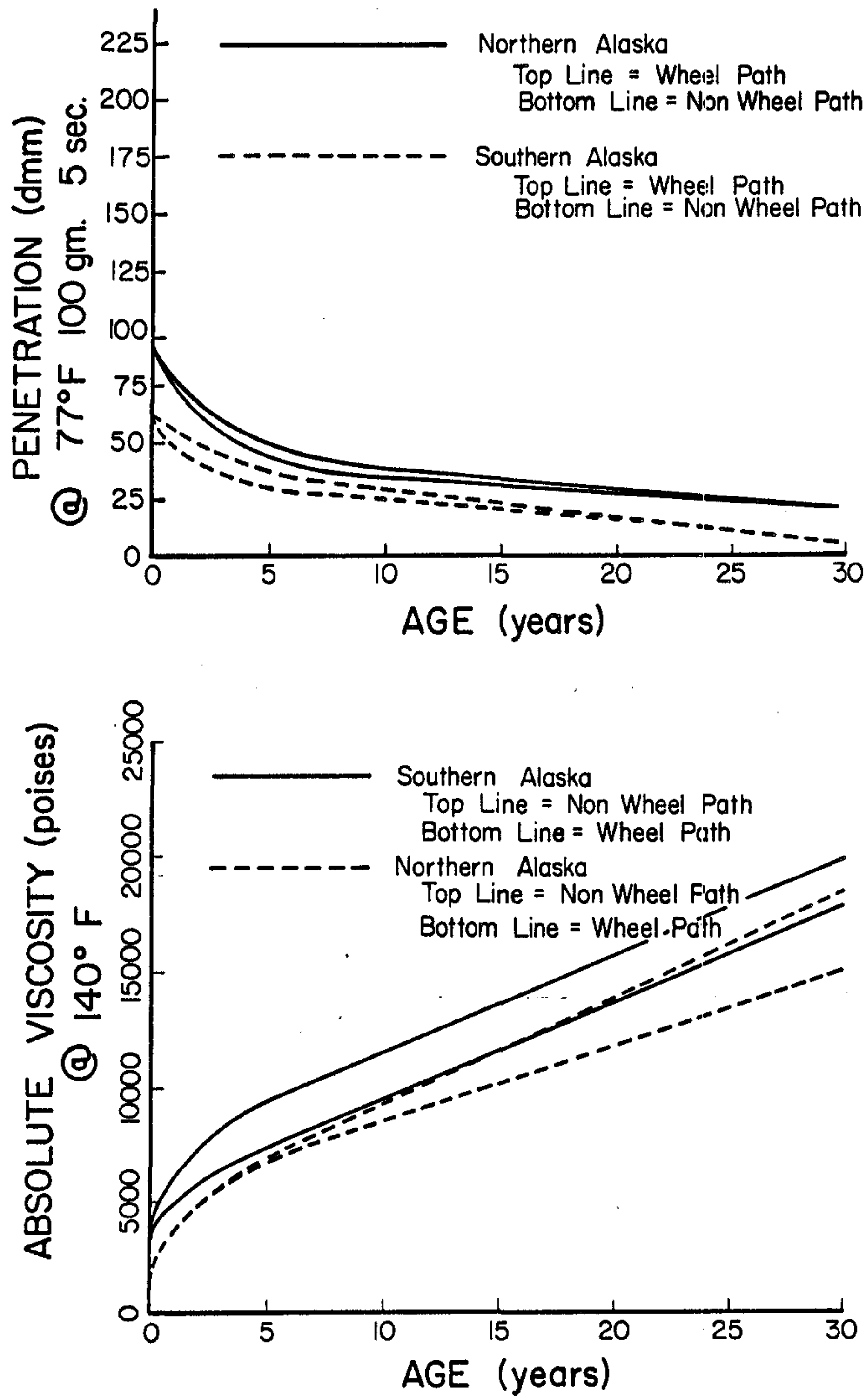


Figure 7

weathering than do non-wheelpath areas. This condition is probably brought about as a result of the kneading section of rubber tired vehicles which reduces the total % voids somewhat and also may seal some of the surface voids, thus limiting the entrance of oxidizing agents. A lesser degree of aging is also exhibited by materials chosen from the more interior regions of the state. These asphalts not only began service life at lower viscosity but have been exposed to lower average temperatures. On the whole, aging appears to have been affected about as strongly by wheelpath location as by differences in the Alaskan climate. The aging process seems to have accelerated very rapidly during the first 5-7 years of pavement life in terms of both penetration and, to a lesser extent, viscosity. This period of time includes not only field weathering but also the hot mix processing which can drastically increase viscosity. Average absolute viscosities have increased to at least 7,000 poises while 77°F penetrations have decreased to below 50 dmm during the first 7 years. As evidenced by these data, it would be ill advised to accept performance predictions which were based on the original-material values. The aging process is further typified by table 2 indicating the extreme ranges of viscosity and penetration noted from the project data.

Table 2

Pavement age (years)	Penetration @ 77°F (dmm)		Absolute Viscosity @ 140°F (poises)	
	high	low	high	low
7	80	15	21,000	1,000
15	60	10	25,000	1,000
25	40	8	31,000	5,000

Upper and lower range asphalt cement contents, measured as % of the aggregate weight, exhibited a significant shift to lower values with increasing age. From a scatter plot of asphalt content versus age, table 3 describes the general trend of this variation.

Table 3

Pavement Age (years)	Asphalt Cement Content (as % of aggregate w/ash correction)	
	High Range Value	Low Range Value
3	8.5%	5.0%
6	7.5%	4.0%
10	6.8%	3.8%
15	6.4%	3.5%
20	5.9%	3.5%
25	5.8%	3.5%

The apparent change in asphalt content probably results from a basic increase in design mix asphalt requirement with time or reflects somewhat the oxidation of previously existing asphalts into non-asphaltic solids. The second method would create an apparent two-fold decrease in asphalt cement by simultaneously reducing the actual content and adding to the ash correction.

Tensile strengths of the asphalt concrete show a somewhat noticeable tendency to increase with pavement age. Both saturated and dry tensile strengths show maximums which increase from approximately 55 psi at 3 years to about 90 psi at 20 years.

Saturated materials curiously showed perhaps a slightly more well-defined trend and somewhat higher maximum values than did dry samples. Lowest strengths for both saturated and dry samples regardless of pavement age were approximately 10-12 psi, again usually slightly higher for asphalt concrete in the saturated state.

In addition to indicating the general aging characteristics of asphalt cements, figure 7, also indicates that asphalt in the wheelpaths tends to age somewhat more slowly than non-wheelpath locations. One should generally be aware that materials properties can vary significantly depending on roadway location and projects involving the field sampling of older pavements should take this into account. Table 4 indicates the degree of precision that can be expected when predicting wheelpath properties from non-wheelpath sample data or vice versa. The reader should be aware that from this point in the report "WP" will be used in place of wheelpath and similarly "NWP" in place of non wheelpath.

Table 4

Wheelpath predictions from non-wheelpath sampling

WP=(A)NWP+B

where: WP = wheelpath

NWP = non wheelpath

A & B = regression constants

	A	B	r	std. error est.	n
penetration at 77°F	0.931	6.77	0.63	19	109
penetration at 39.2°F	0.832	3.91	0.59	8	110
absolute viscosity (140°F)	0.711	1,406	0.80	5,000	113
top layr.pvmt.thickness	1.16	-0.348	0.87	0.20	113
total pavement thickness	1.01	-0.095	0.94	0.22	113
% voids of total mix	1.13	-1.99	0.86	1.3	111
% bitumin content	1.28	-1.68	0.61	0.9	117
S.S.D. density	1.15	-20.3	0.88	1.9	112

These relationships are shown in the following scatter diagrams of figures 8-A through 8-H. The "expected" line of x=y is included along with the calculated best fit line. Scale numbers which label the axes of the plots were usually chosen automatically by the computer to cover the value ranges of the data set being analyzed, and, may therefore appear to be constructed at somewhat odd increments. It is difficult to establish a reasonable explanation for the differences between wheelpath and non-wheelpath locations because the data scatter extends both well above and below the x=y line. Except in the case of % voids and S.S.D. density, the calculated (best fit) line crosses or nearly crosses the equivalency (x=y) line within the range of data investigated. It is obvious that data scatter could be a serious problem in characterizing a roadway's material properties by one or two pavement core samples. It is suggested that asphalt concrete samples be obtained in a way so as to typify the entire lateral extent of the pavement, such as the centerline, inner wheel-path, outer path and shoulder samplings utilized in this study. For this reason, subsequent correlations between material properties and performance are made using asphalt concrete data averaged from the four locations mentioned. Only two scatter plots (8-F and 8-H) indicate expected trends, where % voids are generally lower in the wheelpaths and S.S.D. densities predominantly higher.

Three basic measurements of viscosity were chosen to typify asphalt cement materials and for use in subsequent correlations. Viscosity determinations consisted of penetration at 39.2°F, penetration at 77°F and absolute viscosity at 140°F. The scatter plots in figures 9A-9F indicate the correlations between viscosity variables. Each pair of variables is plotted utilizing only wheelpath data and again using only non-wheelpath data.

The relationship between high and low temperature penetration data is functionalized by computer calculated linear, least squares best fit equations. Scatter about the trend lines produces a standard error of estimate of 10-14 dmm in the prediction of high temperature from low temperature penetrations. Statistically assuming that a band width of about plus or minus 2 std. errors of estimate will include most prediction errors, it would be expected that high temperature penetrations can be predicted from low temperature penetrations to a precision of plus or minus 20-28 dmm. The total range of estimate would therefore be twice these values, or 40-56 dmm.

The plots of penetration versus absolute viscosity were fitted with estimated (eyeball) trend lines and bounded with similarly estimated "2 standard-error-of-estimate" envelopes. Comparatively, wheelpath data provides better correlations than non-wheelpath data and 77° penetration is much better predicted from absolute viscosity than is 39.2° penetration.

Although these viscosity relationships are important in a purely descriptive sense, they also provide useful information on the tem-

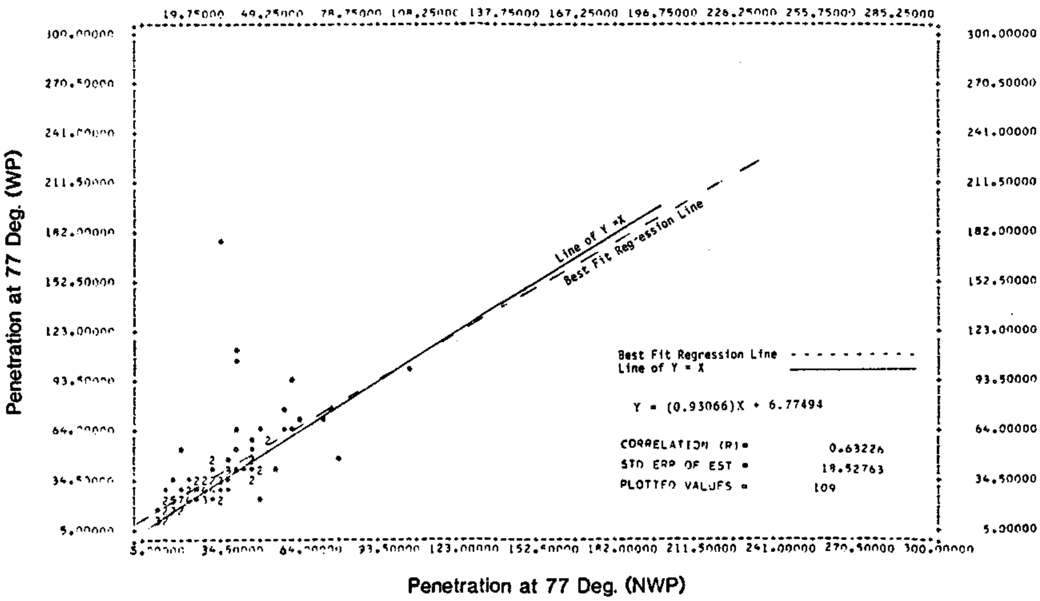


Figure 8-A

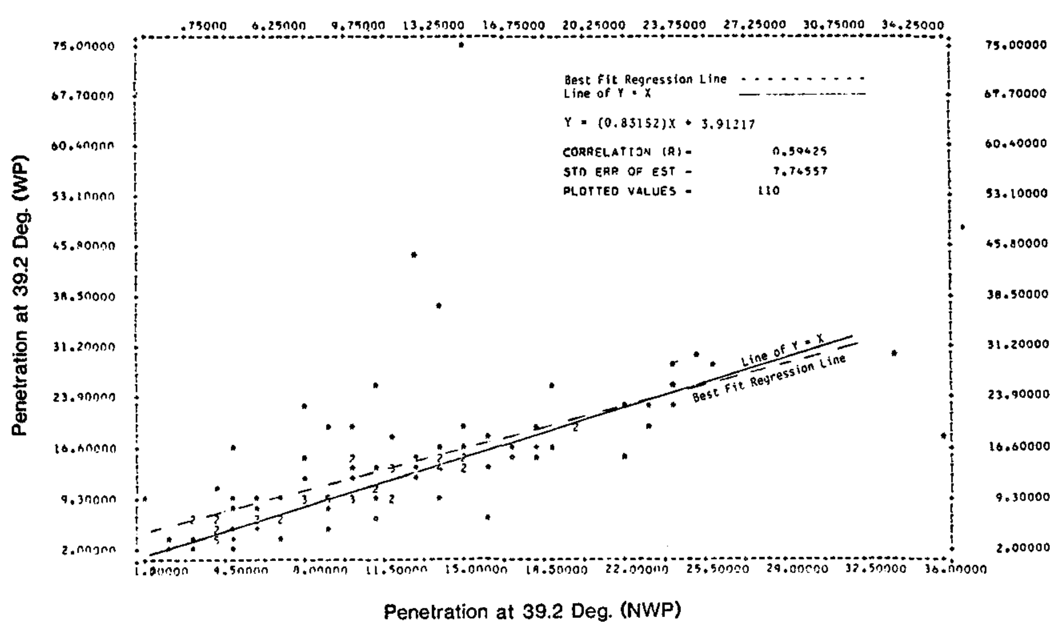


Figure 8-B

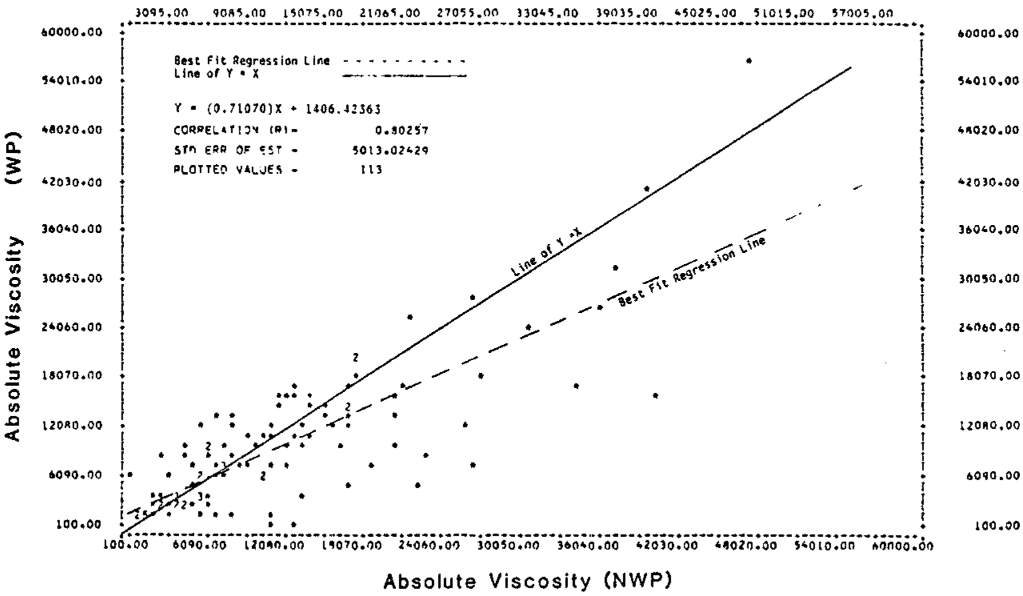


Figure 8-C

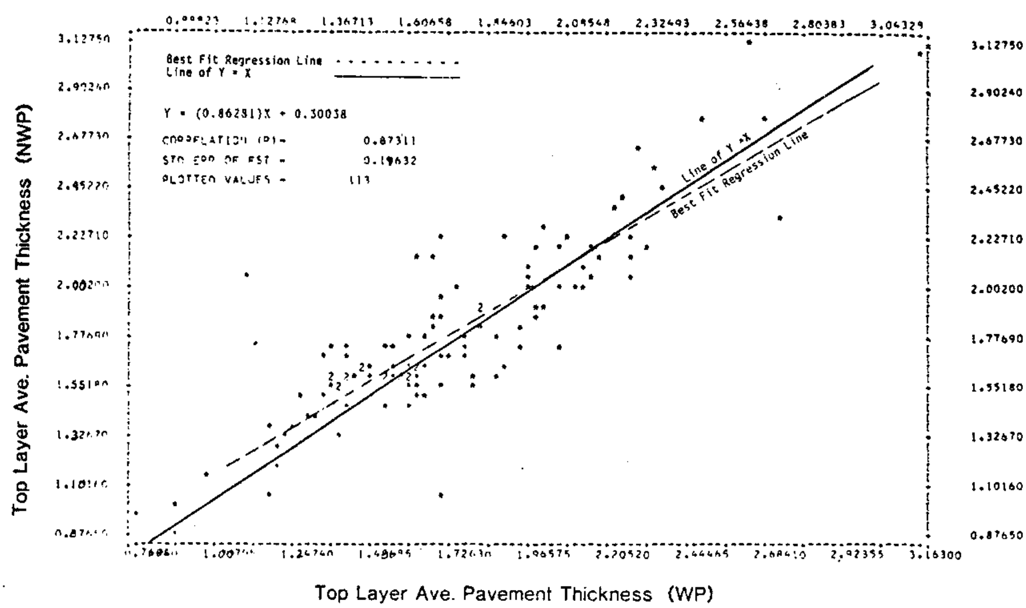


Figure 8-D

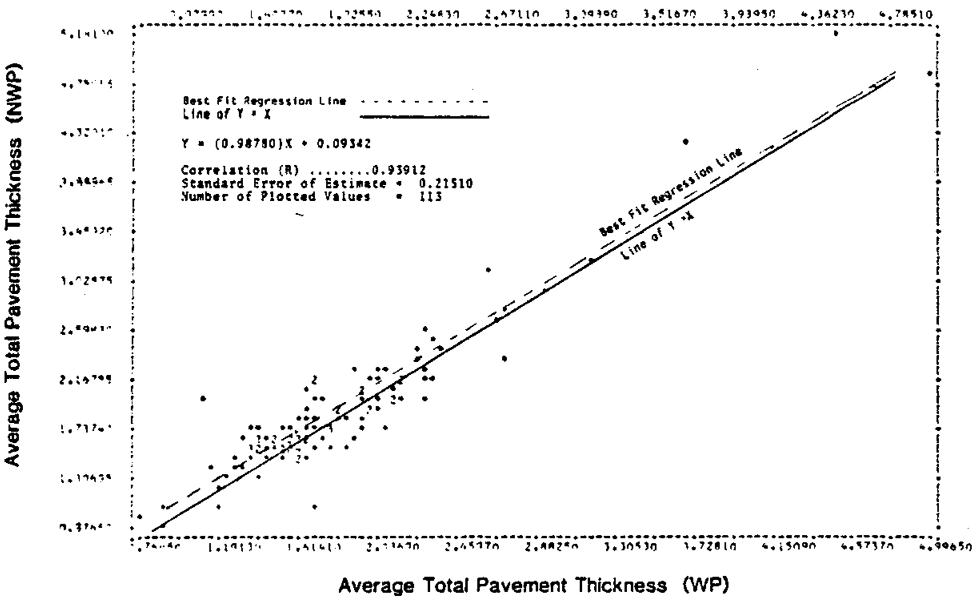


Figure 8-E

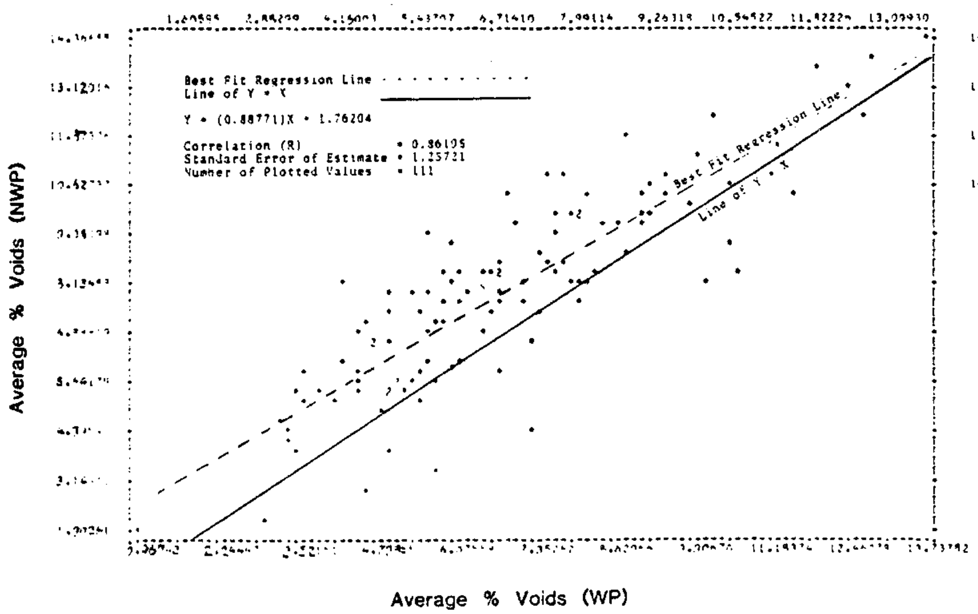


Figure 8-F

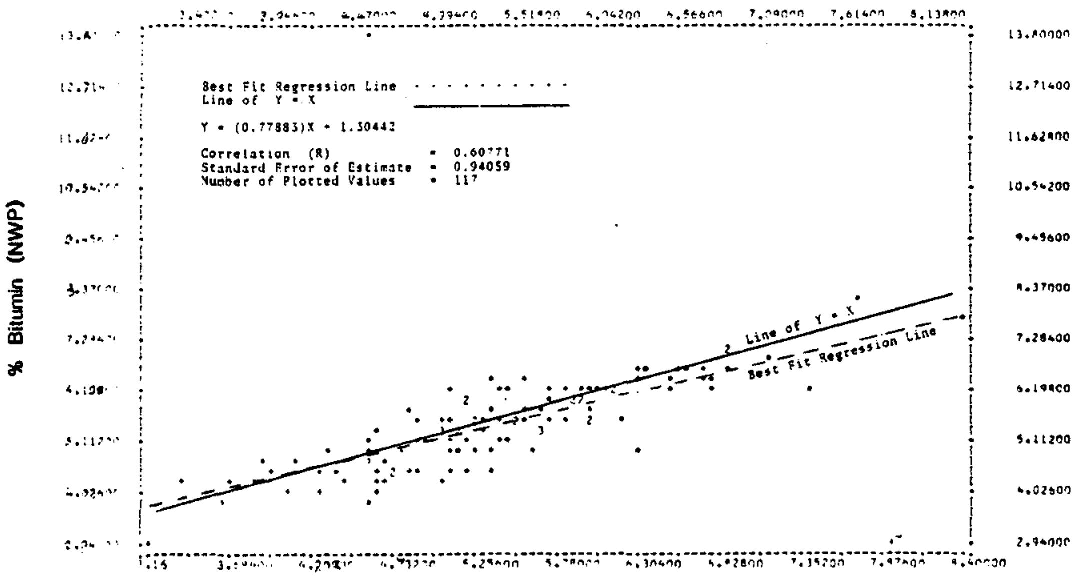


Figure 8-G

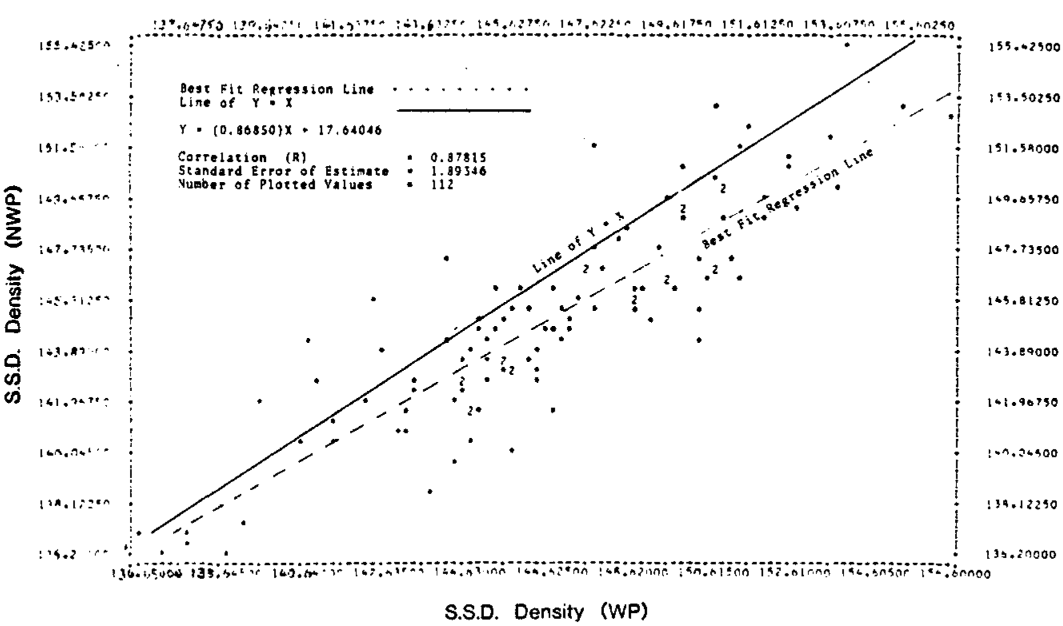


Figure 8-H

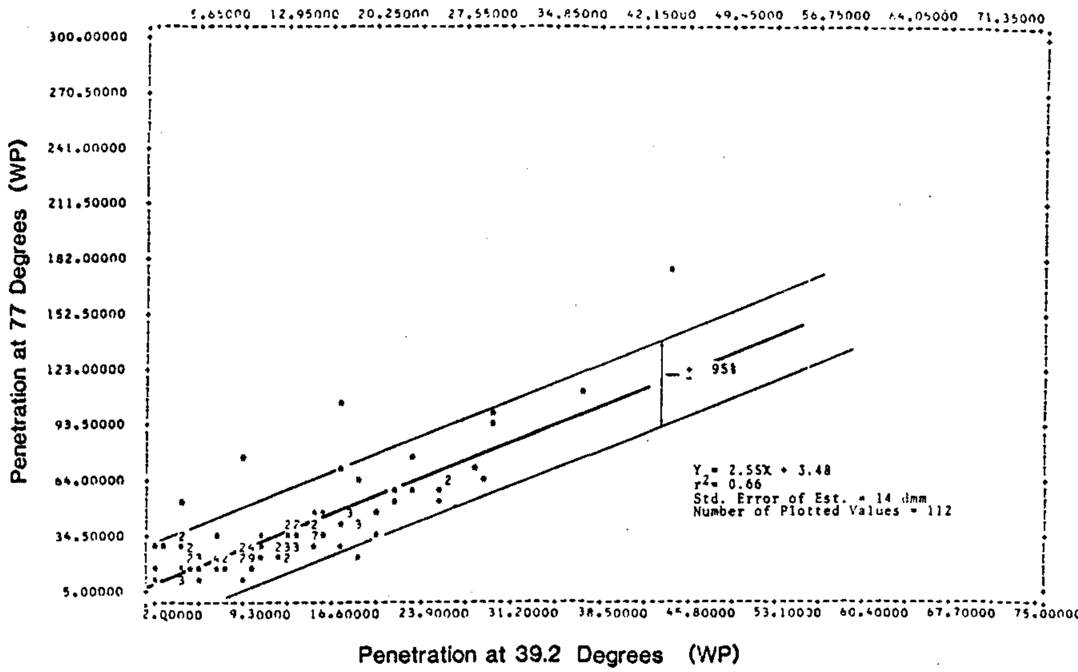


Figure 9-A

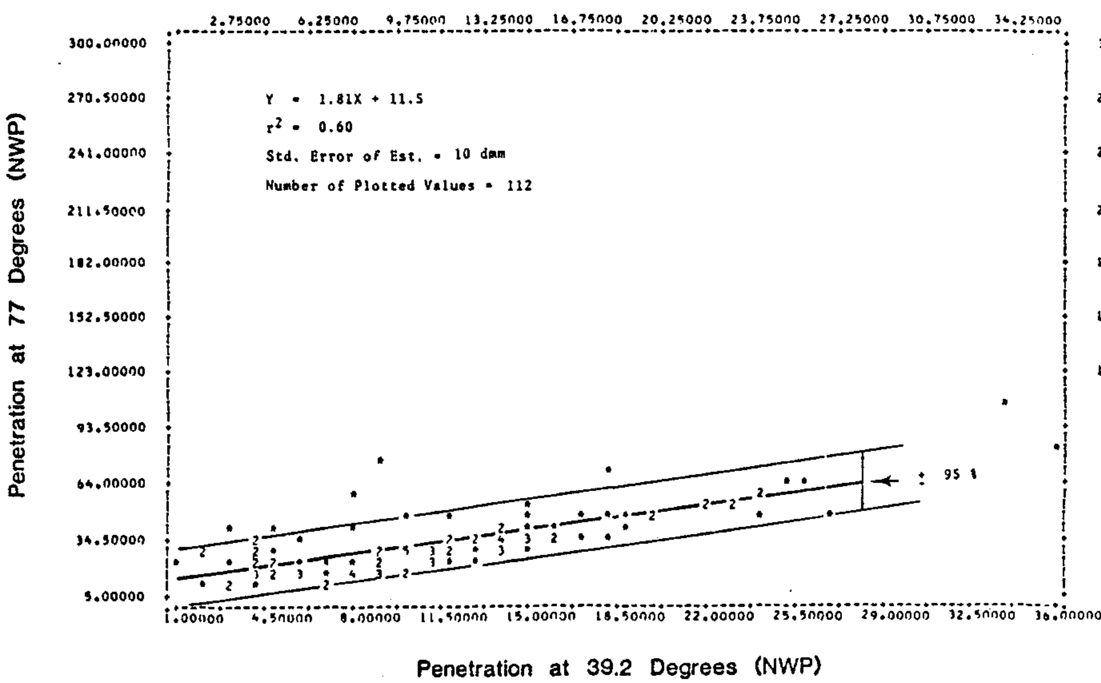


Figure 9-B

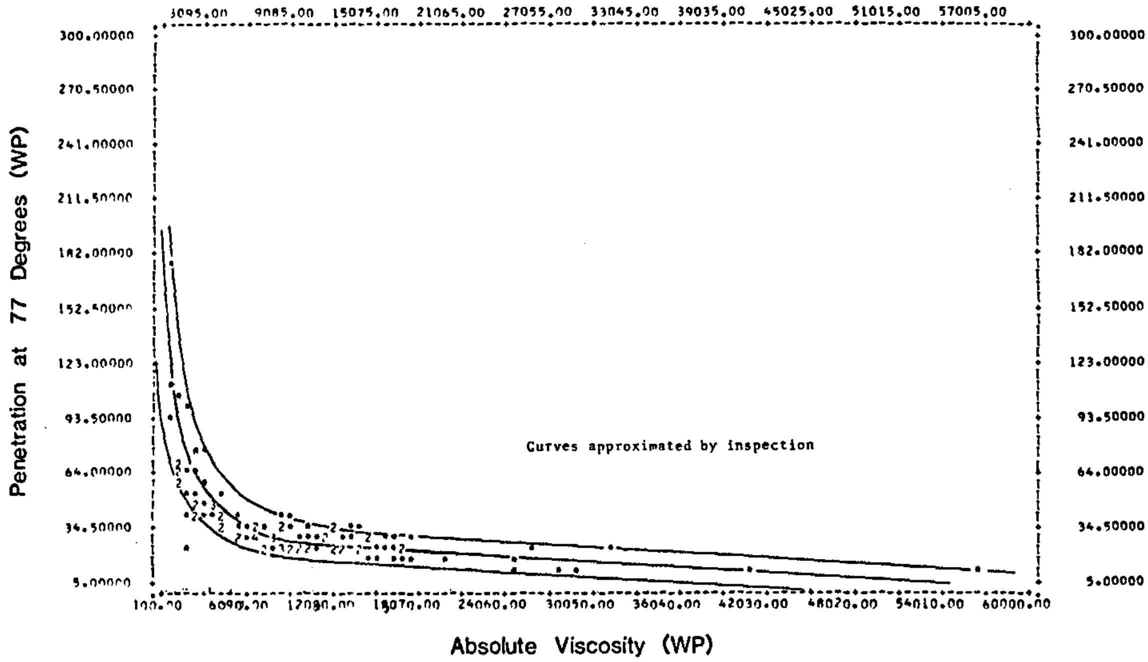


Figure 9-C

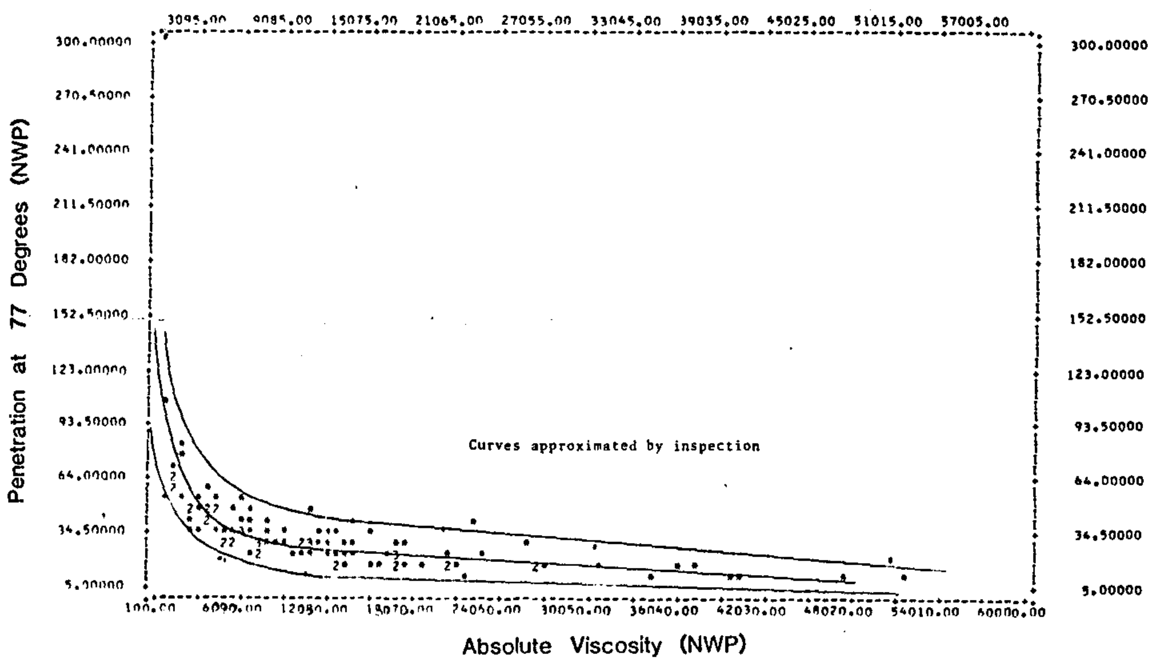


Figure 9-D

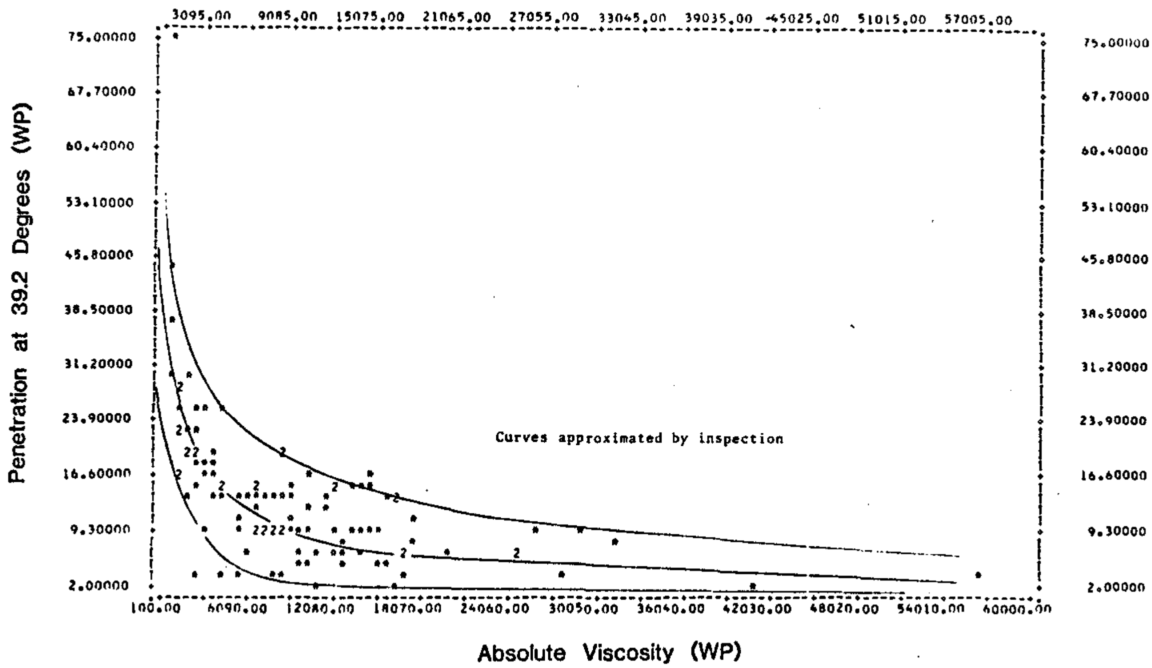


Figure 9-E

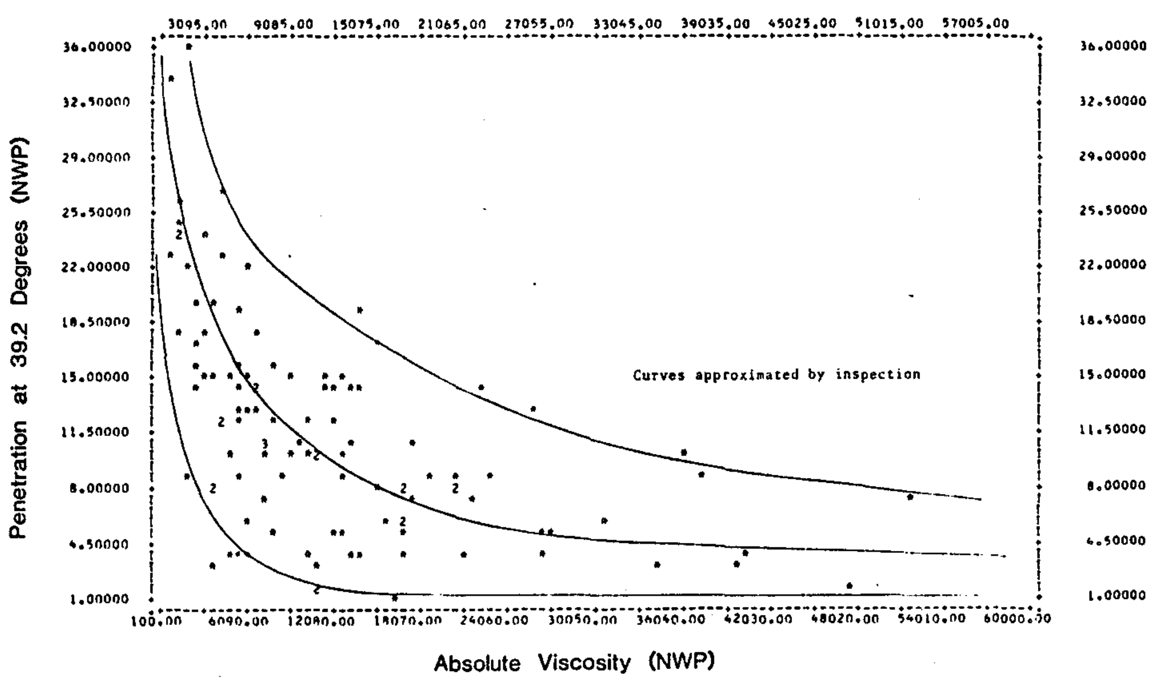


Figure 9-F

perature susceptibility of in-situ Alaskan materials. Temperature susceptibility is described as the amount of viscosity change per change in temperature, where materials of higher susceptibility are more strongly affected. A material property referred to as the "penetration-viscosity number" (PVN) has been described (16,17) in attempts to quantify temperature susceptibility. Numerically higher PVNs are associated with less temperature susceptible asphalts, and lower PVNs with more susceptible types. In general, the more temperature susceptible an asphalt cement, the stiffer and more liable to crack it is under low temperature conditions relative to its performance properties at elevated temperatures. Also, the more highly temperature susceptible material is more easily cracked through thermal fatigue due to temperature cycling. North American paving asphalts usually fall into PVN gradings between -1.5 and +0.5 and these boundaries were plotted in figure 10A and B about the actual data points. It should be realized that while the PVN concept has been developed utilizing penetration at 77°F and viscosities at 275°F, McLeod (17) has provided an interpretation of PVN curves for 77°F penetrations and 140°F viscosity. Data are shown in the context of this modified PVN scheme because the higher temperature viscosity information was not obtained during laboratory testing. It was also primarily due to the lack of 275°F viscosity data that PVN was not chosen as a standard materials variable for use in subsequent analyses. It is noted on both figures 10A and 10B that nearly the entire collection of data points is contained within the range of -1.5 to +0.5 PVN. Although distribution of points between the two PVN boundaries is fairly uniform, there does appear to be a slight tendency for non wheelpath data to group somewhat closer to the higher PVN range.

The literature dealing with asphalt technology abounds with references suggesting that pavement voids are one if not the controlling variable in determining asphalt aging and performance. In order to learn something of the effects of % void content on asphalt properties, the following relationships are evaluated from combined average wheelpath and non-wheelpath data:

1) % Voids Vs Absolute Viscosity at 140°F
2) % Voids Vs Penetration at 39.2°F
3) % Voids Vs Penetration at 77°F
4) % Voids Vs Saturated Tensile Strength
5) % Voids Vs Dry Tensile Strength

Scatter plots indicated no appreciable correlations between any of the data pairs, and values of r^2 were less than 0.1 in every case. Upper and lower boundry data points were also diffuse to the point where no extreme value trends were identifiable. The very lowest correlations were found between % voids and tensile strength.

Conclusions Regarding Analysis of the Descriptive Properties of Asphalt Concrete Materials:

1) Comparisons between wheelpath and non-wheelpath properties indicate that both locations must be sampled to obtain realistic average values for asphalt cement properties

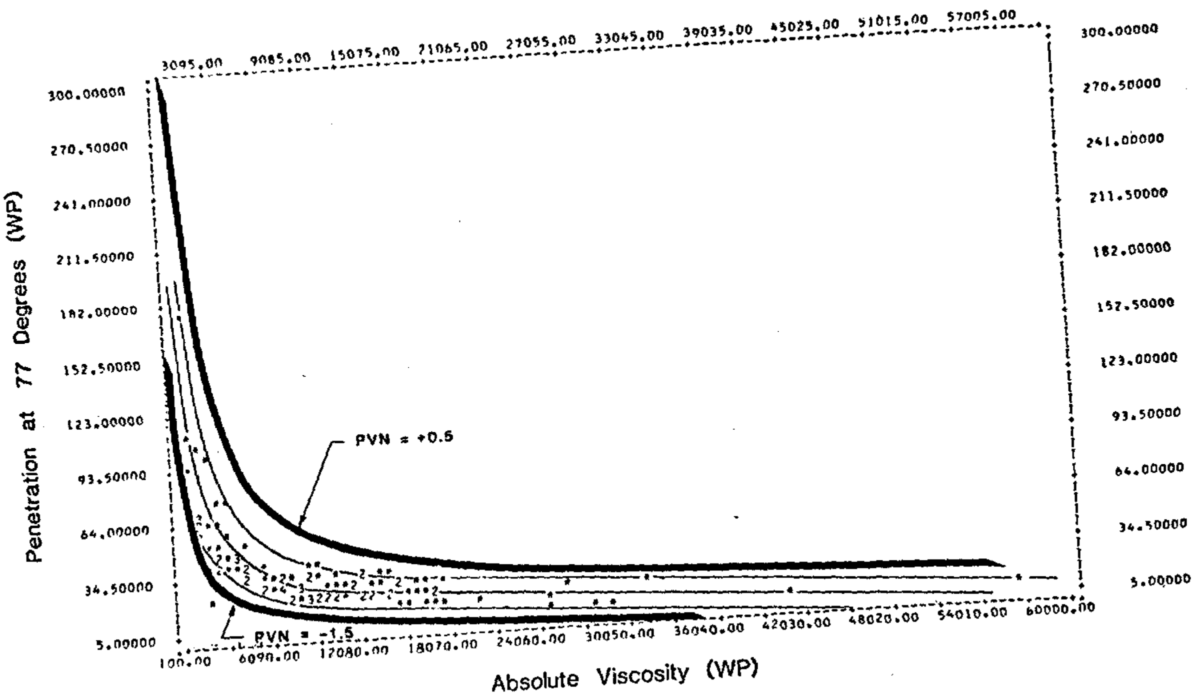


Figure 10-A

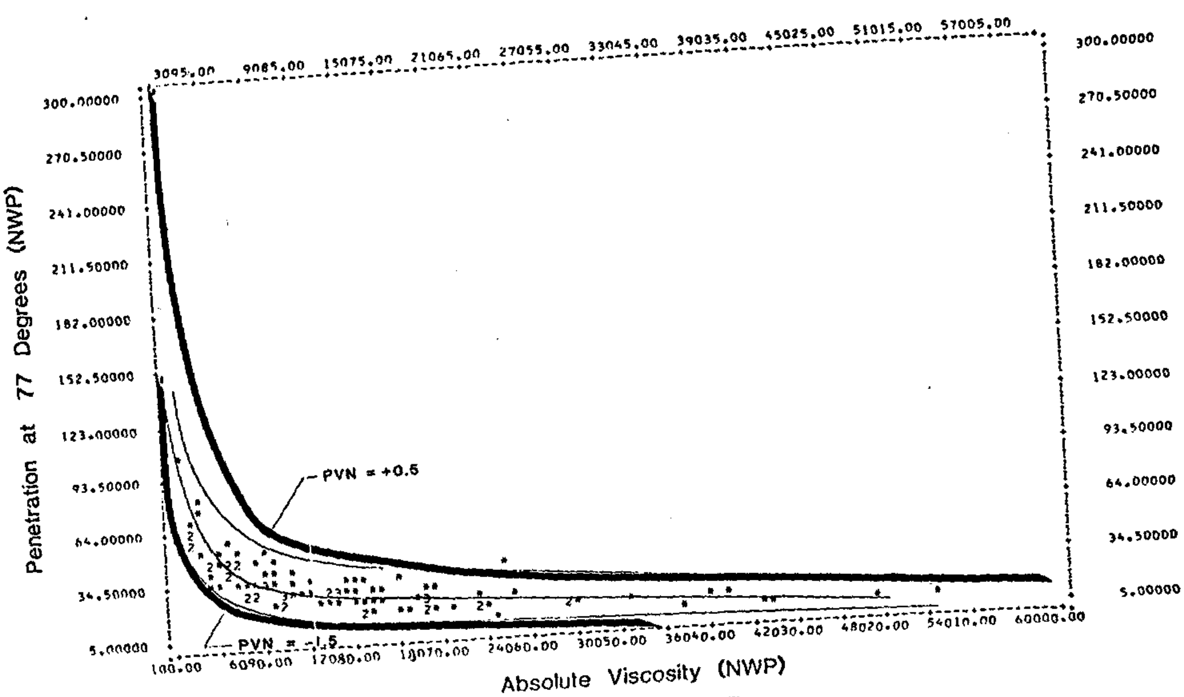


Figure 10-B

2) Plots of absolute viscosity and penetration versus pavement age indicate that considerable age-hardening of asphalts occurs during mixing and placement, or the first 5 to 7 years after placement. These plots also show that materials from the northern areas of Alaska, assumed to have originally been 200-300 pen grade asphalt, ultimately become only slightly less viscous than those which began as 120-150 pen material.

3) Because of the data scatter and obvious non-linearity associated with the asphalt aging process, performance predictions based solely on a knowledge of fresh asphalt properties are simply not possible. Shapes of aging curves illustrated in this report should be considered only as generalizations of the aging process based on available Alaskan data.

4) Temperature susceptibilities vary widely for in-situ Alaskan asphaltic materials. Aging relationships indicate some tendency for asphalts to become somewhat less temperature susceptible with time. This is inferred from the best fit asphalt cement aging curves which show a leveling-out of the decrease in penetration with time while the absolute viscosity continues a fairly steep climb. The nature of the PVN curves are such that holding penetration constant while increasing viscosity will lead to higher positive PVNs and therefore lower temperature susceptibilities.

5) Although usually considered an extremely important predictor of pavement performance, voids content of the asphalt mix showed little correlation with extracted oil viscosities and an even lower

level of correlation with tensile strength of the pavement cores.

CHAPTER VI

- ANALYSIS OF DATA -

PAVEMENT PERFORMANCE

CORRELATIONS AND TRENDS

An Examination of
Pavement Performance Correlations
and Prediction

In this section, an examination is made of the way in which pavement performance tends to be affected by materials and environment. An analytical approach was chosen which would first indicate the relative degree of performance control exerted by any given variable, i.e., through the use of Pearson's correlation (r) values. The performance effects of various combinations of materials variables were then evaluated by 1) multiple regression analysis, 2) the grouping of data at specific performance levels, and 3) examination of extreme performance cases. Standard bivarient and multivarient correlations including regression analysis are herein referred to as "case by case,"i.e., Non-Grouped Data Analysis while examination of averaged grouped-data trends and factors associated with performance extremes will be termed Grouped-Data Analysis. The use of correlation "r" values and regression equations are well known and generally accepted ways of inspecting relationships between variables. It should be noted that correlation coefficients were derived in the form of Pearson's "r" rather than by a ranked data correlation method because trial scatter plots of the data pairs had indicated that the necessary assumption of linear trending data was reasonably justifiable.

Non Grouped Data Analysis:

Bivarient correlation coefficients were calculated for every combination of performance versus materials property. Performance variables were:

1) Rut Depth
2) Miscellaneous Thermal (Map) Cracks
3) Transverse Thermal Cracks
4) Longitudinal Cracks
5) Edge Longitudinal Cracks
6) % Alligator Cracking
7) Full Width Patching

Materials Variables Included:

1) Aggregate Gradation -3/4" to -#200
2) Pavement Thickness
3) % Voids
4) SSD Density
5) Tensile Strength
6) % Asphalt
7) Penetration at 39.2^{o} and $77^{o}F$
8) Absolute Viscosity at $140^{o}F$

Except for aggregate gradation, the materials variables were evaluated in terms of both wheelpath and non-wheelpath data. Correlation coefficients were calculated with and without statistically controlling for the effects of climate. Climate control by means of partial correlation techniques provides, in effect, a correlation coefficient from which the effects of climate have been removed. The reader is referred to previous report section dealing with statistical methods for details concerning partial correlation coefficients. A full listing of coefficients is presented in Appendix D, both with and without climate control. Some of the salient aspects to emerge from the analysis will now be discussed regarding the performance variables.

In table 5, the 10 best correlating factors are summarized for each performance variable. Important variables include tensile strength and penetration/viscosity. No marked differences are obvious between controlled and noncontrolled analysis. Considering those variables with significant r—values of 0.20 or above, it is generally observed that non-thermal, primarily traffic related damage is related to the following in order of decreasing correlation: 1) tensile strength, 2) penetration/viscosity 3) the -#40 and -#200 aggregate fractions and 4) bitumin content. Similarly, thermally induced pavement damage is related to: 1) the -#200 fraction, 2) penetration/viscosity and 3) tensile strength.

Having established the relative statistical strengths of simple bivarient relationships, the next objective was to quantitatively define trends between performance and asphalt concrete variables. At this

Table 5

Note: WP = wheelpath; NWP = non-wheelpath

Best Correlating Variables	Not Controlled for climate effects r—value	Controlled for climate effects r—value
Rut Depth with --		
saturated tensile strength	.50	.41
dry tensile strength	.38	.28
absolute viscosity @140°F, WP	.31	.32
absolute viscosity @140°F, NWP	.28	.32
penetration @77°F, NWP	-.25	-.28
penetration @39.2°F, NWP	-.23	-.26
penetration @39.2°F, WP	-.20	-.19
% - #200 aggregate	.19	.21
% - #40 aggregate	.19	.12
penetration @77°F, WP	-.18	-.19

Important variables include tensile strength and penetration/viscosity. No marked differences are obvious between controlled and noncontrolled analyses.

Alligator Cracking with --		
dry tensile strength	.62	.66
absolute viscosity @140°F, WP	.50	.50
saturated tensile strength	.49	.54
absolute viscosity @140°F, NWP	.47	.48
% - #200 aggregate	.36	.37
penetration @77°F, NWP	-.32	-.35
penetration @39.2°F, NWP	-.25	-.30
penetration @39.2°F, WP	-.23	-.24
penetration @77°F, WP	-.21	-.23
total pvmt. thickness, WP	-.06	-.09

Important variables include tensile strength, penetration/viscosity and %-#200 (mineral filler). No marked differences between controlled and noncontrolled analysis are apparent.

Full Width Patching with --

% - #200 aggregate	.30	.29
total pvmt. thickness, WP	-.13	-.07
penetration @77°F, NWP	-.13	-.16
top layer pvmt. thickness, WP	-.11	-.07
saturated tensile strength	.11	.16
dry tensile strength	.10	.18
total pvmt. thickness, NWP	-.10	-.03
% voids, inner wheelpath	.09	.11
absolute viscosity @140°F, NWP	.08	.08
% voids, @ centerline	.08	.10

Full width patching exhibits only a very low correlation with is significant for only one variable (-#200).

Regular Longitudinal Cracks with --

% - #40 aggregate	.31	.30
dry tensile strength	.28	.20
saturated tensile strength	.24	.16
absolute viscosity @140°F, WP	.21	.18
% - #10 aggregate	.21	.17
maximum density	-.13	.02
penetration @77°F, WP	-.13	-.16
% voids @ shoulder	-.10	-.07
% - #4	.09	.05
penetration @77°F, NWP	-.08	-.13

Important variables include - #10 and #40 aggregate fractions, tensile strength and viscosity of the asphalt.

Edge Longitudinal Cracks with --

penetration @39.2°F, NWP	-.33	-.32
penetration @77°F, NWP	-.30	-.29
penetration @77°F, WP	-.28	-.27
penetration @39.2°F, WP	-.26	-.24
bitumin content, WP	-.22	-.23
saturated tensile strength	.18	.16
% voids @ shoulder	.14	.15
maximum density	.14	.18
top layer pvmt. thickness, WP	-.13	-.18
absolute viscosity @ 140°F, NWP	.12	.13

Important variables include penetration and bitumin content.

Major Transverse Thermal Cracks with --

absolute viscosity @ 140°F, NWP	.32	.32
bitumin content, WP	-.31	-.22
penetration @ 77°F, NWP	-.30	-.33
absolute viscosity @ 140°F, WP	.26	.25
bitumin content, NWP	-.23	-.20
total pvmt. thickness, NWP	-.22	-.05
total pvmt. thickness, WP	-.21	-.05
% - #10 aggregate	-.17	-.07
saturated tensile strength	.17	.31
penetration @ 77°F, WP	-.17	-.16

Important variables include penetration/viscosity, bitumin content and total thickness of the pavement.

Miscellaneous Thermal ("Map") Cracking --

1) Miscellaneous Thermal Cracks (Crossing a Longitudinal Grid Line) with --

% - #40 aggregate	.32	.28
maximum density	-.23	-.16
dry tensile strength	.18	.16
% voids, WP (best correlation is in outer WP)	-.18	-.19
% voids, NWP (best correlation is @ shoulder)	-.17	-.16
% - #200 aggregate	-.13	-.12
% - #10 aggregate	.14	.02
absolute viscosity, NWP	-.12	-.13
bitumin content, WP	.11	.13
saturated tensile strength	.08	.01

Important variables consist of % - #40 aggregate and maximum density.

2) Miscellaneous Thermal Cracks (Crossing a Transverse Grid Line) with --

% - #40 aggregate	.23	.19
penetration @ 77°F, NWP	-.24	-.25
dry tensile strength	.20	.20
penetration @ 77°F, WP	-.15	-.15
saturated tensile strength	.14	.12
absolute viscosity, NWP)	.14	.12
% voids in outer WP	-.13	-.13
bitumin content, NWP	-.11	-.11
S.S.D. density, WP	.11	.18
total pvmt. thickness, WP	-.10	-.10

Important variables include % - #40 aggregate, penetration and tensile strength.

point in the data analysis, the problem of data grouping, i.e., stratification, becomes most obviously important. Ideally, in a study of this type, it would be advisable to construct a controlled experiment. This would require that pavement sections be differentiated for example, into characteristic groups based on similar geologic setting, climatic area and traffic level. The net result of this idealized approach would provide a common base from which to evaluate the relationships of performance versus asphalt concrete materials. As with most things affected by practical reality, this approach would have far exceeded the monetary resources available.

As in other studies of this type, data analysis includes a form of multiple variables analysis. Linear Stepwise Multiple Regression (LSMR) was chosen in order to evaluate each performance variable in terms of combinations of materials properties. In Stepwise analysis, functional relationships are generated from only the "best" of available independent variables. Independent variables in this case are those which describe materials properties. Each analysis was limited to the inclusion of six variables. This was done for uniformity and because the inclusion of additional factors provided no significant enhancement of the analysis. The most important applications of multiple regression analysis are in: 1) determining best fitting linear predictive equations, 2) controlling for extraneous or confounding factors while allowing evaluation of other variables, and 3) delineating general functional relationships which can be used for explaining seemingly complex multivariate relationships. Rather than suggesting direct use of the regression equation as such, they are presented in order that the reader might gain information in the ways suggested below:

1) From the many independent variables considered in a given analysis, which six provide the best correlating group and in what order of priority are they chosen by the stepwise regression approach?

2) From the numerical value and sign of the regression coefficient assigned to each independent variable, it is possible to learn something about the quantitative strength of its control on the dependent variable. One could ask the question, for example: if independent variable "x" changes by a certain amount, how much would the dependent variable "y" be likely to change?

3) It is also possible to use the "multiple r" value as a guide to the significance of each additional variable which is included as a step in the analysis. A new "multiple r" is calculated for the regression equation (as a whole) each time a new variable is added. In many instances, the addition of a fourth or fifth factor affects the multiple r very little and one can assume that further inclusions of variables would be meaningless. The following tables 6 to 11 give the results of LSMR analyses run on the key pavement distress indicator variables. In order to focus on the significance of specific groupings of materials variables, a series of five separate variable assemblages

was evaluated.

Case I N=60 (sample size)

independent variables considered:

1) tensile strength of asphalt concrete cores
2) pavement thickness
3) aggregate gradation
4) air void and density information
5) properties of extracted asphalt

Note: most general case including tensile strength of the asphalt concrete material.

Case II n=60

independent variables considered:

1) tensile strength of asphalt concrete cores
2) pavement thickness
3) air void and density
4) properties of extracted asphalt

Note: removed effects of aggregate gradations on the multi varient equation

Case III n=99

independent variables considered:

1) pavement thickness
2) aggregate gradation
3) air void and density
4) properties of extracted asphalt

Note: removed effects of asphalt concrete strength

Case IV n=99

independent variables considered:

1) pavement thickness
2) air void and density
3) properties of extracted asphalt

Note: removed effects of aggregate gradations and asphalt concrete strength

Case V n=112

independent variables considered:

1) aggregate gradation

An additional regression run was also performed using asphalt core tensile strength as the dependent variable. This was done to delineate those properties of the asphalt concrete core which were apparently controlling tensile strength. In this analysis, the independent variables are as follow:

1) aggregate gradation
2) air void and density
3) properties of extracted asphalt

Regression analysis results are listed in tables 6 through 11, in the order described above. The variables listed on the tables are elements of a standard equation of the type -- $y=a_1x_1+a_2x_2+a_3x_3+....+$ constant; where y is the dependent variable, x = the independent variable and a = the independent variable coefficient.

The regression analyses, taken as a whole, provide an ambiguous picture of pavement performance as related to materials properties. A few generalizations are justifiable, however, in a sense that certain trends do seem fairly evident. The near absence of % voids as an important performance predictor is contrary to the findings of most existing literature. A proposed explanation is that the weathering potential under Alaskan climatic conditions is not high and therefore a relatively high voids mix is not as strongly oxidized by

CASE I REGRESSION ANALYSES Table 6

Number of Cases 60

Type of Independent Variables Considered in Regression Analyses:

1) tensile strength of asphalt concrete core
2) pavement thickness
3) aggregate gradation
4) properties of extracted asphalt
5) air void and density information

RESULTS OF STEPWISE REGRESSION ANALYSES

Dependent Variable	Independent Variable (in order of regression inclusion)	Coefficient	Multiple "R"
Average Rut Depth	absolute viscosity (wheelpath)	3.4 E-06*	.41
	bitumin content (wheelpath)	3.9 E-02	.51
	% - 3/8" aggregate	-3.7 E-03	.53
	% - #200 aggregate	1.0 E-02	.56
	saturated tensile strength	9.0 E-04	.57
	penetration at 77°F (wheelpath)	5.9 E-04	.59
	constant	5.8 E-02	
Regular Longitudinal Cracks	% - #40 aggregate	3.2 E+01	.45
	% - #10 aggregate	3.7 E+01	.52
	absolute viscosity (wheelpath)	2.1 E-04	.56
	bitumin content (non wheelpath)	-6.7 E-01	.58
	absolute viscosity (non wheelpath)	-1.6 E-04	.60
	% voids (non wheelpath)	2.7 E-01	.62
	constant	-16.2	
Edge Longitudinal Cracking	penetration at 39°F (non wheelpath)	-2.4 E-01	.36
	% - #10 aggregate	2.9 E-01	.36
	top layr.pavmt. thickness(wheelpath)	-2.3	.62
	bitumin content (wheelpath)	-1.0	.68
	constant	2.0	
Miscellaneous Thermal Cracks (across transverse grid lines)	% - #40 aggregate	3.9 E-01	.28
	% - #200 aggregate	-7.1 E-01	.34
	bitumin content (non wheelpath)	-7.1 E-01	.37

(* 3.4E-06 = $3.4X10^{6}$)

	top layr.pvmt.thickness(non wheelpath)		.39
	total pvmt. thickness (wheelpath)	5.1	.41
	% voids (non wheelpath)	2.8 E-01	.42
	constant	9.1	
Miscellaneous Thermal Cracks (across longitudinal grid lines)	% - #40 aggregate	6.5 E-01	.46
	absolute viscosity (non wheelpath)	-3.4 E-04	.48
	dry tensile strength	9.4 E-02	.53
	% - #200 aggregate	-9.0 E-01	.55
	top layr.pvmt.thickness(non whlpath)	-4.8	.57
	saturated tensile strength	6.8 E-02	.58
	constant	2.3	
Sum of Alligator Cracking in Both Wheelpaths	dry tensile strength	1.3	.59
	% - #200 aggregate	11.7	.71
	absolute viscosity(non wheelpath)	1.3 E-03	.73
	bitumin content (non wheelpath)	7.0	.74
	% - #40 aggregate	-1.0	.75
	tp.layr.pvmt.thickness(non whlpath)	14.7	.76
	constant	-180.9	
Major Transverse Cracks	bitumin content (wheelpath)	-7.4	.39
	% - 3/8" aggregate	6.5 E-01	.46
	% - #10 aggregate	-2.4	.49
	% - #4 aggregate	1.8	.51
	% - #200 aggregate	-2.1	.53
	penetration at 77°F(non wheelpath)	-1.9 E-01	.54
	constant	57.3	
Full Width Patching	% - #200 aggregate	169.2	.41
	penetration at 77°F(non wheelpath)	-5.9	.48
	% - 3/8" aggregate	-18.0	.49
	total pvmt. thickness(nonwheelpath)	200.5	.51
	dry tensile strength	3.7	.52
	penetration at 39.2°F(wheelpath)	10.0	.53
	constant	-29.1	

CASE 11 REGRESSION ANALYSES Table 7

Number of Cases 60
Type of Independent Variables Considered in Regression Analyses:
1) tensile strength
2) pavement thickness
3) properties of extracted oils
4) air void and density information

RESULTS OF STEPWISE REGRESSION ANALYSES

Dependent Variable	Independent Variable (in order of regression inclusion)	Coefficient	Multiple "R"
Average Rut Depth	absolute viscosity(wheelpath)	4.4 E-06	.41
	bitumin content (wheelpath)	3.8 E-02	.51
	saturated tensile strength	8.7 E-04	.54
	absolute viscosity(non wheelpath)	1.8 E-06	.54
	penetration at 77°F (wheelpath)	4.2 E-04	.55
	top layr.pvmt.thickness(wheelpath)	-2.8 E-02	.56
	constant	-1.1 E-01	
Regular Longitudinal Cracks	S.S.D. Density(non wheelpath)	-2.8 E-01	.21
	% voids (wheelpath)	-1.7 E-01	.27
	saturated tensile strength	4.5 E-02	.31
	penetration at 39.2°F(non wheelpath)	1.1 E-01	.34
	absolute viscosity (wheelpath)	9.1 E-05	.35
	bitumin content (wheelpath)	7.6 E-01	.37
	constant	36.5	
Edge Longitudinal Cracking	penetration at 39.2°F(non wheelpath)	-2.4 E-01	.36
	top layr.pvmt.thickness(wheelpath)	-2.7	.50
	dry tensile strength	-3.7 E-02	.55
	bitumin content (non wheelpath)	3.7 E-01	.59
	S.S.D. Density (wheelpath)	-1.4 E-01	.62
	penetration at 77°F (wheelpath)	-9.9 E-03	.63
	constant	29.3	
Miscellaneous Thermal Cracks (across transverse grid lines)	dry tensile strength	7.9 E-02	.15
	absolute viscosity (wheelpath)	-2.0 E-04	.20
	absolute viscosity (non wheelpath)	1.4 E-04	.23

	penetration at 39.2°F(non wheelpath)	5.6 E-01	.26
	penetration at 77°F(non wheelpath)	-1.9 E-01	.33
	S.S.D.Density (wheelpath)	2.5 E-01	.36
	constant	-35.2	
Miscellaneous Thermal Cracks (across longitudinal grid lines)	maximum density	-1.0 E-01	.35
	dry tensile strength	1.1 E-01	.38
	absolute viscosity (non wheelpath)	-3.7 E-04	.42
	penetration at 77°F (non wheelpath)	-1.2 E-01	.44
	top layr.pvmt.thickness(nonwheelpath)	-4.4	.46
	bitumin content (non wheelpath)	-7.9 E-01	.47
	constant	177.0	
Sum of Alligator Cracking in Both Wheelpaths	dry tensile strength	9.2 E-01	.59
	absolute viscosity (non wheelpath)	1.4 E-03	.60
	bitumin content (wheelpath)	16.7	.64
	saturated tensile strength	4.8 E-01	.66
	bitumin content (non wheelpath)	6.3	.67
	maximum density	2.5	.68
	constant	-581.0	
Major Transverse Cracks	bitumin content (wheelpath)	-5.2	.39
	% voids (wheelpath)	5.3	.45
	dry tensile strength	-2.8 E-01	.47
	penetration at 77°F(non wheelpath)	-5.1 E-01	.49
	% voids (non wheelpath)	-3.8	.51
	penetration at 77°F (wheelpath)	1.3 E-01	.53
	constant	101.0	
Full Width Patching	dry tensile strength	4.6	.20
	penetration at 77°F (non wheelpath)	-8.1	.22
	top layr.pvmt.thickness(wheelpath)	-521.4	.24
	total pvmt.thickness(nonwheelpath)	492.0	.27
	penetration at 39.2°F (non wheelpath)	13.0	.28
	bitumin content (non wheelpath)	22.2	.29
	constant	27.6	

CASE 111 REGRESSION ANALYSES Table 8

Number of Cases 99

Type of Independent Variables Considered in Regression Analyses:

1) pavement thickness
2) aggregate gradation
3) properties of extracted oils
4) air void and density information

RESULTS OF STEPWISE REGRESSION ANALYSES

Dependent Variable	Independent Variable (in order of regression inclusion)	Coefficient	Multiple "R"
Average Rut Depth	absolute viscosity (non wheelpath)	2.4 E-06	.22
	bitumin content (wheelpath)	8.1 E-03	.31
	penetration at 39.2°F (non wheelpath)	-3.4 E-03	.35
	maximum density	-9.2 E-03	.39
	top layr.pvmt.thickness(wheelpath)	5.5 E-02	.42
	total pvmt.thickness(non wheelpath)	1.5	.49
	constant		
Regular Longitudinal Cracks	% - #40 aggregate	2.4 E-01	.36
	absolute viscosity (wheelpath)	1.1 E-04	.39
	penetration at 39.2°F (wheelpath)	3.3 E-01	.43
	penetration at 77°F (wheelpath)	-8.8 E-02	.49
	% - #10 aggregate	1.9 E-01	.51
	top layr.pvmt.thickness (wheelpath)	1.7	.54
	constant	-15.0	
Edge Longitudinal Cracks	penetration at 39.2°F (non wheelpath)	-8.3 E-02	.32
	penetration at 77°F (wheelpath)	-1.9 E-02	.36
	% - #10	1.3 E-01	.38
	% - #40	-8.5 E-02	.41
	bitumin content (wheelpath)	-7.5 E-01	.44

	bitumin content (non wheelpath)	3.8 E-01	.46
	constant	2.0	
Miscellaneous Thermal Cracks (across transverse grid lines	% - #40 aggregate	4.0 E-01	.25
	penetration at 77°F (non wheelpath)	-9.1 E-02	.34
	penetration at 39.2°F (wheelpath)	4.2 E-01	.39
	penetration at 77°F (wheelpath)	-9.8 E-02	.43
	maximum density	3.0 E-01	.45
	% - #200 aggregate	-3.6 E-01	.46
	constant	-47.0	
Miscellaneous Thermal Cracks (across longitudinal grid lines)	% - #40 aggregate	3.9 E-01	.38
	% - #200 aggregate	-7.4 E-01	.42
	maximum density	-1.4 E-02	.43
	% - #4 aggregate	-1.2	.45
	% - 3/8" aggregate	5.6 E-01	.46
	% - #10 aggregate	9.4 E-01	.51
	constant	-9.0	
Sum of Alligator Cracking in Both Wheelpaths	absolute viscosity (non wheelpath)	1.6 E-03	.44
	% - #200 aggregate	6.8	.55
	bitumin content (wheelpath)	9.3	.57
	absolute viscosity (wheelpath)	9.9 E-04	.59
	top layr.pvmt.thickness(nonwheelpath)	18.2	.60
	total pvmt.layr.thickness(wheelpath)	-8.3	.60
	constant	-128.0	
Major Transverse Cracks	bitumin content (wheelpath)	-9.9	.31
	penetration at 39.2°F (wheelpath)	2.1	.38
	penetration at 77°F (wheelpath)	-4.8 E-01	.48
	absolute viscosity (non wheelpath)	7.4 E-04	.52
	% - 3/8" aggregate	1.4	.55
	% - #10 aggregate	-1.5	.58
	constant	38.0	
Full Width Patching	% - #200 aggregate	127.2	.36
	penetration at 77°F (non wheelpath)	-8.2	.42
	penetration at 39.2°F (non wheelpath)	9.4	.44
	% - #4 aggregate	-16.9	.45
	% voids (wheelpath)	32.8	.46
	bitumin content (wheelpath)	65.1	.47
	constant	-167.0	

CASE IV REGRESSION ANALYSES Table 9

Number of Cases 99

Type of Independent Variables Considered in Regression Analyses:

1) pavement thickness
2) properties of extracted oils
3) air void and density information

RESULTS OF STEPWISE REGRESSION ANALYSES

Dependent Variable	Independent Variable (in order of regression inclusion)	Coefficient	Multiple "R"
Average Rut Depth	absolute viscosity (non wheelpath)	2.4 E-06	.22
	bitumin content (wheelpath)	8.1 E-03	.31
	penetration at 39.2°F (non wheelpath)	-3.4 E-03	.34
	maximum density	-8.4 E-03	.39
	top layr.pvmt.thickness(wheelpath)	-9.2 E-02	.42
	total pvmt. thickness(nonwheelpath)	5.5 E-02	.49
	constant	1.5	
Regular Longitudinal Cracks	maximum density	-1.0 E-01	.14
	absolute viscosity (wheelpath)	1.8 E-04	.20
	penetration at 39.2°F (wheelpath)	3.0 E-01	.76
	penetration at 77°F (wheelpath)	-6.8 E-02	.35
	absolute viscosity (non wheelpath)	-1.1 E-04	.36
	penetration at 77°F(non wheelpath)	-3.4 E-02	.37
	constant	19.0	
Edge Longitudinal Cracks	penetration at 39.2°F(non wheelpath)	-1.3 E-01	.32
	penetration at 77°F (wheelpath)	-3.4 E-02	.36

	bitumin content (wheelpath)	-7.2 E-01	.37
	bitumin content (non wheelpath)	4.5 E-01	.41
	absolute viscosity (wheelpath)	-4.3 E-05	.42
	penetration at 39.2°F (wheelpath)	7.2 E-02	.43
	constant	5.0	
Miscellaneous Thermal Cracks (across transverse grid lines)	penetration at 77°F (non wheelpath)	-1.2 E-01	.22
	penetration at 39.2°F (non wheelpath)	5.7 E-02	.30
	% voids (wheelpath)	-3.1 E-02	.33
	penetration at 39.2°F (wheelpath)	3.3 E-01	.34
	penetration at 77°F (wheelpath)	-7.7 E-02	.36
	bitumin content (non wheelpath)	-4.5 E-01	.37
	constant	11.0	
Miscellaneous Thermal Cracks (across longitudinal grid lines)	maximum density	-8.4 E-01	.24
	penetration at 77°F (non wheelpath)	-2.1 E-01	.26
	absolute viscosity (non wheelpath)	-1.6 E-04	.30
	penetration at 39.2°F (non wheelpath)	2.8 E-01	.32
	S.S.D.Density (wheelpath)	3.0 E-01	.34
	bitumin content (non wheelpath)	-6.0 E-01	.35
	constant	100.0	
Sum of Alligator Cracking in Both Wheel Paths	absolute viscosity (non wheelpath)	1.7 E-03	44
	bitumin content (wheelpath)	14.6	50
	absolute viscosity (wheelpath)	7.9 E-04	52
	top layr.pvmt.thickness(nonwheelpath)	18.7	53
	total pvmt.thickness(wheelpath)	-12.4	54
	penetration at 39.2°F (wheelpath)	-5.5 E-01	55
	constant	-93.0	
Major Transverse Cracks	bitumin content (wheelpath)	-8.2	.31
	penetration at 39.2°F (wheelpath)	1.1	.38
	penetration at 77°F (wheelpath)	-9.2 E-02	.48
	absolute viscosity (non wheelpath)	6.0 E-04	.52
	penetration at 77°F (non wheelpath)	-8.2 E-01	.53
	penetration at 39.2°F(non wheelpath)	1.8	.56
	constant	84.0	
Full Width Patching	penetration at 77°F (non wheelpath)	-4.8	.15
	total pvmt.thickness(wheelpath)	-342.9	.19
	total pvmt.thickness(non wheelpath)	256.2	.23
	bitumin content (wheelpath)	53.9	.25
	absolute viscosity (wheelpath)	7.7 E-03	.26
	penetration 39.2°F (wheelpath)	6.1	.27
	constant	49.3	

CASE V REGRESSION ANALYSES Table 10

Number of Cases 112
Type of Independent Variables Considered in Regression Analyses:
1) aggregate gradation

RESULTS OF STEPWISE REGRESSION ANALYSES

Dependent Variable	Independent Variable (in order of regression inclusion)	Coefficient	Multiple "R"
Average Rut Depth	% - #40 aggregate	5.5 E-03	.18
	% - #200 aggregate	6.5 E-03	.20
	% - 3/8" aggregate	-5.5 E-03	.22
	% - #4 aggregate	9.7 E-03	.24
	% - #10 aggregate	-7.5 E-03	.28
	constant	0.2	
Regular Longitudinal Cracks	% - #40 aggregate	2.1 E-01	.33
	% - #200 aggregate	4.7 E-01	.36
	% - #10 aggregate	3.4 E-01	.39
	% - 3/8" aggregate	1.6 E-01	.39
	% - #4 aggregate	-2.9 E-01	.40
	constant	-8.0	
Edge Longitudinal Cracks	% - #200 aggregate	-2.5 E-01	.16

	% - 3/8" aggregate	-1.6 E-01	.17
	% - #4 aggregate	2.7 E-01	.24
	% - #10 aggregate	-1.4 E-01	.26
	% - #40 aggregate	1.6 E-02	.26
	constant	7.0	
Miscellaneous Thermal Cracks (across transverse grid lines)	% - #40 aggregate	4.0 E-01	.24
	% - #200 aggregate	-6.0 E-01	.30
	% - #10 aggregate	-2.9 E-01	.31
	% - #4 aggregate	1.9 E-01	.32
	% - 3/8" aggregate	-8.7 E-02	.32
	constant	9.0	
Miscellaneous Thermal Cracks (across longitudinal grid lines)	% - #40 aggregate	3.1 E-01	.35
	% - #200 aggregate	-8.5 E-01	.41
	% - #4 aggregate	-1.2	.42
	% - #10 aggregate	1.1	.47
	% - 3/8" aggregate	4.2 E-01	.50
	constant	-6.0	
Sum of Alligator Cracking in Both Wheelpaths	% - #200 aggregate	7.0	.31
	% - 3/8" aggregate	-2.2	.32
	% - 4 aggregate	4.1	.34
	% - #10 aggregate	3.6	.36
	% - #40 aggregate	9.7 E-01	.38
	constant	35.0	
Major Transverse Cracks	% - #10 aggregate	-3.8	.23
	% - #4 aggregate	2.2	.30
	% - #200 aggregate	3.7	.35
	% - #40 aggregate	5.1 E-01	.36
	% - 3/8" aggregate	1.3 E-01	.36
	constant	84.0	
Full Width Patching	% - #200 aggregate	91.6	.32
	% - 3/8" aggregate	-15.5	.35
	% - #10 aggregate	-26.9	.36
	% - #4 aggregate	20.7	.37
	% - #40 aggregate	7.3	.37
	constant	516.0	

REGRESSION ANALYSES Table 11

CORRELATION OF ASPHALT CORE TENSILE STRENGTH WITH MATERIAL PROPERTIES

Number of Cases 60

Type of Independent Variables Considered in Regression Analyses:

1) aggregate gradation
2) properties of extracted oil
3) air void and density information

RESULTS OF STEPWISE REGRESSION ANALYSES

Dependent Variable	Independent Variable (in order of regression inclusion)	Coefficient	Multiple "R"
Saturated Tensile Strength	absolute viscosity (wheelpath)	1.3 E-03	.61
	penetration at 39.2°F (non wheelpath)	-1.6	.68
	maximum density	-1.2	.70
	bitumin content (non wheelpath)	-1.8	.71
	absolute viscosity (non wheelpath)	-3.9 E-04	.71
	penetration at 77°F (wheelpath)	6.7 E-02	.71
	constant	262.0	
Dry Tensile Strength	absolute viscosity (wheelpath)	9.9 E-04	.58
	penetration at 39.2°F (non wheelpath)	-7.3 E-01	.62
	bitumin content (wheelpath)	6.8	.68
	bitumin content (non wheel path)	-3.1	.70
	maximum density	-1.0	.71
	penetration at 77°F (non wheelpath)	-2.4 E-01	.72
	constant	198.0	

the environment as noted in many locations. The existing voids may also exhibit relatively low interconnection due to the soft asphalts or other properties of the asphalt concrete mix which are utilized in Alaska. The net result may provide low permeability for a given voids content and prevent chemically active fluids and air from oxidizing the asphalt cement. Low tensile strengths are usually but not always associated with better performance. Best performance also appears associated most frequently with high penetrations (77°F) and low viscosities (140°F). In viewing these results, one should keep in mind that the multiple r-values are much lower than would ideally be obtained. The change in multiple r with the addition of succeeding regression variables also indicates that usually only the first two or three terms are actually significant. The fourth through sixth terms should in most cases be disregarded.

Regarding the use of regression equations derived for the prediction of saturated and dry tensile strength, it is interesting to note that low absolute viscosity and high penetration is associated with lower asphalt concrete tensile strengths. It is also interesting that aggregate gradation was not brought into the equation of tensile strength, which reinforces the importance of asphalt cement as a principal factor in determining the ultimate tensile strength of asphalt concrete.

The author cautions readers to beware of attempting to read too much into the regression analyses. This statistical tool is quite as well known for raising additional questions as it is for providing an understanding of the problem at hand. The assumption that lack of sample stratification and generally small sample size adversely affects analytical results is justified by observing multiple r—values which rarely rise above 0.6.

The Preceding regressions considered wheelpath and non-wheelpath data as separate variables in the same analyses. A comparison was also made, however, between multiple regression r — values derived using <u>only</u> wheelpath data with those derived using <u>only</u> non-wheelpath data. The correlations indicated in table 12 were produced by using only variables which could be differentiated as wheelpath or non-wheelpath in nature. The purpose intended here is to determine the best locations, i.e., WP or NWP from which to obtain pavement core samples (or data) which is most highly associated with performance.

Table 12

dependent variable	Multiple r from wheelpath data	Multiple r from non-wheelpath data
Rut depth	.54	.42
Reg. longitudinal cracks	.38	.30
Edge longitudinal cracks	.47	.55
Misc. thermal cracks, crossing transverse line	.25	.28
Misc. thermal cracks, crossing longitudinal line	.38	.44
Alligator cracking	.61	.51
Major transverse cracks	.47	.39
Patching	.21	.21

In view of these data, it would be difficult to justify the suggestion that performance can be best related to either wheelpath or non-wheelpath materials although the r-values are slightly different. There is some subtle inclination, however, to form the highest fatigue damage correlations with wheelpath data. Conversely, non-wheelpath data is slightly better correlated with thermal distress, notably excepting major transverse thermal cracks.

Grouped Data Analysis:

Figures 11 through 18 are data plots based on the assumption that similar levels of performance can be characterized by similar materials properties. Each of the figures is a series of bivarient plots describing a specific performance variable. Six materials variables were chosen for each figure on the basis of highest simple correlation. It should be noted that in each figure, bivarient correlations, and therefore statistical significance of the trend line, decreases in normal reading fashion (left to right-top to bottom). This approach, as explained in an earlier section of this report, allows the researcher to evaluate bivarient relationships while filtering (averaging) out the extraneous controls exerted by other variables. Materials properties were plotted using both mean and median values because each is a strong indicator of central tendency.

The interval separating mean and median values could, in fact, be thought of as a range of central tendency. The highest degree of confidence would of course be placed on central tendency points arising from a coincident mean and median. Although a somewhat "abstract" form of analysis, the expedient of using grouped-data plots allows a fairly simple interpretation of trends and optimum values when meaningful point by point correlations have been found to have low statistical significance.

Figures 11 through 18 are easily interpreted in their present form without the addition of trend lines, which are, themselves, another unnecessary level of interpretation. Optimum materials properties are summarized for each figure in table 13, for cases where relationships appear significant.

Figure 11
RELATIONSHIPS BETWEEN AVERAGE RUT DEPTH AND ASPHALT CONCRETE PROPERTIES

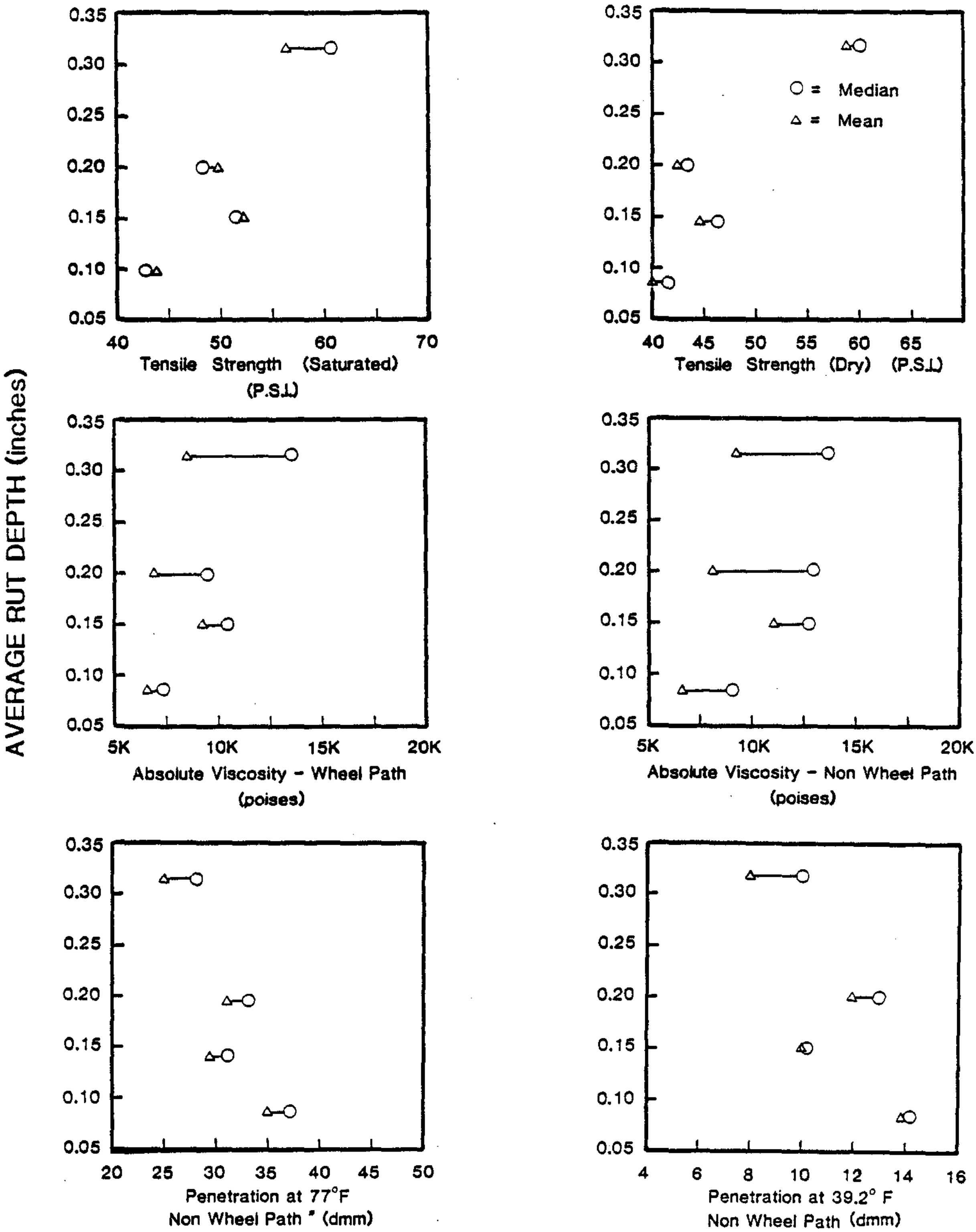


Figure 12

RELATIONSHIPS BETWEEN MISCELLANEOUS THERMAL CRACKS
(CROSSING LONGITUDINAL GRID LINES)
AND ASPHALT CONCRETE PROPERTIES

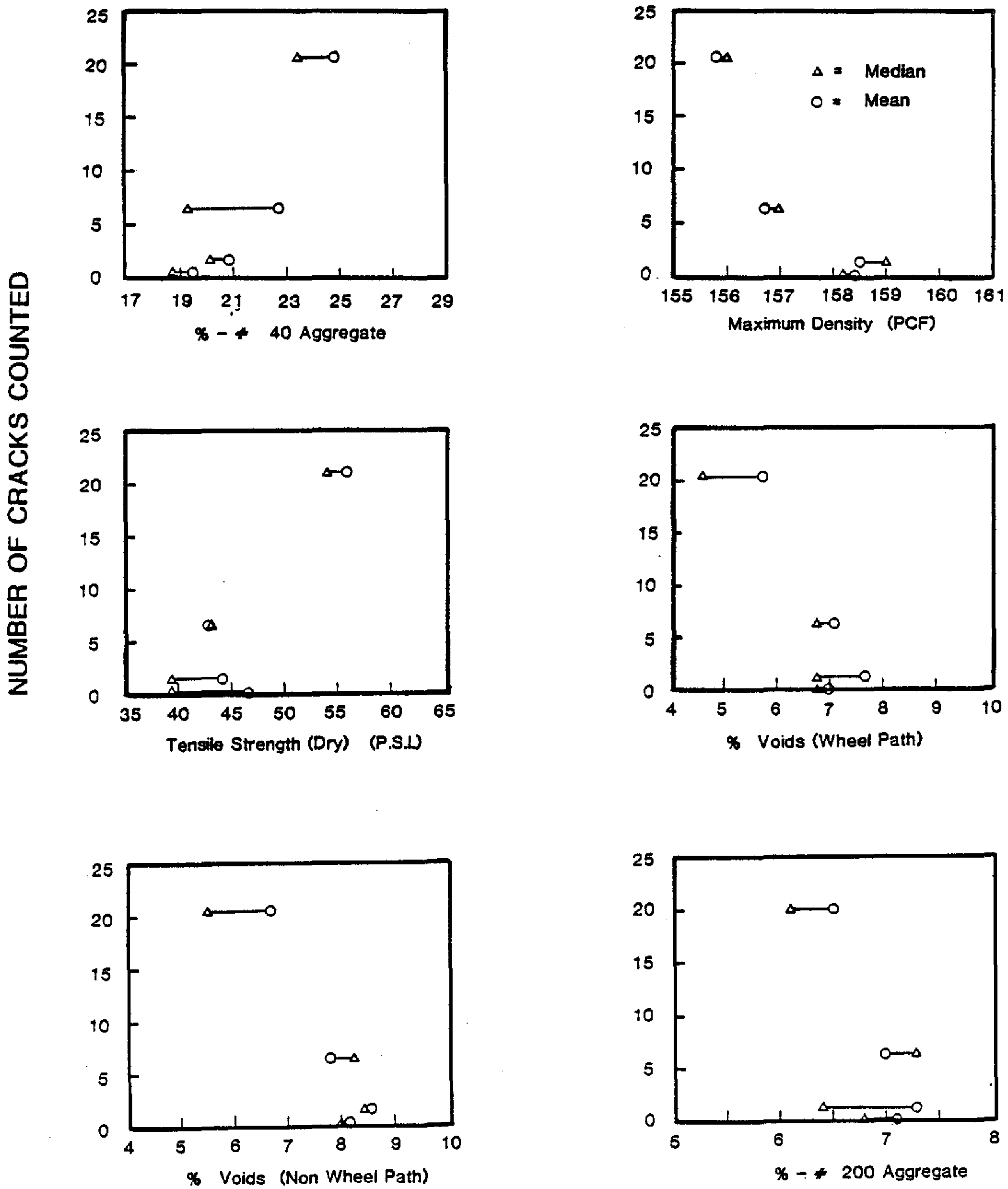


Figure 13

RELATIONSHIPS BETWEEN MISCELLANEOUS THERMAL CRACKS (CROSSING TRANSVERSE GRID LINES) AND ASPHALT CONCRETE PROPERTIES

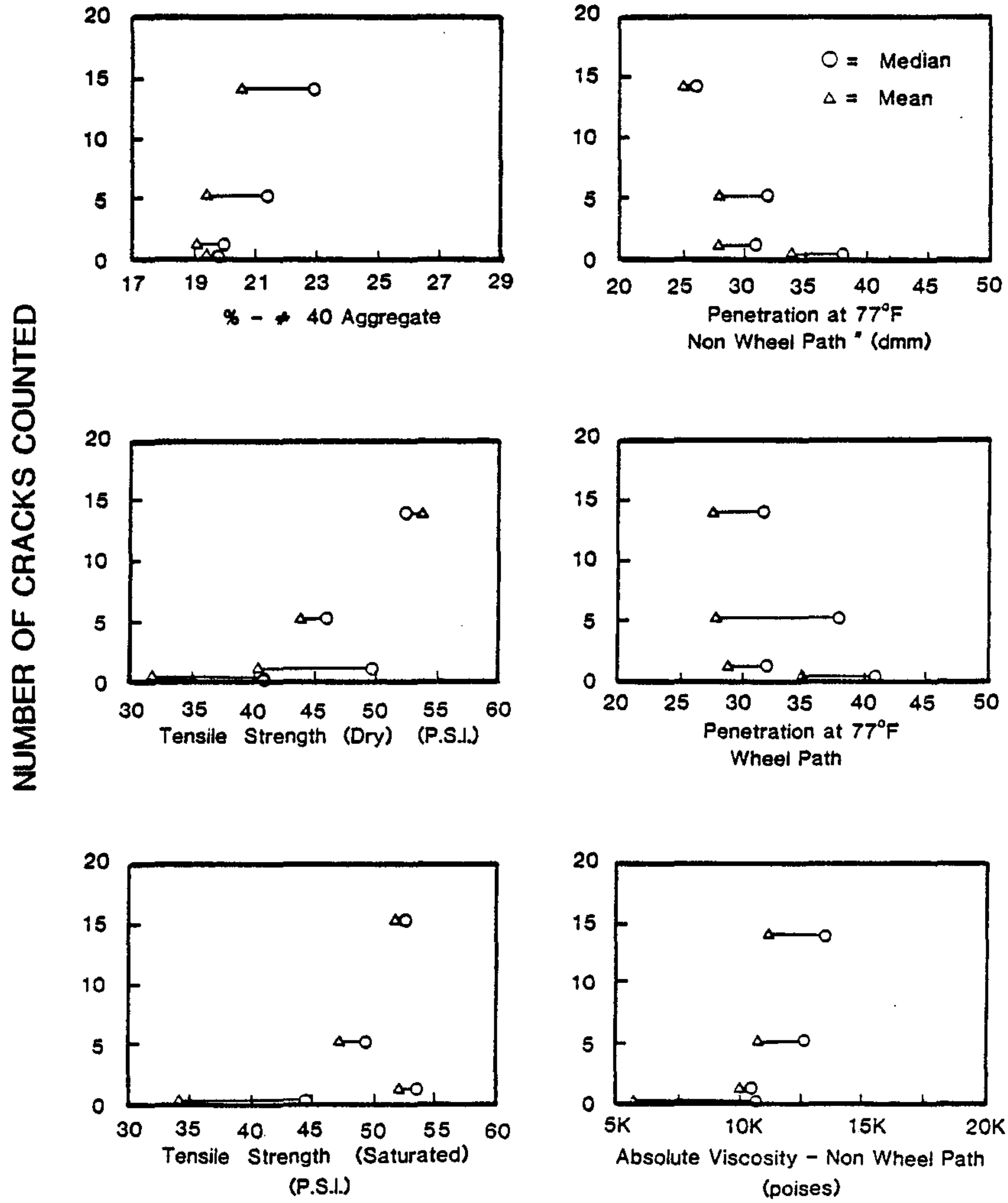


Figure 14

RELATIONSHIPS BETWEEN EDGE LONGITUDINAL CRACKING AND ASPHALT CONCRETE PROPERTIES

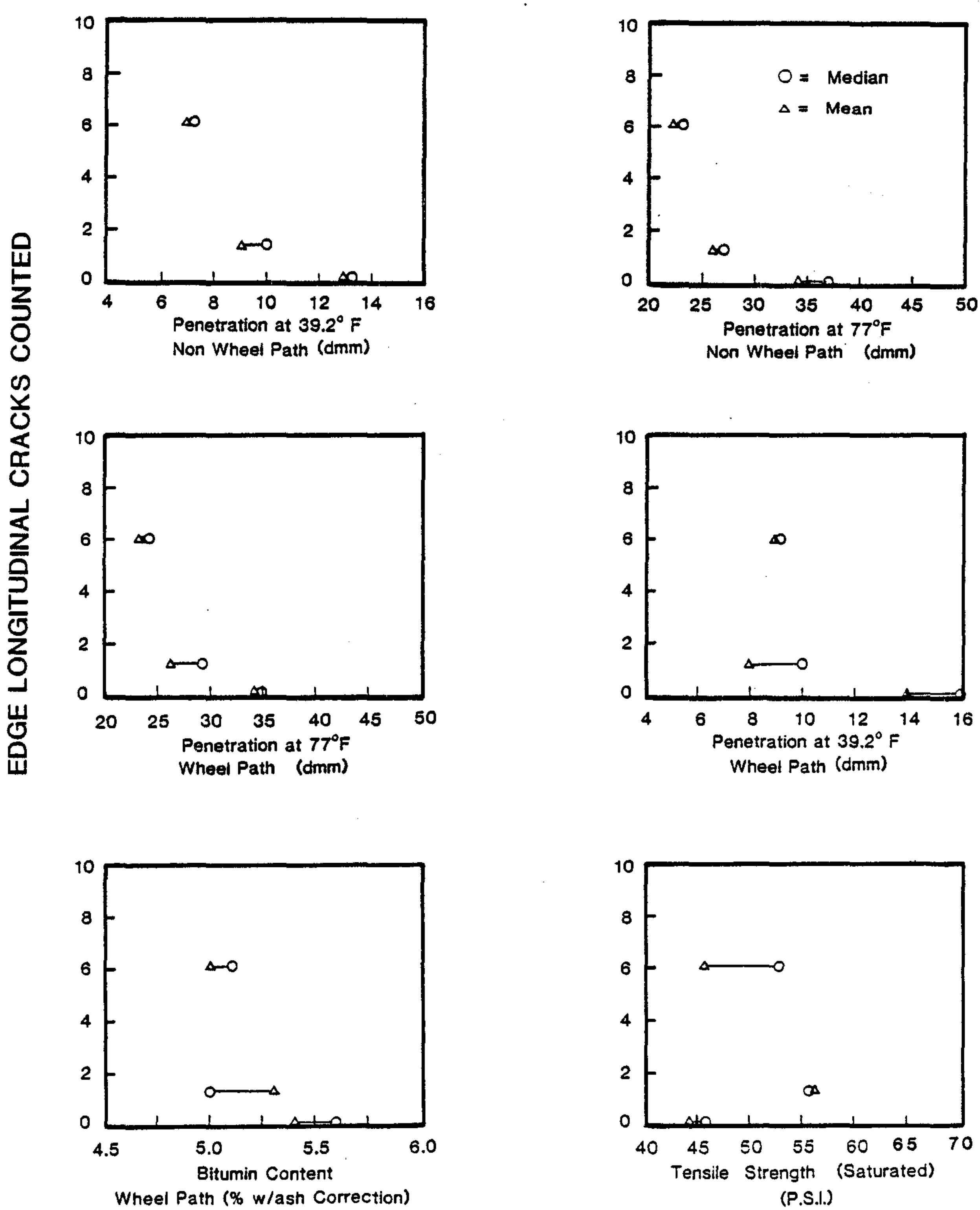


Figure 15

RELATIONSHIPS BETWEEN REGULAR LONGITUDINAL CRACKS AND ASPHALT CONCRETE PROPERTIES

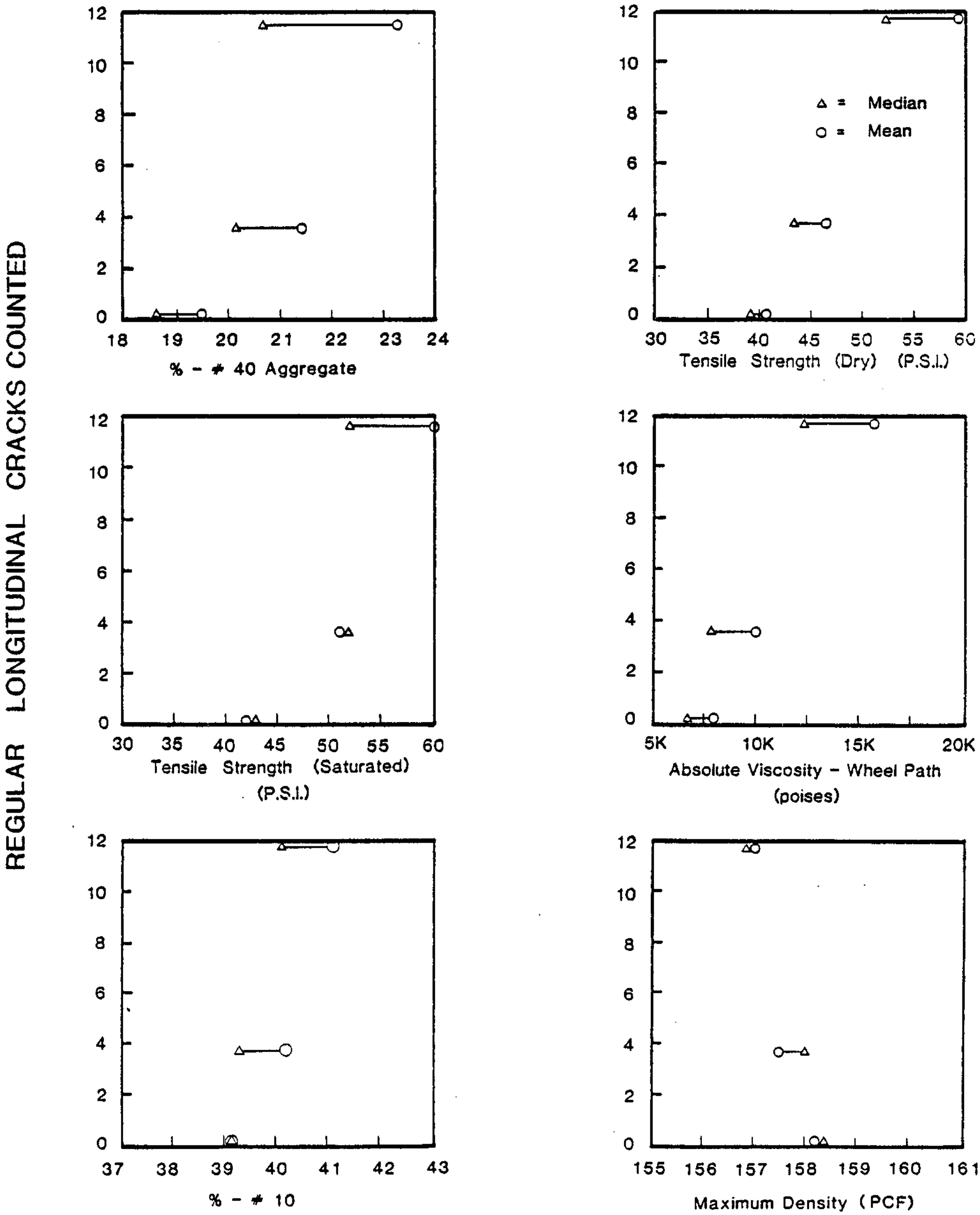


Figure 16

RELATIONSHIPS BETWEEN TOTAL PERCENT ALLIGATOR CRACKING AND ASPHALT CONCRETE PROPERTIES

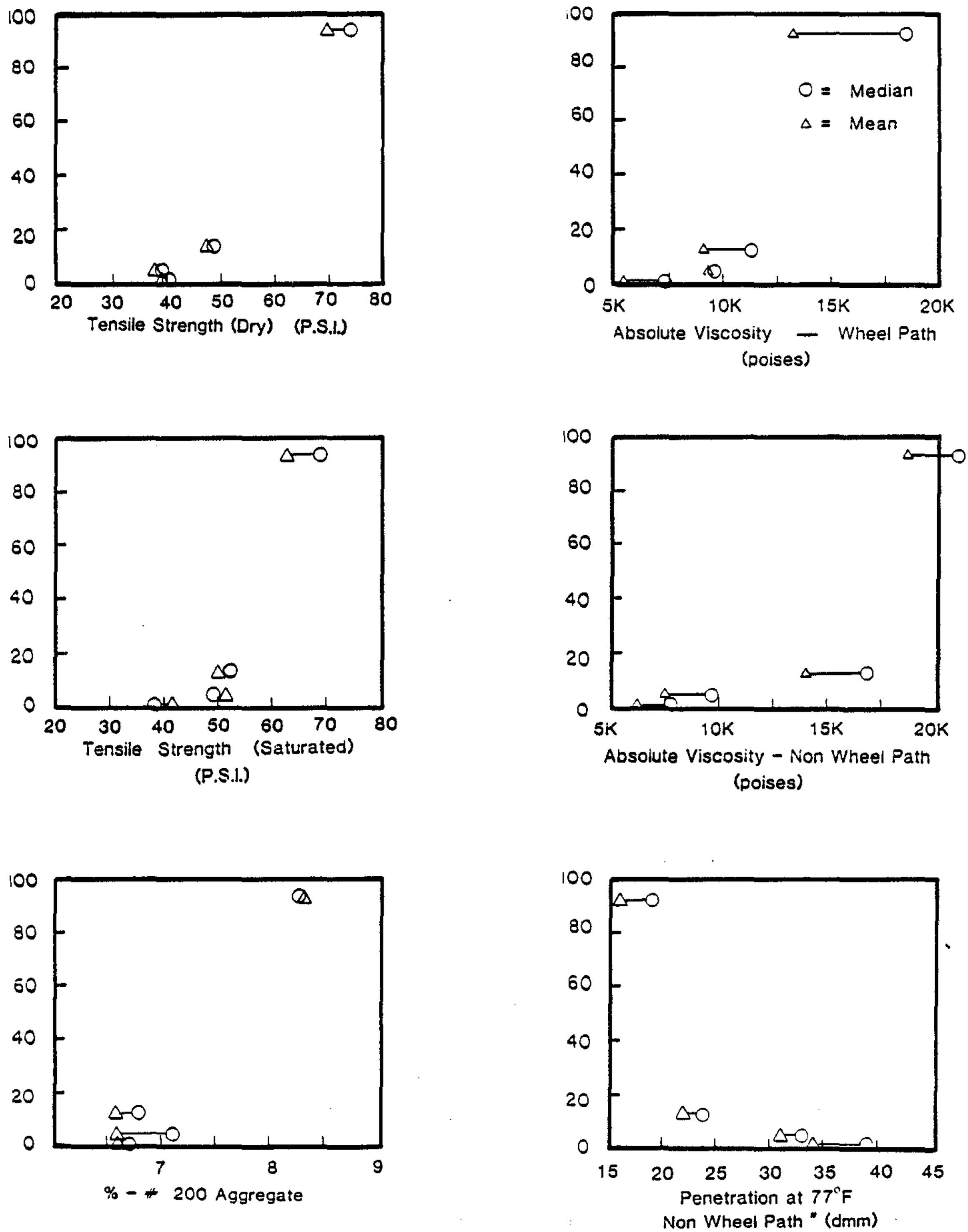


Figure 17

RELATIONSHIPS BETWEEN MAJOR THERMAL CRACKING AND ASPHALT CONCRETE PROPERTIES

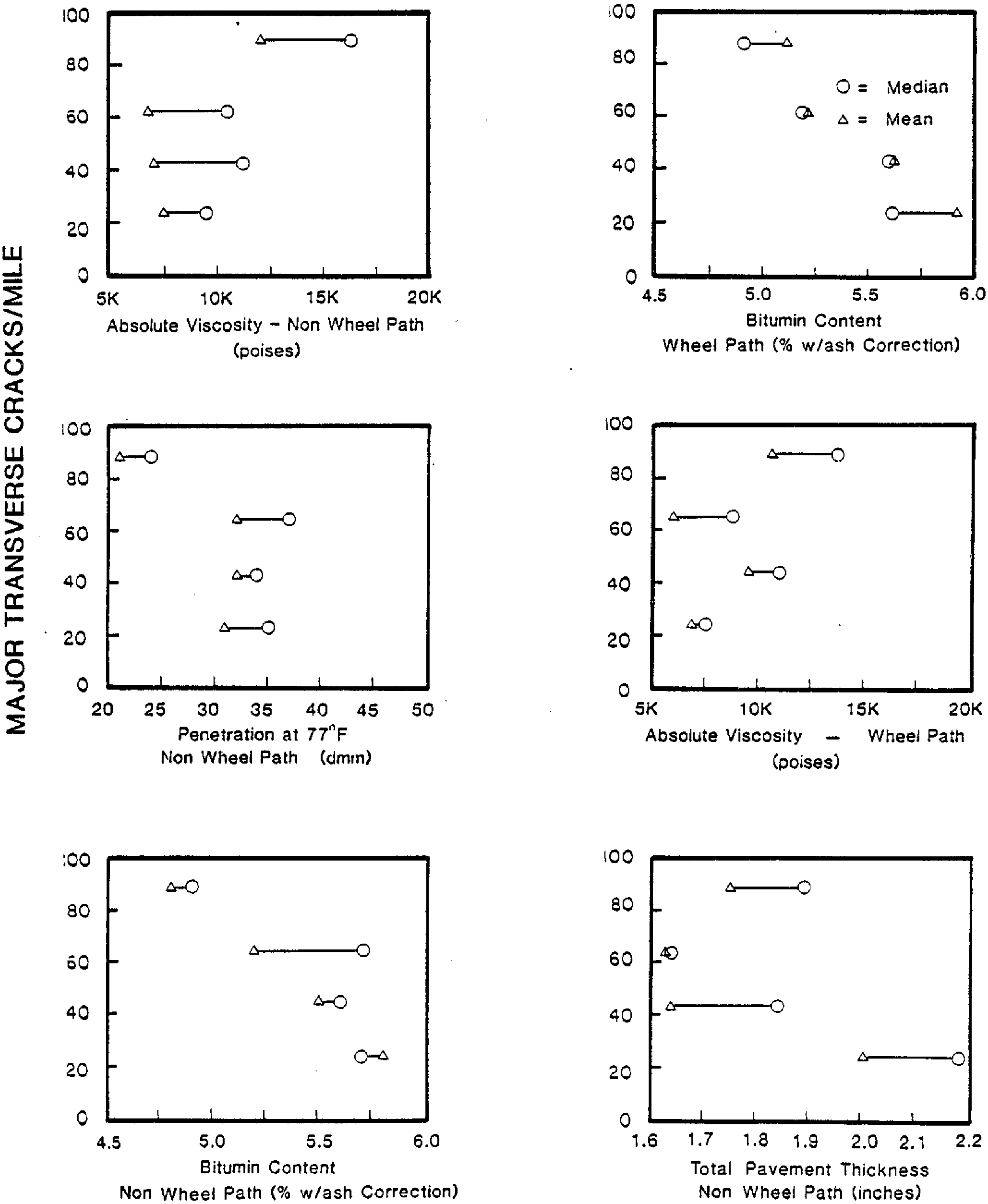
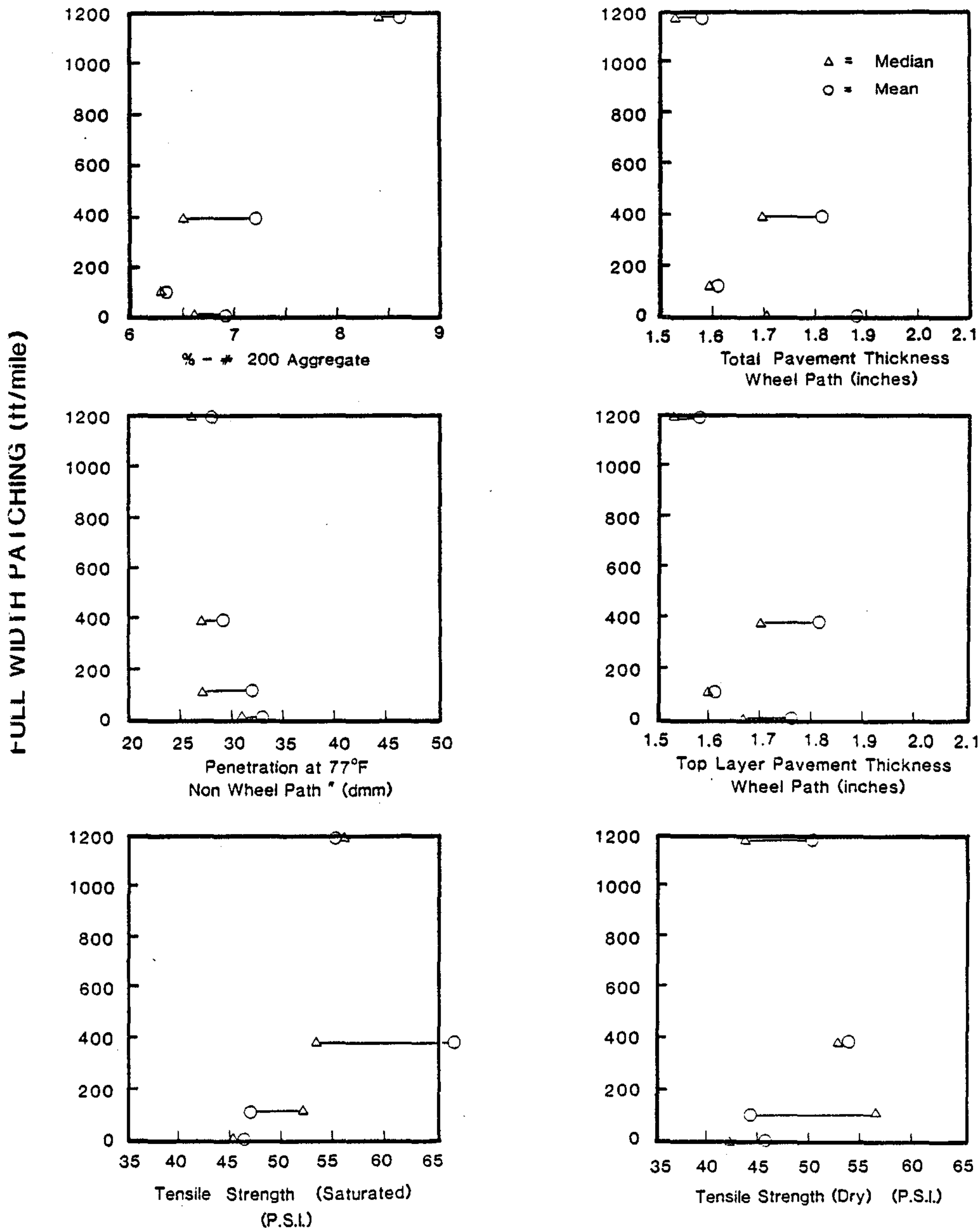


Figure 18

RELATIONSHIPS BETWEEN FULL WIDTH PATCHING AND ASPHALT CONCRETE PROPERTIES



-Table 13-

From Figure 11

Dependent Variable--Average Rut Depth

Optimum Materials:

saturated tensile strength	40 psi max *
dry tensile strength	40 psi max
absolute viscosity @ 140°F	6,000 poises max
penetration @ 77°F	40 dmm min
penetration @ 39.2°F	15 dmm min

* see proposed explanation for these apparently anomalous trends in the following text.

From Figure 12

Dependent Variable--Miscellaneous Thermal Cracks (crossing longitudinal grid lines)

Optimum Materials:

-#40 aggregate	19% max
maximum density	160 pcf min
dry tensile strength	40 psi max
% voids	7.5% min *
-#200 aggregate	7.5% *

*considered questionable

From Figure 13

Dependent Variable--Miscellaneous Thermal Cracks (crossing transverse grid lines)

Optimum Materials:

-40 aggregate	19% max
penetration @77°F	35 dmm min

dry tensile strength	40 psi max
saturated tensile strength	40 psi max
absolute viscosity @ 140°F	8,000 poises max

From Figure 14

Dependent Variable--Edge Longitudinal Cracks

Optimum Materials:

penetration @ 39.2°F	13 dmm min
penetration @ 77°F	35 dmm min
bitumin content	5.5% min
saturated tensile strength	45 psi max *

* considered questionable

From Figure 15

Dependent Variable--Regular Longitudinal Cracks

Optimum Materials:

-#40 aggregate	19% max
dry tensile strength	40 psi max
saturated tensile strength	42 psi max
absolute viscosity @ 140°F	7,000 poises max
-#10 aggregate	39% max
maximum density	158 pcf min

From Figure 16

Dependent Variable--Total % Alligator Cracking

Optimum Materials:

dry tensile strength	38 psi max
absolute viscosity @ 140°F	7,000 poises max
saturated tensile strength	40 psi max
-#200 aggregate	approx. 6.2% *
penetration @ 77°F	38 dmm min

* no strong relationship indicted by plot

From Figure 17

Dependent Variable--Major Thermal (Transverse) Cracks

Optimum Materials:

absolute viscosity @ 140°F	7,000 poises max

bitumin content	5.5% min
penetration @ 77°F	35 dmm min
pavement thickness	2+ inches min

From Figure 18

Dependent Variable--Full Width Patching

Optimum Materials:

-#200 aggregate	app.6.5-7.0% *
pavement thickness	trend not defined
penetration @ 77°F	33 dmm min
saturated tensile strength	50 psi max

* no strong relationship indicated by plot

It is perhaps necessary to first address the apparent correlation of softer, lower tensile strength asphalts with lower rutting potential. In the companion study (2) which primarily examines the soil support aspects of a road structure, it was concluded that rutting is often a distress manifestation occurring on previously fatigue cracked pavements. Field observations indicate that this is probably true, especially in cases of severe rutting. It is suggested that although minor rutting is due in part to lateral plastic flow of the asphalt concrete under wheel loadings, the deeper ruts form as a consequence of the asphalt concrete simply conforming to soil displacements. The mechanism most likely to produce deep rutting in Alaska is therefore thought to be the kneading action of rubber tires on a cracked pavement structure which is kept softened by the intrusion of surface waters. This implies that if fatigue (alligator) cracking can be controlled, the problem of severe rutting will automatically be controlled for the most part.

A few important generalizations are obvious from the preceding table and best overall Alaskan pavement performance is associated with the following aged materials properties as measured on asphalts extracted from existing pavements:

1) tensile strengths, both saturated and dry of less than 40 psi
2) $77^{\circ}F$ penetrations of at least 40 dmm
3) $39.2^{\circ}F$ penetrations of at least 15 dmm
4) absolute viscosity of less than 8,000 poises
5) bitumin content of at least 5.5%

An advantage is also suggested in asphalt concrete materials having the highest maximum theoretical densities and for pavements at least 2 inches thick. A desirable pavement thickness minimuim of 2 inches is also indicated from a previous Alaskan study (2). The aggregate gradation should key on the following:

% - #10 = 39 maximum

% - #40 = 19 maximum

% - #200 = 7 maximum

A ".45 power plot" indicting an idealized gradation based on the above sieve fractions is shown on figure 19 in the context of present class I and class II Alaskan specifications. This would produce a more or less mid-specification material based on the range of screen sizes found most significant in this study.

GRADATION CHART

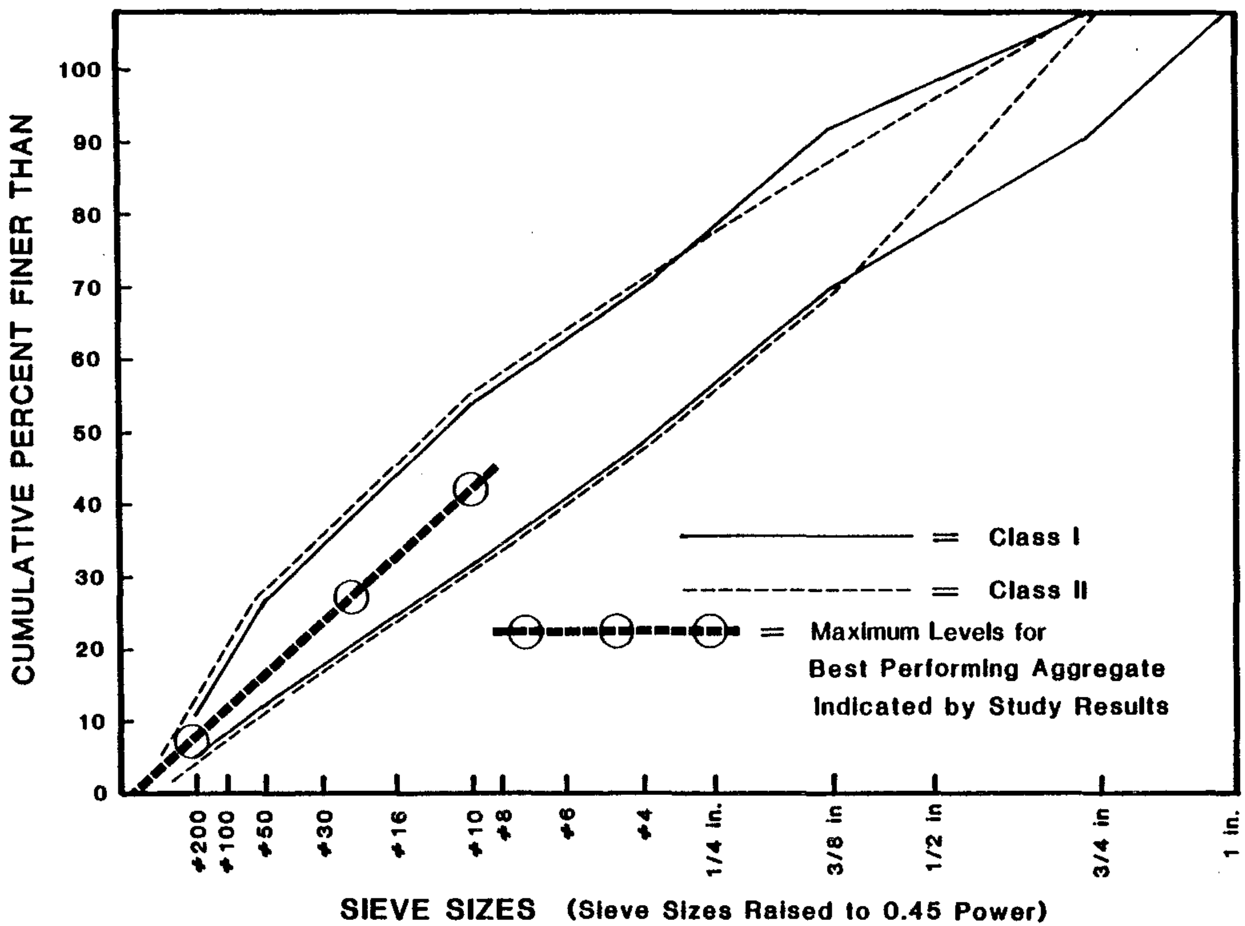


Figure 19

As a final form of data analysis, it is worthwhile to simply examine the material properties common to the better performing pavements. Table 14 is a listing of properties derived from the upper 50 percentile pavements on the basis of: 1) general fatigue + thermally induced distress, 2) longitudinal cracking + thermal distress and 3) thermal distress only. The reader will notice that the sampling (n=15) is very small of pavements rating in the upper 50 percentile in more than one performance catagory although these do represent the all—around best performers. It is interesting to compare the values shown of table 14 with results of the previous method of analysis. Conclusions drawn from this comparison are:

1) the necessity for a 2 inch + pavement thickness
2) the desirability of a -#10 aggregate fraction which lies at or below the gradation line indicated on figure 19
3) recommended asphalt cement contents ranging 5.6-5.9%
4) the overall desirability of relatively soft (low viscosity) asphalt cements
5) the desirability of asphalt concrete components which combine to produce a relatively low tensile strength pavement

Table 14

MATERIAL PROPERTIES ASSOCIATED WITH A HIGH LEVEL OF PERFORMANCE

DESCRIPTION		From Best 50% in: patching, alligatoring longitudinal cracking, map cracking n=15			From Best 50% in: longitudinal cracking, map cracking n=25			From Best 50% in: map cracking n=47	
		MEDIAN	MEAN	STD.DEV.	MEDIAN	MEAN	STD.DEV.	MEDIAN	MEAN	STD.DEV.
Top layer pavement thickness, wheelpath		1.53 inch	1.72	0.59	1.58	1.72	0.48	1.64	1.75	0.45
Top layer pavement thicknes, non wheelpath		1.59 inch	1.79	0.57	1.64	1.81	0.49	1.65	1.80	0.46
Total pavement thickness, wheelpath		1.65 inch	2.15	1.06	1.65	1.96	0.84	1.67	1.92	0.77
Total pavement thickness, non wheelpath		1.64	2.24	1.10	1.74	2.06	0.87	1.74	1.99	0.84
Gradation (Cum. % less than)	1"	100%	100	0	100	100	0	100	100	0
	3/8"	82%	81	5	82	81	7	80	80	7
	#4	57%	58	6	56	58	7	56	57	6
	#10	42	42	4	40	41	5	40	40	5
	#40	21%	20	2	20	21	3	19	20	3
	#200	7%	7	2	8	8	2	7	7	2
Maximum density of asphalt core		157.6 pcf	157.2	2.2	157.5	157.0	2.47	157.8	157.8	3.1
Average S.S.D. density		146.9 pcf	146.0	3.4	146.1	145.4	4.0	146.1	146.0	3.8
S.S.D. density in wheelpath		147.6 pcf	146.4	3.8	146.1	146.0	4.2	146.6	146.8	4.0
S.S.D. density, non wheelpath		146.1 pcf	145.2	3.5	144.8	144.4	4.2	145.2	144.9	4.0
Average % void content		6.9%	7.2	2.2	7.3	7.5	2.3	7.4	7.5	2.0
% void content, wheelpath		6.2%	6.8	2.3	6.7	7.1	2.4	6.7	6.9	2.1
% void content, non wheelpath		7.4%	7.6	2.2	7.6	8.0	2.5	8.0	8.1	2.2
Average % bitumin content w/ash correction		6.0%	5.9	0.9	5.8	5.8	0.8	5.6	5.6	1.0
Average absolute viscosity		3871 poises	4656	3461	4681	6480	5515	7172	10473	11330
Absolute viscosity, wheelpath		2728 poises	3500	2563	3162	5360	5689	6312	9797	12155
Absolute viscosity, non wheelpath		3989 poises	5812	5440	6246	7600	6425	7571	11124	10966
Average penetration at 39.2°F		15 dmm	15	8	15	15	9	11	12	8
Penetration at 39.2°F, wheelpath		16 dmm	16	9	15	17	14	12	14	11
Penetration at 39.2°F, non wheelpath		14 dmm	14	9	13	13	7	10	11	7
Average penetration at 77°F		46 dmm	51	21	40	45	21	31	36	19
Penetration at 77°F, wheelpath		49 dmm	54	24	43	48	24	31	38	22
Penetration at 77°F, non wheelpath		45 dmm	48	21	39	42	19	31	34	17
Tensile strength, saturated core		30.0 psi	32.2	14.2	41.7	36.3	14.1	43.5	50.0	26.0
Tensile Strength, dry core		29.4 psi	29.0	11.6	31.7	35.2	15.9	39.5	47.1	28.5

CHAPTER VII

SUMMARY CONCLUSIONS

AND

RECOMMENDATIONS

SUMMARY

This study is a first attempt at relating pavement performance to the properties of asphalt concrete materials on a statewide sampling of 117 Alaskan roadway sections. The main objective of this report has been to characterize the asphalt pavements of 117 older Alaskan roadway sections and determine the extent to which various asphalt concrete and asphalt cement properties control long term performance.

This report attempts to provide information of two general types:

1) A descriptive and comparative examination of a large number of older Alaskan pavements, which documents the physical state of performance and materials properties at a single point in time

2) Recommendations concerning the in-situ properties of asphalt concrete which have resulted in "best" performance levels

Sample data were analyzed by means of standard statistical techniques which included:

1) variable descriptions and frequency information
2) scatter plot analysis
3) investigation of Pearson correlations and partial correlations
4) regression analyses and trend line plots using points representing group average data

A simple examination of properties common to the best performing sections was also made and the results compared to the optimal values implied from analyses of trends. Tables were then presented in the report which indicate the most desirable physical properties, i.e., those associated with long service life where a high performance pavement surface condition is retained. A general "rule of thumb" arises after all factors have been considered. The very best asphalt concrete materials are indicated as being those which remain relatively soft with the passage of time. This holds true in viewing "soft" in terms of lower retained viscosity and "soft" in terms of low retained tensile strength.

The project was generally hampered by the lack of available construction records although asphalt cements are assumed to have originally met specifications. A similar but more serious problem was the inability to document the process of performance deterioration with time. It is known, for example that neither pavement performance nor asphalt cement properties change linearly with age. In order to simplify the study in such a way as to minimize conjecture, it was decided that both pavement performance and materials properties would be analyzed in terms of values measured at the present time. A case can certainly be made for considering the time dependent nature of performance and also time dependent materials variables, e.g., the ratio of present to original penetration. The fact remains, however, that an ideal data base simply could not be constructed from which to perform a totally comprehensive study which would include consideration of original properties. On the other hand, the reader should note that no attempts have intentionally been made to force fit data into popular models or to delete portions of analyses simply because the numbers do not fit preconceived notions of pavement mechanics or aging processes.

CONCLUSIONS

Physical Properties of Sampled Materials:

The cataloging of asphalt concrete materials properties from a large number of Alaskan pavement sections indicates:

1) the amount of variability which can be expected in common physical properties after long periods of field aging have taken place (see Appendix C)

2) the general rate and extent of asphalt cement hardening attributable to both Coastal and Interior Alaska climates (see Figure 7)

Historical data was unavailable from which to draw actual aging curves on individual pavement sections.

Results from indirect (diametral) tensile testing were useful because of the information they provided about asphalt concrete strength (range 13-100 psi, mean 48 psi) and their inclusion as materials strength variables in correlation analyses. Tensile strength appeared to show a good general correlation with pavement performance. It is suggested that tensile strength testing and, eventually, elastic modulus testing become a regular part of asphalt concrete evaluation of new mixes and existing pavements. Logically, testing which involves the asphalt concrete mix, in total, rather than its component parts would inherently provide the best indication of expected field performance.

No explanation is obvious as to why the tensile strengths of vacuum saturated cores often proved as high or higher than dry core strengths. This was simply an observed fact and in deference to existing literature, the author would again suggest continued tensile strength testing of Alaskan materials.

Summary Outline Regarding the Descriptive Characteristics of Sample Materials:

1) both wheelpath and non wheelpath locations must be included when sampling asphalt concrete pavements

2) The non-linearity of asphalt cement aging curves would indicate that valid performance assumptions cannot necessarily be based on original properties. It is suggested that lab procedures be developed to simulate field aging.

3) Generalized asphalt aging plots indicate that the bulk of age hardening as measured by 77 degree penetration tests, occurs within:

4-5 years -- South (Coastal Area) Alaska

7-8 years -- North (Interior) Alaska

Laboratory test-method development should consider the above figures as guidelines for developing aged materials specifications and in standardizing test procedures

4) Split tensile tests on new paving mixes and on subsequent cores should be made to determine asphalt cement changes with time.

Correlation and Trend Analyses of Asphalt/Asphalt Concrete Properties versus Pavement Surface Performance:

Long term flexibility resulting from low strength, relatively soft asphaltic materials is the key to good, long term pavement performance. Reduction in the fines content of mixes appears justified. Although not readily apparent from direct analysis, the reduction of field voids should assist in reducing hardening of the asphalt cement. However, the beneficial effects of low voids may be at least partially cancelled by a consequent tensile strength increase.

Why does a low tensile strength, soft asphalt seem to have such an edge on more stable materials, given the Alaskan environment? It is the authors opinion, based on the results of this and similar studies, that the greatest amount of severe load related cracking is directly or indirectly a product of springtime thaw weakening in the pavement structure. The asphalt concrete pavement surface, in the thicknesses presently used in Alaska, must absorb and survive the cumulative effects of load caused deflections, controlled for the most part by upper level soil fines (ref. 2). It is this need to withstand abnormally severe bending which dictates use of softest possible asphalt concrete. "Softest possible," in this case, is intended to mean stopping short of severe lay-down problems and summertime bleeding in the wheelpath areas.

Low temperature susceptibilities would definitely be preferred in asphalt materials during the spring thaw. The advantage gained is evident when one considers that very low nighttime temperatures often occur after the pavement's soil support layers have been drastically weakened by average warm air temperatures and solar radiation. A very stiff asphalt concrete layer would, under such conditions, carry a much increased bending load and be susceptible to cracking by very few heavy vehicle loadings.

Summary Outline of Best Long Term Asphalt Concrete Properties:

From an examination of 117 Alaskan pavement sections averaging 12-14 years in age, the values listed for the following properties were found to be representative of road sections which have performed best. This listing is intended to apply to Interior as well as Coastal areas of the state because no definitive differences could be shown upon an explorative separate analysis of data from the two climate areas.

asphalt concrete pavement thickness min. = 2 inches

tensile strength maximum = 40 psi

77°F penetration minimum = 40 dmm

39.2°F penetration minimum = 15 dmm

absolute viscosity maximum = 8,000 poises

bitumin content minimum = 5.5%

% - #10 aggregate maximum = 39%

% - #40 aggregate maximum = 19%

% - #200 aggregate maximum = 7%

IMPLEMENTATION RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

In keeping with the initial objectives of this research project the findings of the grouped data analysis are most directly applicable to materials and design problems. The question which must be addressed therefore is how to utilize guides to the optimum properties of aged materials in either design work or the evaluation of existing roads.

Use of aged material properties in new designs can be approached through specifications which require that asphalt cement be accepted or rejected on the basis of laboratory aging test results. A discussion of actual methods used in performing such a test are beyond the scope of this study, although something analogous to the Rolling Thin Film Oven (RTFO) test with an extended operational time is suggested. Such methods for specifying asphalt cements are similar in concept to the previously used AR grading system. The RTFO test intended for AR gradings is supposed to provide laboratory aging equivalent to the asphalt concrete mixing process. A more severe test technique would be necessary which could simulate approximately 4-8 years of field service in the expected Alaskan environmental area in addition to the aging caused by the mixing process. The required severity of simulated aging is based on the shapes of viscosity and penetration plots included in this report. A laboratory aging method providing up to 8 years equivalent field aging would seem to be necessary considering the marked attenuation of penetration decrease after this time. The author considers the principal of using aged-property specifications very important in the selection of paving asphalts because one must face the fact that asphalt concrete will change markedly in physical properties with the passage of time. Not only will the material change, but it will change only in a generally predictable manner, i.e., it will become harder to some degree. No standardized method is presently used to measure extended aging of asphalt cements or asphalt concrete mixes. There remains also the requirement to determine just how much laboratory aging by a given process would be equivalent to a known period of field service in a specific environmental area of the State. The following line of research is suggested which will provide a viable laboratory test for the classification of asphalt materials:

1) A literature search will investigate state-of-the-art methods for conducting extended aging tests on laboratory specimens of asphalt materials. In addition to investigating methods

for laboratory aging of asphalt cements, it may be desirable to examine the possibility of developing test methods which produces accelerated aging on asphalt concrete specimens.

2) A field/laboratory study would be necessary in order to develop curves relating field aging to laboratory aging.

The previous requirement underscores the general goal of collecting historical data on presently constructed roadways. It is suggested that new pavements located in key climate areas be monitored for long term changes in tensile strength, fatigue life, elastic properties and asphalt cement viscosity. An admitted short coming of this study was the lack of knowledge as to how material properties actually changed with time and a similar lack of information on surface distress development. Until further information becomes available, target values for the aged materials specifications should probably be those which are outlined in this report's conclusions. The designer can make direct use of non-time-dependent materials properties such as recommended aggregate gradation and by requiring that pavement thickness be no less than 2 inches.

In the area of pavement recycling, the engineer can examine in a critical manner the existing asphalt surface material to see how well it would conform to the optimum specifications suggested in this report. The materials engineer should realize that Alaska's limited experience in the field of asphalt recycling has produced indications that the positive effects of rejuvenating agents can be offset by the aging effects of remixing and short term field aging. If there is, in fact, any possibility that recycling may fail to produce a long term rejuvenation then it becomes increasingly important that candidate materials comply with optimum aged-asphalt specifications. An evaluation of aged materials properties should guide the addition of rejuvenating agents and/or very soft virgin asphalts to compensate for hardness in existing materials.

Another example of how aged-properties specifications might guide the materials or design engineer would be the case of an overlay design. The example consists of an older road, which might normally require a good chip seal coating on a thermally cracked but otherwise good pavement. If, however, preliminary core samples suggest poor aged materials properties, implying a short remaining service life, a decision might well favor a thick hot mix overlay or recycling in anticipation of short term fatigue cracking.

A suggestion is offered that asphalt concrete tensile strength might serve as a particularly useful single property with which to categorize existing pavements as it represents the overall state of the asphalt concrete. The diametral compression test is easy to perform and the better, more crack-resistant materials seem to be associated with long term tensile strengths of 40 psi or less. However, additional data concerning changes in tensile strength with time are needed to set design criteria.

It is urged that the State of Alaska's present program of pavement condition inventory be expanded to include the acquisition of deflection data and periodic materials sampling. These data would form a basis for predicting long term performance by providing the feedback necessary to improve correlations between performance and materials.

References

1. Bureau of Public Roads: "Load Limit Tests on Alaska Highways," BPR Report, 1951

2. McHattie, R.L., B. Connor and D. Esch: "Pavement Structural Evaluation of Alaskan Highways," Alaska Department of Transportation and Public Facilities, Report No. FHWA-AK-RD-80-1, 1980.

3. Esch, D., R. McHattie, and B. Connor: "Frost Susceptibility Ratings and Pavement Structural Performance," Alaska Department of Transportation and Public Facilities, Report No. AK-RD-81-9, 1981.

4. Highway Research Board: "The WASHO Road Test -- part 1: Design, Construction and Testing Procedures," HRB, Special Report 18, 1954.

5. Highway Research Board: "The WASHO Road Test -- Part 2: Test Data, Analyses, Findings," HRB, Special Report 22, 1955.

6. Highway Research Board: "The AASHO Road Test -- Report 5: Pavement Research," HRB, Special Report 61E, 1962.

7. Highway Research Board: "The AASHO Road Test -- Report 7: Summary Report," HRB, Special Report 61G, 1964.

8. E.J. Yoder, A. Faiz and D.G. Shurig: "A Comprehensive Pavement Evaluation System: application to C.R.C.P.," Presentation at 55th Annual Meeting of Transportation Research Board, January, 1976.

9. C.W. Hartman and P.R. Johnson: "Environmental Atlas of Alaska, Institute of Water Resources, University of Alaska, 2nd edition, 1978.

10. A.J. Hoiberg: "Bituminous Materials: Asphalts, Tars and Pitches," Volume 1, Wiley, 1964.

11. Robert P. Lottman: "Predicting Moisture - Induced Damage to Asphaltic Concrete," Highway Research Board, NCHRP Report 192, 1978.

12. E.J. Yoder and M.W. Witczak: "Principles of Pavement Design," 2nd edition, Wiley, 1975.

13. Hudson, W.R. and T.W. Kennedy, "An Indirect Tensile Test for Stabilized Materials," Center for Highway Research, University of Texas at Austin, 1968.

14. Maupin, G.W., and J.R. Freeman: "Simple Procedure for Fatigue Characterization of Bituminous Concrete," Final Report No. FHWA-RD-76-102, contract No. DOT-FH-11-8324, June 1976.

15. Timeshenko, S., And J.N. Goodier: "Stresses in a Circular Disk," Theory of Elasticity, Second Edition, McGraw-Hill, 1951.

16. Van Der Poel, C.: "Time and Temperature Effects on the Deformation of Asphaltic Bitumens and Bitumen-Mineral Mixtures," Society of Plastics Eng., J. Vol. II, No. 7, 1955.

17. McLeod, N.W.: "Asphalt Cement Specifications, Some Facts and Challenges," Proc. Sixty-Fifth Annual Meeting of AASHTO, Hartford, Connecticut, AASHTO Publication, 1979.

-ACKNOWLEDGEMENTS-

The Alaskan Department of Transportation and Public Facilities acknowledges the project funding and technical assistance provided by the Federal Highway Administration under the Highway Planning and Research Program.

Recognition is given to the Materials Engineers of the Interior, Central, South Central and Southeastern Regions for providing assistance in pavement core sampling. The Interior Region also provided much of the time and effort involved in laboratory testing of asphaltic materials.

A special "thank you" is intended for personnel of the various highway maintenance camps who kept our equipment functioning during several seasons of field work.

APPENDIX A

DESCRIPTION OF CONSTRUCTION HISTORIES AND LOCATIONS OF ALASKAN ROADWAY SECTIONS SELECTED FOR STUDY

Section Number	Route	Mile	Section History	
005	FAP 37-1 Airport Road (Fairbanks)	Peger Road to Lathrop Street (east bound lane)	1967	F-062-4(10) Reconstruction hot bituminous concrete 78 ft. roadway, 48 ft. surface 3 in. pavement, 6" base
			1958	F-062-4(7) Reconstruction pavement repair
			1950	ARC Section A Reconstruction gravel, plant mix 24 ft. roadway, 20 ft. surface 2 in. pavement, 4 in. base
			(pre-) 1950	No Record Original Construction clear, grade and drainage
010	FAP 665 Vanhorn Road (Fairbanks)	Peger Road to Cushman Street (east bound lane)	1963	S-0665(2) Reconstruction grade, drain, BST 36 ft. roadway, 32 ft. surface 3/4 in. BST, 6 in. base
			(pre-) 1959	No Record Original Construction clear, grade, drain
015	Urban Road (Fairbanks)	Davis Road (west bound lane)	1969	clear, grade, drain, BST Reconstruction no records available
020	Urban Road (Fairbanks)	Old Nenana Highway (east bound lane)	1973	Hot Mix
			1963	BST

Section Number	Route	Mile	Section History	
025	Urban Street (Fairbanks)	Illinois Street (north bound lane)	1950-1951	Last Paving Reconstruction 2 in. Class F hot asphalt pavement with RC-3 seal coat 4 in. base (crushed aggregate) (AASHO M-62)
030	Urban Road (Fairbanks)	Old Airport Road (east bound lane)	1958	No Records 20 ft. surface 1½ in. hot asphalt pavement
035	FAP 95 Glacier Expressway (Juneau)	Sunny Point to Sunny Point North 0.5 mi. (north bound lane)	1975	4 lane 2 - 24 ft. surfaces 2 in. hot asphalt pavement
040	FAP 95 Glacier Expressway (Juneau)	Douglas Bridge to High School	1975	Resurface hot asphalt mix
045	FAS 966 Mendenhall Loop Road (Juneau)	Mi. 1.9 to 2.2 (measured from south leg of intersection of Loop Road and Glacier Highway) (north bound lane)	1963	S-0966(4) Reconstruction 24 ft. surface 2 in. hot asphalt pavement 6 in. base
			1960	FH2-A14 H4 Reconstruction grade, drain 28 ft. roadway 18 in. base
			1943	FH2-A11 Reconstruction 20 ft. roadway

Section Number	Route	Mile	Section History
045	*(Continued)*		*(pre-) 1920 FH2-A Original Construction* *clear, drain* *10 ft. roadway*
050	*FAS 966* *Mendenhall Loop Road* *(Juneau)*	*Montana Creek to* *0.5 Mi. West* *(west bound lane)*	*1969 S-0966(6) Reconstruction* *grade, drain and pave* *26 ft. roadway, 24 ft. surface* *1½ in. pavement, 4½ in. base*
			1957 FH2-06E3H3 Reconstruction *grade* *28 ft. roadway, 18 in. gravel*
			1922 FH2-E Original Construction *grade, gravel* *14 ft. roadway, 12 ft. surface* *4 in. gravel*
055	*FAS 961* *Old Glacier Highway* *(Juneau)*	*Mi. 24.5 to 24.8* *(north bound lane)*	*1964 S-0961(2) Reconstruction* *pave* *28 ft. roadway, 22 ft. surface* *2 in. hot asphalt pavement, 6 in. base*
			1962 FH2-G4 F-095-4(9) Reconstruction *grade, drain* *30 ft. roadway*
			1925 FH2-G Original Construction *14 ft. roadway, 12 ft. surface* *9 in. gravel top*

Section Number	Route	Mile	Section History
060	FAS 961 Old Glacier Highway (Juneau)	Mi. 21.5 to 22.5 (north bound lane)	1963 S-0961(1) Reconstruction grade, pave 22 ft. surface 2 in. pavement, 6 in. base
			1959 FH2-F10, G3, DF-095-4(6) Reconstruction grade, drain 30 ft. roadway, 18 in. base
			1925 FH2-G Original Construction 14 ft. roadway, 12 ft. surface 9 in. gravel surface
065	FAS 961 Old Glacier Highway (Juneau)	Mi. 6.9 to 8.0 (north bound lane)	1956 FH2-F9 Reconstruction 26 ft. roadway, 22 ft. surface 2¼ in. plant mix, 4 in. base
			MP 16-16.9 1938 FH2-G1 Reconstruction 18 ft. roadway, 16 ft. surface 4 in. crushed gravel, 8 in. base
			MP 16.9-17.0 1932 FH2-F2 Reconstruction 16 ft. roadway, 14 ft. surface 4 in. gravel surface
			1924 FH2-F Original Construction 14 ft. roadway, 12 ft. surface 4 in. gravel surface
070	FAP 95 Old Glacier Highway (Juneau)	Mi. 10.2 to 10.7 (north bound lane)	1966 F-095-8(6) Reconstruction and Realign bridges and approaches 42 ft. roadway, 24 ft. surface 3 in. pavement, 6 in. base

Section Number	Route	Mile	Section History
070	(Continued)		1952 FH2-05,F7 Pave 32 ft. roadway, 22 ft. surface 2¼ in. bituminous plant mix, 4 in. base
			1952 FH2-04,F6 Reconstruction grade 32 ft. roadway
			<u>MP 10.2-10.3</u> 1931 FH2-D2 Bridge and Approaches 22 ft. roadway, 20 ft. surface 4 in. pavement, 5 in. base
			1921 FH2-D Original Construction grade, gravel 14 ft. roadway, 12 ft. surface 4 in. gravel surfacing
075	FAP 95 Old Glacier Highway (Juneau)	Mi. 6.9 to 8.0 (north bound lane)	1968 F-095-8(10) Resurface 30 ft. roadway, 22 ft. surface 1½ in. plant mix
			1949 F2-A12 Reconstruction pave 30 ft. roadway, 22 ft. surface 2 3/4 in. plant mix, 8 in. base
			1943 DA-WR3 Reconstruction grade, gravel 34 ft. roadway, 30 ft. surface 6 in. gravel surfacing

Section Number	Route	Mile	Section History
075	(Continued)		1927 FH2-A2 Reconstruction grade, gravel 20 ft. roadway, 18 ft. surface 4 in. gravel surfacing, 2 in. base (pre-) 1920 ARC FH2-A Original Construction clear, grade 10 ft. roadway
080	FAS 959 North Douglas Road (Douglas)	Mi. 4.8 to 5.0 (south bound lane)	1973 Pave 24 ft. surface, 1½ in. plant mix 1956 FH31-E Original Construction grade, drain 22 ft. roadway, 12 in. base
085	FAS 959 North Douglas Road (Douglas)	Mi. 2.75 to 3.25 (south bound lane)	1966 S-0959(1) Construction grade, drain, pave 34 ft. roadway, 24 ft. surface 2 in. pavement, 6 in. base 1956 FH-E Original Construction 22 ft. roadway, 12 in. base
090	FAP 44 Muldoon Road (Anchorage urban)	Northern Lights to Old Harbor Road (north bound lane)	1965 ER-AO-22(1) Reconstruction gravel, plant mix 28 ft. roadway, 24 ft. surface 2 in. pavement

Section Number	Route	Mile	Section History
090	*(Continued)*		*1955* *Anchorage Area Paving* *gravel, plant mix* *28 ft. roadway, 24 ft. surface* *2 in. pavement, 4 in. base*
			1954 *ARC, Anchorage Thru Route, Reconstruction* *28 ft. roadway, 24 ft. surfacing* *4 in. base*
			? *Original Construction No Record* *clear grade, drain* *20 ft. surface*
095	*FAP 44* *Muldoon Road* *(Anchorage urban)*	*Boundry Street to* *6th Avenue* *(north bound lane)*	*1955* *Anchorage Area Paving Reconstruction* *gravel, plant mix* *28 ft. roadway, 24 ft. surface* *4 in. base*
			1954 *ARC Anchorage Thru Route* *gravel* *28 ft. roadway, 24 ft. surface* *4 in. base*
			? *Original Construction No Record* *clear, grade, drain* *20 ft. surface*
100	*FAP 44-1* *Tudor Road* *(Anchorage urban)*	*Baxter Road to* *South Bragaw Street* *west bound lane)*	*1970* *Reconstruction* *2 ea. 45 ft. paved surfaces (4 lane)* *3 in. pavement*

Section Number	Route	Mile	Section History
100	*(Continued)*		*1965 ER-AO-22(1) Reconstruction* *grade, drain, pave* *32 ft. roadway, 24 ft. surface* *2 in. pavement, 6 in. base*
			1955 Anchorage Area Paving Reconstruction *gravel, plant mix* *28 ft. roadway, 24 ft. surface* *2 in. pavement, 4 in. base*
			1954 ARC Anchorage Thru Route Reconstruction *28 ft. roadway, 24 ft. surface* *4 in. base*
			? Original Construction No Record *clear, grade, drain* *20 ft. surface*
105	*FAP 42* *Internation Airport Road* *(Anchorage urban)*	*Mi. 0.6 to 1.0* *West of RR Overpass* *(west bound lane)*	*1958 F-031-2(2) Reconstruction* *24 ft. surface* *2 in. pavement, 4 in. base*
			? Original Construction No Records *clear, drain, grade, gravel* *20 ft. surface*
110	*FAP 42* *Ocean Dock Road* *(Anchorage urban)*	*North End to* *RR Crossing* *(south bound lane)*	*1975 New Base and Pavement*
			1964 F-042-1(23) *preliminary engineering for hot mix*

Section Number	Route	Mile	Section History
110	*(Continued)*		*(pre-) 1955* *Original Construction No Record* *clear, grade, drain, gravel* *20 ft. surface*
115	*FAP 31* *New Seward Highway* *(Anchorage urban)*	*MP 121.0 to 122.0* *(north bound lane)*	*1971* *4 lane consisting of two 36 ft. surfaces* *2 in. pavement*
120	*FAS 525* *Goose Bay Road* *(Wasilla)*	*Mi. 2.0 to 2.5* *(south bound lane)*	*1970* *RS-0525(4) Reconstruction* *pave* *30 ft. roadway, 24 ft. surface* *2 in. pavement, 6 in. base* *1966* *S-0525(2) Reconstruction* *grade, drain, beautify* *40 ft. roadway* *?* *Original Construction No Records* *clear, grade, drain*
125	*Old Seward Highway* *(Anchorage urban)*	*Klatt Road to 0.4 Mi. South* *(north bound lane)*	*1958* *F-031-2(6) Reconstruction* *seal coat with RC-3* *1952* *ARC, Section, D1 Reconstruction* *plant mix* *24 ft. roadway, 20 ft. surface* *2 in. pavement, 4 in. base* *1951* *Original Construction No Record* *clear, grade, drain*

Section Number	Route	Mile	Section History
130	Old Seward Highway (Anchorage urban)	Old-New Seward Highway Junction to 0.5 Mi. North (south bound lane)	1958 F-031-2(6) Reconstruction seal coat with RC-3
			1952 ARC, Section D1 Reconstruction plant mix 24 ft. roadway, 20 ft. surface 2 in. pavement, 4 in. base
			1951 Original Construction No Record clear, grade, drain
135	Old Seward Highway (Anchorage urban)	Dowling to International Airport Road (north bound lane)	1958 F-031-2(16) Reconstruction seal coat with RC-3
			1952 ARC, Section D1 Reconstruction plant mix 24 ft. roadway, 20 ft. surface 2 in. pavement, 4 in. base
			1951 Original Construction No Record clear, grade, drain
140	FAP 71-4 Richardson Highway	Mi. 261 to 262 (north bound lane)	1952 ARC, Section C Reconstruction plant mix 24 ft. roadway, 20 ft. surface 1¼ in. pavement, 4 in. base
			? Original Construction No Record clear, grade, drain

Section Number	Route	Mile	Section History
145	*FAP 71-4* *Richardson Highway*	*Mi. 256 to 257* *(north bound lane)*	*1952 ARC, Section C Reconstruction* *plant mix* *24 ft. roadway, 20 ft. surface* *1¼ in. pavement, 4 in. base* *? Original Construction No Record* *clear, grade, drain*
150	*FAP 71* *Richardson Highway*	*Mi. 250 to 251* *(north bound lane)*	*1952 ARC, Section C Reconstruction* *plant mix* *24 ft. roadway, 20 ft. surface* *1¼ in. pavement, 4 in. base* *? Original Construction No Record* *clear, grade, drain*
155	*FAP 71* *Richardson Highway*	*Mi. 213.5 to 214.5* *(north bound lane)*	*1957 F-071-4(1)* *seal coat* *1957 ARC, Section D1 Reconstruction* *gravel, plant mix* *24 ft. roadway, 20 ft. surface* *1½ in. pavement, 4½ in. base* *1956 ARC, Section D Reconstruction* *grade, drain* *28 ft. roadway* *? Original Construction No Record* *clear, grade, drain*

Section Number	Route	Mile	Section History
160	FAP 71 Richardson Highway	Mi. 209.3 to 210.0 (north bound lane)	1957 F-071-4(1) seal coat 1957 ARC, Section D1 Reconstruction gravel, plant mix 24 ft. roadway, 20 ft. surface 1½ in. pavement, 4½ in. base 1956 ARC, Section D Reconstruction grade, drain 28 ft. roadway ? Original Construction No Record clear, grade, drain
165	FAP 71 Richardson Highway	Mi. 206.4 to 206.6 (north bound lane)	1957 F-071-4(1) seal coat 1957 ARC, Section D1 Reconstruction gravel, plant mix 24 ft. roadway, 20 ft. surface 1½ in. pavement, 4½ in. base 1956 ARC, Section D Reconstruction grade, drain 28 ft. roadway ? Original Construction No Record clear, grade, drain
170	FAP 71 Richardson Highway	Mi. 196.1 to 197.1 (north bound lane)	1957 F-071-4(1) seal coat

Section Number	Route	Mile	Section History
170	*(Continued)*		*1957 ARC, Section D1 Reconstruction gravel, plant mix 24 ft. roadway, 20 ft. surface 1½ in. pavement, 4½ in. base*
			1956 ARC, Section D Reconstruction grade, drain 28 ft. roadway
			? Original Construction No Record clear, grade, drain
175	*FAP 71 Richardson Highway*	*Mi. 193.0 to 194.0 (north bound lane)*	*1957 F-071-4(1) seal coat*
			1957 ARC, Section D1 Reconstruction gravel, plant mix 24 ft. roadway, 20 ft. surface 1½ in. pavement, 4½ in. base
			1956 ARC, Section D Reconstruction grade, drain 28 ft. roadway
			? Original Construction No Record clear, grade, drain
180	*FAP 71 Richardson Highway*	*Mi. 174.5 to 175.5 (north bound lane)*	*1957 F-071-4(1) seal coat*
			1957 ARC, Section D1 Reconstruction gravel, plant mix 24 ft. roadway, 20 ft. surface 1½ in. pavement, 4½ in. base

Section Number	Route	Mile	Section History
180	*(Continued)*		*1956* *ARC, Section D Reconstruction* *grade, drain* *28 ft. roadway*
			1953 *ARC, Section E Reconstruction* *regrade, drain* *28 ft. roadway*
			? *ARC, Original Construction No Record* *clear, grade, drain*
185	*FAP 71* *Richardson Highway*	*Mi. 131.0 to 132.0* *(north bound lane)*	*1957* *F-071-4(1)* *seal coat*
			1957 *ARC, Section D1 Reconstruction* *gravel, plant mix* *24 ft. roadway, 20 ft. surface* *1½ in. pavement, 4½ in. base*
			1956 *ARC, Section D Reconstruction* *grade, drain* *28 ft. roadway*
			1953 *ARC, Section E Reconstruction* *regrade, drain* *28 ft. roadway*
			? *ARC, Original Construction No Record* *clear, grade, drain*
190	*FAP 71* *Richardson Highway*	*Mi. 119.0 to 120.0* *(north bound lane)*	*1966* *F-071-2(12) Resurface* *plant mix* *24 ft. roadway, 20 ft. surface* *1½ in. pavement*

Section Number	Route	Mile	Section History
190	(Continued)		1953 ARC, Section F Reconstruction plant mix 24 ft. roadway, 20 ft. surface 1½ in. pavement, 4½ in. base 1943 Original Construction No Record clear, grade, drain
200	FAP 71 Richardson Highway	Mi. 105.5 to 106.5 (north bound lane)	1973 Resurface 24 ft. surface, 1½ in. pavement 1953 ARC, Section F Reconstruction plant mix 24 ft. roadway, 20 ft. surface 1½ in. pavement, 4½ in. base 1943 Original Construction No Record clear, grade, drain
205	FAP 71 Richardson Highway	Mi. 102.5 to 103.5 (north bound lane)	1953 ARC, Section F Reconstruction plant mix 24 ft. roadway, 20 ft. surface 1½ in. pavement, 4½ in. base 1943 Original Construction No Record clear, grade, drain
210	FAP 71 Richardson Highway	Mi. 89.5 to 90.5 (north bound lane)	1953 ARC, Section F Reconstruction plant mix 24 ft. roadway, 20 ft. surface 1½ in. pavement, 4½ in. base

Section Number	Route	Mile	Section History	
210	(Continued)		1943	Original Construction No Record clear, grade, drain
215	FAP 71 Richardson Highway	Mi. 87.5 to 88.5 (north bound lane)	1953	ARC, Section F Reconstruction plant mix 24 ft. roadway, 20 ft. surface 1½ in. pavement, 4½ in. base
			1943	Original Construction No Record clear, grade, drain
220	FAP 71 Richardson Highway	Mi. 69.0 to 70.0 (north bound lane)	1967	F-071-1(12) Reconstruction grade, drain, surface, utilities 36 ft. roadway, 24 ft. surface 1½ in. pavement, 4 in. base
			1956	ARC, Section G-1 Reconstruction plant mix 28 ft. roadway, 24 ft. surface 1½ in. pavement, 4½ in. base
			1953	ARC, Section G Reconstruction gravel 28 ft. roadway, 6 in. base
			?	Original Construction No Record clear, grade, drain
225	FAP 71 Richardson Highway	Mi. 58.7 to 59.7 (north bound lane)	1960	F-071-1(1) seal coat

Section Number	Route	Mile	Section History
225	*(Continued)*		*1956* ARC, Section G-1 Reconstruction plant mix 28 ft. roadway, 24 ft. surface 1½ in. pavement, 4½ in. base
			1953 ARC, Section G Reconstruction gravel 28 ft. roadway, 6 in. base
			? Original Construction No Record clear, grade, drain
230	FAP 71 Richardson Highway	Mi. 46.5 to 47.5 (north bound lane)	*1960* F-071-1(1) seal coat
			1956 ARC, Section G-1 Reconstruction plant mix 28 ft. roadway, 24 ft. surface 1½ in. pavement, 4½ in. base
			1953 ARC, Section G Reconstruction gravel 28 ft. roadway, 6 in. base
			? Original Construction No Record clear, grade, drain
235	FAP 71 Richardson Highway	Mi. 43.4 to 43.6 (north bound lane)	*1965* F-071-1(10) Reconstruction grade, drain, BST 36 ft. roadway, 24 ft. surface 3/4 in. BST, 6 in. base
			1960 F-071-1(10) seal coat

Section Number	Route	Mile	Section History
235	*(Continued)*		*1956 ARC, Section G-1 Reconstruction* *plant mix* *28 ft. roadway, 24 ft. surface* *1½ in. pavement, 4½ in. base*
			1953 ARC, Section G. Reconstruction *gravel* *28 ft. roadway, 6 in. base*
			? Original Construction No Record *clear, grade, drain*
240	*FAP 71* *Richardson Highway*	*Mi. 37.0 to 37.8* *(north bound lane)*	*1960 F-071-1(1)* *seal coat*
			1956 ARC, Section G-1 Reconstruction *plant mix* *28 ft. roadway, 24 ft. surface* *1½ in. pavement, 4½ in. base*
			1953 ARC, Section G Reconstruction *gravel* *28 ft. roadway, 6 in. base*
			? Original Construction No Record *clear, grade, drain*
245	*FAP 71* *Richardson Highway*	*Mi. 32.5 to 33.5* *(north bound lane)*	*1956 ARC, Section H Reconstruction* *plant mix* *24 ft. roadway, 20 ft. surface* *2 in. pavement, 4 in. base*

Section Number	Route	Mile	Section History	
245	(Continued)		?	Original Construction No Record clear, grade, drain, gravel 48 ft. roadway, 24 ft. surface
250	FAP 71 Richardson Highway	Mi. 26.5 to 27.5 (north bound lane)	1956	ARC, Section H Reconstruction plant mix 24 ft. roadway, 20 ft. surface 2 in. pavement, 4 in. base
			?	Original Construction No Record clear, grade, drain, gravel 48 ft. roadway, 24 ft. surface
251	FAP 71 Richardson Highway	Mi. 17.1 to 18.1 (north bound lane)	1956	ARC, Section H Reconstruction plant mix 24 ft. roadway, 20 ft. surface 2 in. pavement, 4 in. base
			?	Original Construction No Record clear, grade, drain, gravel 48 ft. roadway, 24 ft. surface
252	FAP 71 Richardson Highway	Mi. 9.8 to 10.8 (north bound lane)	1956	ARC, Section H Reconstruction plant mix 24 ft. roadway, 20 ft. surface 2 in. pavement, 4 in. base
			?	Original Construction No Record clear, grade, drain, gravel 48 ft. roadway, 24 ft. surface

Section Number	Route	Mile	Section History	
253	FAP 71 Richardson Highway	Mi. 6.5 to 7.0 (north bound lane)	1956	ARC, Section H Reconstruction plant mix 24 ft. roadway, 20 ft. surface 2 in. pavement, 4 in. base
			?	Original Construction No Record clear, grade, drain, gravel 48 ft. roadway, 24 ft. surface
255	FAP 62 Steese Highway	Mi. 9.0 to 10.0 (north bound lane)	1959	F-061-1(5) Reconstruction grade, drain, BST 24 ft. roadway, 24 ft. surface 3/4 in. BST, 6 in. base
			1958	F-061-1(1) Reconstruction grade, drain 28 ft. roadway
			?	Original Construction No Record gravel
260	FAP 62 Steese Highway	Mi. 5.8 to 6.4 (north bound lane)	1959	F-061-1(5) Reconstruction grade, drain, BST 24 ft. roadway, 24 ft. surface 3/4 in. BST, 6 in. base
			1958	F-061-1(1) Reconstruction grade, drain 28 ft. roadway
			?	Original Construction No Record gravel

Section Number	Route	Mile	Section History
265	*FAP 62* *Richardson Highway*	*Mi. 359.0 to 360.0* *(north bound lane)*	*1971* *Resurface* *four lane consisting of two 38 ft. surfaces* *1½ in. pavement* *1966* *F-062-4(16) Construction* *grade, drain, BST* *84 ft. roadway* *3/4 in. BST, 6 in. base*
270	*FAP 62* *Richardson Highway*	*Mi. 319.5 to 320.5* *(north bound lane)*	*1968* *F-062-4(17) Reconstruction* *grade, drainage, pave* *40 ft. roadway, 24 ft. surface* *1½ in. plant mix, 4 in. base* *1950* *ARC, Section B Reconstruction* *24 ft. roadway, 20 ft. surface* *1½ in. plant mix, 4 in. base* *1943* *Original Construction No Record* *clear, grade, drain*
275	*FAP 62* *Richardson Highway*	*Mi. 318.5 to 319.5* *(north bound lane)*	*1968* *F-062-4(17) Reconstruction* *grade, drain, pave* *40 ft. roadway, 24 ft. surface* *1½ in. plant mix, 4 in. base* *1950* *ARC, Section B Reconstruction* *24 ft. roadway, 20 ft. surface* *1½ in. plant mix, 4 in. base* *1943* *Original Construction No Record* *clear, grade, drain*

Section Number	Route	Mile	Section History	
280	FAP 62 Alaska Highway	Mi. 1419.0 to 1420.0 (west bound lane)	1953	ARC, A-Bl Reconstruction gravel, plant mix 24 ft. roadway, 20 ft. surface 1½ in pavement, 4½ in. base
			1943	Public Roads Administration Original Construction No Records clear, drain, grade
285	FAP 62 Alaska Highway	Mi. 1413.0 to 1414.0 (west bound lane)	1953	ARC, A-Bl Reconstruction gravel, plant mix 24 ft. roadway, 20 ft. surface 1½ in. pavement, 4½ in. base
			1943	Public Roads Administration Original Construction No Records clear, drain grade
290	FAP 62 Alaska Highway	Mi. 1402.5 to 1403.5 (west bound lane)	1953	ARC, A-Bl Reconstruction gravel, plant mix 24 ft. roadway, 20 ft. surface 1½ in. pavement, 4½ in. base
			1943	Public Roads Administration Original Construction No Records
291	FAP 62 Alaska Highway	Mi. 1407.0 to 1408.0 (west bound lane)	1953	ARC, A-Bl Reconstruction gravel, plant mix 24 ft. roadway, 20 ft. surface 1½ in pavement, 4½ in. base

Section Number	Route	Mile	Section History
291	(Continued)		1943 Public Roads Administration Original Construction No Records clear, drain, grade
295	FAP 62 Alaska Highway	Mi. 1394.0 to 1395.0 (west bound lane)	1953 ARC, A-B1 Reconstruction gravel, plant mix 24 ft. roadway, 20 ft. surface 1½ in. pavement, 4½ in. base 1943 Public Roads Administration Original Construction No Records clear, drain, grade
300	FAP 62 Alaska Highway	Mi. 1374.0 to 1375.0 (west bound lane)	1953 ARC, A-B1 Reconstruction gravel, plant mix 24 ft. roadway, 20 ft. surface 1½ in. pavement, 4½ in. base 1949 ARC, Section B Reconstruction grade, surface 26 ft. roadway, 24 ft. surface 4 in. pavement, 6 in. base 1943 Public Roads Administration Original Construction No Records clear, drain, grade
305	FAP 62 Alaska Highway	Mi. 1370.5 to 1371.5 (west bound lane)	1966 F-062-2(8) Resurface plant mix 20 ft. surface, 1½ in. pavement

Section Number	Route	Mile	Section History
305	*(Continued)*		*1953* *ARC, A-B1 Reconstruction* *gravel, plant mix* *24 ft. roadway, 20 ft. surface* *1½ in. pavement, 4½ in. base*
			1949 *ARC, Section Reconstruction* *grade, surface* *26 ft. roadway, 24 ft. surface* *4 in. pavement, 6 in. base*
			1943 *Public Roads Administration* *Original Construction No Records* *clear, drain, grade*
310	*FAP 62* *Alaska Highway*	*Mi. 1365.5 to 1366.5* *(west bound lane)*	*1966* *F-062-2(8) Resurface* *plant mix* *20 ft. surface, 1½ in. pavement*
			1957 *ARC, B-2 Reconstruction* *gravel, BST* *28 ft. roadway, 20 ft. surface* *3/4 in. pavement, 4½ in. base*
			1949 *ARC, Section B Reconstruction* *grade, surface* *26 ft. roadway, 24 ft. surface* *4 in. pavement, 6 in. base*
			1943 *Public Roads Administration* *Original Construction No Records* *clear, drain, grade*

Section Number	Route	Mile	Section History
315	FAP 62 Alaska Highway	Mi. 1354.0 to 1355.0 (west bound lane)	1966 F-062-2(8) Resurface plant mix 20 ft. surface, 1½ in. pavement 1957 F-062-2(1) seal coat 1957 ARC, B-2 Reconstruction gravel, BST 28 ft. roadway, 20 ft. surface 3/4 in. pavement, 4½ in. base 1949 ARC, Section B Reconstruction grade, surface 26 ft. roadway, 24 ft. surface 4 in. pavement, 6 in. base 1943 Public Roads Administration Original Construction No Records clear, drain, grade
320	FAP 62 Alaska Highway	Mi. 1331.0 to 1332.0 (west bound lane)	1966 F-062-2(8) Resurface plant mix 20 ft. surface, 1½ in. pavement 1957 F-062-2(1) seal coat 1957 ARC, B-2 Reconstruction gravel, BST 28 ft. roadway, 20 ft. surface 3/4 in pavement, 4½ in. base

Section Number	Route	Mile		Section History
320	(Continued)		1949	ARC, Section B Reconstruction grade, surface 26 ft. roadway, 24 ft. surface 4 in. pavement, 6 in. base
			1943	Public Roads Administration Original Construction No Records clear, drain, grade
325	FAP 62 Alaska Highway	Mi. 1317.5 to 1318.5 (west bound Lane)	1957	F-062-2(1) seal coat
			1957	ARC, B-2 Reconstruction gravel, BST 28 ft. roadway, 20 ft. surface 3/4 in. pavement, 4½ in. base
			1949	ARC, Section B Reconstruction grade, surface 26 ft. roadway, 24 ft. surface 4 in. pavement, 6 in. base
			1943	Public Roads Administration Original Construction No Records clear, drain, grade
330	FAP 62 Alaska Highway	Mi. 1313.4 to 1314.1 (west bound lane)	1971	Reconstruction 36 ft. surface, 2 in. pavement
			1954	ARC, C-1 Reconstruction gravel, plant mix 24 ft. roadway, 20 ft. surface 1½ in pavement, 4½ in. base

Section Number	Route	Mile	Section History
330	(Continued)		1943 Public Roads Administration Original Construction No Records
335	FAP 62 Alaska Highway	Mi. 1300.0 to 1301.0 (west bound lane)	1966 F-062-1(12) Reconstruction 24 ft. roadway, 20 ft. surface 1½ in. pavement
			1954 ARC, C-1 Reconstruction gravel, plant mix 24 ft. roadway, 20 ft. surface 1½ in pavement, 4½ in. base
			1943 Public Roads Administration Original Construction No Records
340	FAP 62 Alaska Highway	Mi. 1288.0 to 1289.0 (west bound lane)	1966 F-062-1(12) Reconstruction 24 ft. roadway, 20 ft. surface 1½ in. pavement
			1960 F-DF-062-1(5) Reconstruction grade, drain, pave 26 ft. roadway, 24 ft. surface 3/4 in. BST, 4 in. base
			1954 ARC, C-1 Reconstruction gravel, plant mix 24 ft. roadway, 20 ft. surface 1½ in. pavement, 4½ in. base
			1943 Public Roads Administration Original Construction No Records

Section Number	Route	Mile	Section History
345	FAP 46 Tok Cutoff	Mi. 33.0 to 34.0 (west bound lane)	*1955* ARC, Section C1, D1 Reconstruction plant mix 24 ft. roadway, 20 ft. surface 1½ in. pavement, 4½ in. base *1953* ARC Reconstruction regrade, drain 28 ft. roadway *1936* ARC Reconstruction gravel 20 ft. roadway *?* ARC Original Construction No Record 20 ft. roadway
350	FAP 42 Glenn Highway	Mi. 186.5 to 187.5 (north bound lane)	*1964* F-042-3(11) Reconstruction gravel, bituminous surface 40 ft. roadway, 24 ft. surface 3/4 in. pavement, 6 in. base *1963* F-042-3(6) Reconstruction grade, drain 40 ft. roadway *1954* ARC, B-3 Reconstruction gravel, plant mix 24 ft. roadway, 20 ft. surface 1½ in. surface, 4½ in. base *1943* ARC Original Construction No Record clear, grade, drain

Section Number	Route	Mile	Section History
355	*FAP 42* *Glenn Highway*	*Mi. 164.0 to 165.0* *(north bound lane)*	*1969 F-042-3(12) Reconstruction* *grade, drain, bituminous surface* *44 ft. roadway, 24 ft. surface* *1½ in. pavement, 4½ in. base* *1954 ARC, B-3 Reconstruction* *gravel, plant mix* *24 ft. roadway, 20 ft. surface* *1½ in. surface, 4½ in. base* *1943 ARC Original Construction No Record* *clear, grade, drain*
360	*FAP 42* *Glenn Highway*	*Mi. 160.0 to 161.0* *(north bound lane)*	*1965 F-042-3(10) Reconstruction* *grade, drain, bituminous surface* *40 ft roadway, 24 ft. surface* *3/4 in. pavement, 6 in. base* *1954 ARC, B-3 Reconstruction* *gravel, plant mix* *24 ft. roadway, 20 ft. surface* *1½ in. surface, 4½ in. base* *1943 ARC Original Construction No Record* *clear, grade, drain*
365	*FAP 42* *Glenn Highway*	*Mi. 149.0 to 150.0* *(north bound lane)*	*1966 F-042-3(4) Reconstruction* *plant mix* *20 ft. surface, 1½ in. pavement* *1954 ARC, B-3 Reconstruction* *gravel, plant mix* *24 ft. roadway, 20 ft. surface* *1½ in. surface, 4½ in. base*

Section Number	Route	Mile	Section History
365	(Continued)		1943 ARC Original Construction No Record clear, grade, drain
370	FAP 42 Glenn Highway	Mi. 136.75 to 137.25 (north bound lane)	1966 F-042-3(4) Reconstruction plant mix 20 ft. surface, 1½ in. pavement
			1954 ARC, B-3 Reconstruction gravel, plant mix 24 ft. roadway, 20 ft. surface 1½ in. surface, 4½ in. base
			1943 ARC Original Construction No Record clear, grade, drain
375	FAP 42 Glenn Highway	Mi. 130.0 to 131.0 (north bound lane)	1967? X-51910 widening at various locations
			1966 F-042-3(4) Reconstruction plant mix 20 ft. surface, 1½ in. pavement
			1954 ARC, B-3 Reconstruction gravel, plant mix 24 ft. roadway, 20 ft. surface 1½ in. surface, 4½ in. base
			1943 ARC Original Construction No Record clear, grade, drain
380	FAP 42 Glenn Highway	Mi. 128.0 to 129.0 (north bound lane)	1967? X-41910 widening at various locations

Section Number	Route	Mile	Section History
380	*(Continued)*		*1966 F-042-3(4) Reconstruction* *plant mix* *20 ft. surface, 1½ in. pavement*
			1954 ARC, B-3 Reconstruction *gravel, plant mix* *24 ft. roadway, 20 ft. surface* *1½ in. pavement, 4½ in. base*
			1943 ARC Origiknal Construction No Record *clear, grade, drain*
385	*FAP 42* *Glenn Highway*	*Mi. 74.0 to 75.0* *(north bound lane)*	*1971 3/8 in. slurry seal*
			1966 X-12780 *slurry seal*
			1951 ARC, B-1 Reconstruction *24 ft. roadway, 20 ft. surface* *1½ in. pavement, 4½ in. base*
			? Original Construction No Record *clear, grade, drain*
390	*FAP 42* *Glenn Highway*	*Mi. 69.0 to 70.0* *(north bound lane)*	*1971 X-12780* *slurry seal*
			1966 F-042-2(3) Resurface *plant mix* *20 ft. surface, 1½ in. pavement*
			1951 ARC, B-1 Reconstruction *24 ft. roadway, 20 ft. surface* *1½ in. pavement, 4½ in. base*

Section Number	Route	Mile	Section History	
390	*(Continued)*		*?*	*Original Construction No Record* *clear, grade, drain*
395	*FAP 42* *Glenn Highway*	*Mi. 58.7 to 59.7* *(north bound lane)*	*1971*	*X-12780* *slurry seal*
			1966	*F-042-2(3) Resurface* *plant mix* *20 ft. surface, 1½ in. pavement*
			1951	*ARC, B-1 Reconstruction* *24 ft. roadway, 20 ft. surface* *1½ in. pavement, 4½ in. base*
			?	*Original Construction No Record* *clear, grade, drain*
400	*FAP 42* *Glenn Highway*	*Mi. 32.5 to 33.5* *(north bound lane)*	*1970*	*pave* *40 ft. surface, 2 in. pavement*
			1966	*ER-40-33(1) Reconstruction* *grade, drain, pave* *28 ft. roadway, 24 ft. surface* *3/4 in. pavement, 6 in. base*
			1952	*ARC, Section A Reconstruction* *gravel, plant mix* *24 ft. roadway, 20 ft. surface* *1½ in. pavement, 4½ in. base*
			?	*Original Construction No Record* *clear, grade, drain* *20 ft. surface*

Section Number	Route	Mile	Section History	
415	FAP 42 Glenn Highway	Mi. 18.8 to 19.8 (north bound lane)	1971	Seal Coat
			1970	RF-042-1(36) Seal Coat 44 ft. roadway, 24 ft. surface 2 in. pavement, 6 in. base
			1969	F-042-1(30) Relocation grade, drain, pave 44 ft. roadway, 24 ft. surface 2 in. pavement, 6 in. base
440	FAP 37 Parks Highway	Mi. 318.75 to 319.25 (north bound lane)	1970- 1971	F-037-1(24) Construction base, pave 40 ft. roadway, 24 ft. surface 1½ in. pavement, 5 in. base
			1968	F-FG-037-1(19) Reconstruction grade, drain, beautify 44 ft. roadway, 6 in. base
			1958	F-037-1(5) Original Construction grade, drain 28 ft. roadway
450	FAP 37 Parks Highway	Mi. 316.2 to 317.2 (north bound lane)	1970- 1971	F-037-1(24) Construction base, pave 40 ft. roadway, 24 ft. surface 1½ in. pavement, 5 in. base
			1968	F-FG-037-1(19) Reconstruction grade, drain, beautify 44 ft. roadway, 6 in. base

Section Number	Route	Mile	Section History
450	*(Continued)*		*1958 F-037-1(5) Original Construction* *grade, drain* *28 ft. roadway*
455	*FAP 37* *Parks Highway*	*Mi. 315.0 to 316.0* *(north bound lane)*	*1970-1971 F-037-1(24) Construction* *base, pave* *40 ft. roadway, 24 ft. surface* *1½ in. pavement, 5 in. base* *1968 F-FG-037-1(19) Reconstruction* *grade, drain, beautify* *44 ft. roadway, 6 in. base* *1958 F-037-1(5) Original Construction* *grade, drain* *28 ft. roadway*
465	*FAP 37* *Parks Highway*	*Mi. 272.5 to 273.5* *(north bound lane)*	*1972 Asphalt Concrete* *24 ft. surface, 1½ in. pavement* *1969 F-037-2(16) Reconstruction* *44 ft. roadway, 24 ft. surface* *1½ in. pavement, 6 in. base* *1964 F-037-2(16) Original Construction* *grade, drain* *44 ft. roadway*
470	*FAP 37* *Parks Highway*	*Mi. 271.0 to 271.5* *(north bound lane)*	*1972 F-037-2(16) Paving* *44 ft. roadway, 24 ft. surface* *1½ in. pavement, 6 in. base*

Section Number	Route	Mile	Section History
470	(Continued)		1964 F-037-2(6) Original Construction grade, drain 44 ft. roadway
475	FAP 37 Parks Highway	Mi. 251.0 to 252.0 (north bound lane)	1972 F-037-1(16) Paving 44 ft. roadway, 24 ft. surface 1½ in. pavement, 6 in. base 1964 F-037-2(6) Original Construction grade, drain 44 ft. roadway
480	FAP 37 Parks Highway	Mi. 232.5 to 233.5 (north bound lane)	1975 Pave 24 ft. surface, 1½ in. pavement 1969 F-FG-037-2(14) Reconstruction grade, drain, beautify 44 ft. roadway, 6 in. base ? Original Construction No Record clear, grade, drain 28 ft. roadway
485	FAP 35 Parks Highway	Mi. 204.6 to 205.61972 (north bound lane)	Asphalt Concrete Surfacing 24 ft. surface, 1½ in. pavement 1967 F-035-4(5) Original Construction grade, drain 44 ft. roadway
490	FAP 35 Parks Highway	Mi. 201.1 to 201.8 (north bound lane)	1972 Asphalt Concrete Surfacing 24 ft. surface, 1½ in. pavement

Section Number	Route	Mile	Section History
490	(Continued)		1967 F-035-4(5) Original Construction grade, drain 44 ft. roadway
495	FAP 35 Parks Highway	Mi. 192.3 to 193.3 (north bound lane)	1972 Asphalt Concrete Surfacing 24 ft. surface, 1½ in. pavement 1967 F-035-4(5) Original Construction grade, drain 44 ft. roadway
500	FAP 35 Parks Highway	Mi. 189.3 to 189.6 (north bound lane)	1972 Asphalt Concrete Surfacing 24 ft. surface, 1½ in. pavement 1967 F-035-4(5) Original Construction grade, drain 44 ft. roadway
505	FAP 35 Parks Highway	Mi. 181.3 to 181.8 (north bound lane)	1972 Asphalt Concrete Surfacing 24 ft. surface, 1½ in. pavement 1966 F-035-4(7) Original Construction grade, drain 44 ft. roadway, 6 in. base
510	FAP 35 Parks Highway	Mi. 74.0 to 75.0 (north bound lane)	1970 F-FG-035-1(11) Pave 32 ft. roadway, 24 ft. surface 2 in. pavement, 5 in. base 1962 F-035-1(2) Original Construction grade, drain 36 ft. roadway

Section Number	Route	Mile	Section History
515	FAP 35 Parks Highway	Mi. 58.4 to 58.9 (north bound lane)	1965 F-035-1(12) Reconstruction grade, drain, pave 32 ft. roadway, 24 ft. surface 2 in. hot mix, 6 in. base 1962 F-035-1(6) Reconstruction grade, drain 36 ft. roadway 1954 ARC Original Construction clear, drain, grade 24 ft. roadway
520	FAP 35 Parks Highway	Mi. 37.75 to 38.25 (north bound lane)	1973 Realignment 40 ft. surface, 2 in. pavement
522	FAP 31-2 Seward Highway	Mi. 116.0 to 116.5 (north bound lane	1970-1971 F-031-2(13) Construction 36 ft. surface, 4 lane, 2 in. pavement 1958 F-031-2(6) Reconstruction seal coat with RC-3 1952 ARC Section D1 Reconstruction plant mix 24 ft. roadway, 20 ft. surface 2 in. pavement, 4 in. base 1951 Original Construction No Record clear, grade, drain

Section Number	Route	Mile	Section History
523	FAP 31-2 Seward Highway	Mi. 99.5 to 100.5 (north Bound lane)	1968 F-031-2(23) Resurface 20 ft. surface, 1½ in. plant mix
			1952 ARC Section D2 Reconstruction 24 ft. roadway, 20 ft. surface 2 in. plant mix, 4 in. base
			1951 Original Construction No Record
524	FAP 31-2 Seward Highway	Mi. 97.5 to 98.5 (south bound lane)	1970 RF-031-1(26) Construction seal coat 40 ft. roadway, 24 ft. surface
			1967 ER-AL-27(1) Reconstruction grade, drain, pave 44 ft. roadway, 24 ft. surface 2 in. pavement, 4 in. base
			1965 ER-FO-1(13)/ER-AO-1(4) Reconstruction grade, drain 24 ft. roadway
			1952 ARC Section D2 Reconstruction 24 ft. roadway, 20 ft. surface 2 in. plant mix, 4 in. base
			1951 Original Construction No Record clear, grade, drain
525	FAP 31-2 Seward Highway	Mi. 80.5 to 81.5 (south bound lane)	1970 RF-031-2(26) Construction seal coat 40 ft. roadway, 24 ft. surface 2 in. pavement, 4 in. base

Section Number	Route	Mile	Section History	
525	*(Continued)*		*1967*	*ER-FO-20(1) Reconstruction* *grade, drain, pave* *40 ft. roadway, 24 ft. surface* *2 in. pavement, 4 in. base*
			1965	*ER-FO-1(3)/ER-40-1(4) Reconstruction* *grade, drain* *24 ft. roadway*
			1952	*FH3 Reconstruction* *plant mix* *24 ft. roadway, 20 ft. surface* *2 in. pavement, 4 in. base*
			1950	*FH3 Section F1 Original Construction* *clear, grade*
530	*FAP 31-2* *Seward Highway*	*Mi. 68.0 to 67.5* *(south bound lane)*	*1970*	*ER-FO-6(1) Reconstruction* *hot bituminous concrete* *24 ft. roadway* *2 in. pavement, 4 in. base*
			1952	*FH3 Section C1 and D1 Reconstruction* *grade, drain, pave* *24 ft. roadway, 20 ft. surface* *2 in. pavement, 4 in. base*
			1950	*FH3 Section C and D Original Construction* *clear, grade* *26 ft. roadway*
532	*FAP 31-2* *Seward Highway*	*Mi. 45.0 to 44.5* *(south bound lane)*	*1966*	*EF-RO-6(1) Reconstruction* *grade, drain, bituminous concrete* *24 ft. roadway, 24 ft. surface* *2 in. pavement, 4 in. base*

Section Number	Route	Mile	Section History
532	*(Continued)*		*1953* *FH3-B2 Reconstruction* *24 ft. roadway, 20 ft. surface* *2 in. pavement, 4 in. base*
			1932 *FH14-A1 Reconstruction* *14 ft. roadway, 12 ft. surface* *3 in. top layer*
			1925 *FH14-B Original Construction* *gravel, grade* *10 ft. roadway, 8 ft. surface* *7 in. top layer*
535	*FAP 31-1* *Seward Highway*	*Mi. 17.0 to 18.0* *(south bound lane)*	*1965* *F-031-1(8)/ER-FO-10(1) Realignment* *grade, drain, surface* *40 ft. roadway, 24 ft. surface* *3/4 in. pavement, 6 in. base*
540	*FAP 31-1* *Seward Highway*	*Mi. 14.1 to 15.0* *south bound lane)*	*1954* *FH3-A2/FH3-A1 Reconstruction* *26 ft. roadway, 22 ft. surface* *2 in. pavement, 4 in. base*
			1923-1924 *FH3-E/FH3-D Original Construction* *12 ft. roadway, 10 ft. surface* *6 in. gravel pavement*
545	*FAP 31-1* *Seward Highway*	*Mi. 1.8 to 2.8* *(south bound lane)*	*1972* *Reconstruction* *24 ft. surface, 2 in. pavement*
			1967 *ER-FO-5(1) Reconstruction* *grade, drain, plant mix* *40 ft. roadway, 24 ft. surface* *1½ in. pavement, 4 in. base*

Section Number	Route	Mile	Section History
545	*(Continued)*		*1954* *FH3-A3 Reconstruction* *gravel, plant mix* *26 ft. roadway, 22 ft. surface* *2 in. pavement, 4 in. base*
			1939 *FH3-A1-E1 Screened Gravel* *18 ft. roadway, 16 ft. surface* *4 in top layer, 12 in. second layer*
			1936 *FH3-A5 Screened Gravel* *18 ft. roadway, 16 ft. surface* *6 in. top layer, 12 in. second layer*
			(pre-) 1920 *Original Construction No Record* *clear, grade, drain* *12 ft. roadway*
550	*FAP 21-1* *Sterling Highway*	*Mi. 162.0 to 163.0* *(south bound lane)*	*1964* *F-021-1(10) Reconstruction* *hot bituminous concrete* *36 ft. roadway, 24 ft. surface* *2 in. pavement, 6 in. base*
			1960 *F-021-1(1) Reconstruction* *clear, grade, drain* *36 ft. roadway*
			(pre-) 1950 *Original Construction No Record* *clear, grade, drain* *14 ft. surface*
555	*FAP 21* *Sterling Highway*	*Mi. 144.5 to 145.0* *(south bound lane)*	*1967* *F-021-1(21) Reconstruction* *plant mix* *36 ft. roadway, 24 ft. surface* *1½ in. pavement, 4 in. base*

Section Number	Route	Mile	Section History
555	*(Continued)*		*1964* *F-021-1(11) Reconstruction* *grade, drain* *36 ft. roadway* *(pre-) 1948* *Original Construction No Record* *clear, grade, drain*
560	*FAP 21-1* *Sterling Highway*	*Mi. 128.0 to 129.0* *(south bound lane)*	*1967* *F-021-1(20) Reconstruction* *hot bituminous concrete* *36 ft. roadway, 24 ft. surface* *1½ in. pavement, 4 in. base* *1966* *F-021-1(7) Reconstruction* *36 ft. roadway* *(pre-) 1948* *Original Construction No Record* *clear, grade, drain*
565	*FAP 21-2* *Sterling Highway*	*Mi. 65.0 to 66.0* *(south bound lane)*	*1959* *F-021-2(1) Reconstruction* *bituminous concrete* *28 ft. roadway, 24 ft. surface* *2 in. pavement, 4 in. base* *1957* *ARC B-2 Reconstruction* *gravel* *28 ft. roadway, 24 ft. surface* *1½ in. top layer, 4½ in. second layer* *(pre-) 1921* *Original Construction No Record* *grade*

Section Number	Route	Mile	Section History
570	*FAP 21-2* *Sterling Highway*	*Mi. 56.0 to 57.0* *(south bound lane)*	*1959 F-021-2(1) Reconstruction* *bituminous concrete* *28 ft. roadway, 24 ft. surface* *2 in. pavement, 4 in. base*
			1957 ARC B-2 Reconstruction *gravel* *28 ft. roadway, 24 ft. surface* *1½ in top layer, 4½ in. second layer*
			(pre-) Original Construction No Record *grade*
572	*FAP 21-2* *Sterling Highway*	*Mi. 41.5 to 42.5* *(south bound lane)*	*1966 ER-AO-17(1)/ER-AO-16(1) Reconstruction* *hot bituminous concrete* *24 ft. surface* *2 in. pavement, 6 in. base*
			1957 FH5-A6-B4 Reconstruction *24 ft. roadway, 22 ft. surface* *2 in. pavement, 4 in. base*
			1952 FH5-B3 Reconstruction *gravel* *24 ft. roadway, 22 ft. surface* *4 in. top layer, 12 in. base*
			1936 FH5-B Original Construction *10 ft. roadway*
575	*FAP 21-2* *Sterling Highway*	*Mi. 40.0 to 41.0* *(south bound lane)*	*1957 FH5-A6-B4 Reconstruction* *24 ft. roadway, 22 ft. surface* *2 in. pavement, 4 in. base*

Section Number	Route	Mile	Section History
575	*(Continued)*		*1952 FH5-B3 Reconstruction* *gravel* *24 ft. roadway, 22 ft. surface* *4 in. top layer, 12 in. base*
			1936 FH5-B Original Construction *10 ft. roadway*
580	*FAS 680* *Elliott Highway*	*Mi. 6.5 to 7.5* *(north bound lane)*	*1970 S-0680(11) Reconstruction* *base, pavement* *30 ft. roadway, 24 ft. surface* *1½ in. pavement, 1½ in. base*
			1965 S-0680(12) Realignment *grade, drain* *34 ft. roadway*
585	*FAS 680* *Elliott Highway*	*Mi. 3.5 to 4.5* *(north bound lane)*	*1970 S-0680(11) Reconstruction* *base, pavement* *30 ft. roadway, 24 ft. surface* *1½ in. pavement, 1½ in. base*
			1965 S-0680(12) Realignment *grade, drain* *34 ft. roadway*
590	*FAS 680* *Elliott Highway*	*Mi. 1.0 to 2.0* *(north bound lane)*	*1970 S-0680(11) Reconstruction* *base, pavement* *30 ft. roadway, 24 ft. surface* *1½ in. pavement, 1½ in. base*

Section Number	Route	Mile	Section History
590	(Continued)		1965 S-0680(12) Realignment grade, drain 34 ft. roadway
595	FAS 490 North Kenai Road	Mi. 20.0 to 21.0 (south bound lane)	1966 S-0490(7) Reconstruction grade, drain, pave 40 ft. roadway, 24 ft. surface 2 in. pavement, 6 in. base (pre-) 1959 Original Construction No Record clear, drain, grade 20 ft. roadway
600	FAS 463 Kalifonski Loop Road	1 Mi. from north end to 2 Mi. from north end (south bound lane)	1972 S0463(11) Reconstruction 1½ in. hot bituminous pavement 4½ in. D-1 base 1959 DS-0463(2) Construction grade, drain
605	FAS 414 Homer East Road	Mi. 1.0 to 2.0 (east bound lane)	1975 Reconstruction upgrade, pave (pre-) 1960 Original Construction No Record clear, grade, drain

APPENDIX B

Pavement Condition Survey

APPENDIX B FIGURES

PAVEMENT CONDITION SURVEY

Most pavement rating systems have evolved from the need to quantify ride quality and distress manifestations identified during the original AASHO road test at Ottawa, Illinois. Contemporary rating schemes usually combine some mixture of ride quality and structural distress measurement into a single serviceability (PSI) type rating. This number can then be used for purposes of comparison. In this case, however, a technique was needed which would allow the examination and evaluation of individual distress factors and could easily be utilized for computerized statistical studies. To facilitate this type of application and in keeping with more or less recognized and standardized rating trends, a method was developed based on the following features:

I. Longitudinal surface variation (roughness)

II. Rut depth

III. Thermal Cracking

IV. Fatigue (alligator) cracking

V. Patching

Structural distress is described basically in one of two ways, either as cracking or as permanent vertical deformation (rutting).

Patching could be classified as a third basic type but is thought to usually represent an effort to maintain fatigue cracking failures.

One other category of pavement problems commonly termed "surface defects" was not included as part of this rating system. These consist of defects such as coarse aggregate loss "popping," ravelling and flushing. These were considered to be of fairly minor importance when considering the most serious failure modes of Alaskan roads. They are also among the most difficult factors to accurately quantify by any reasonably rapid field method.

Each type of distress is more fully described in the following text. It was intended that each factor be measured as objectively as possible and in a manner which would allow its use in a meaningful analysis of causal relationships.

I. SURFACE ROUGHNESS

The Mays Ridemeter is normally used in the State of Alaska for collecting surface roughness data. Although roughness would usually be part of any normal inventory related pavement rating, its use was excluded in this project. Previous experience has indicated that surface roughness correlates better with general embankment and foundation stability than with upper level pavement structural problems on Alaskan roadways.

II. RUT DEPTH MEASUREMENT

The determination of average rut depth and variability is required by both safety and structural considerations. Rutting is generally defined as the longitudinal (wheel path) depressions which result from repeated wheel loadings. Rut depth results from a combination of compaction and shoving of the pavement structure as well as surface wear such as that caused by studded tires. Several structural problems which could lead to rutting are:

1. poor compaction of layers during construction

2. loss of strength during thaw periods

3. unstable asphalt concrete

4. low shoulder stability allowing lateral shoving

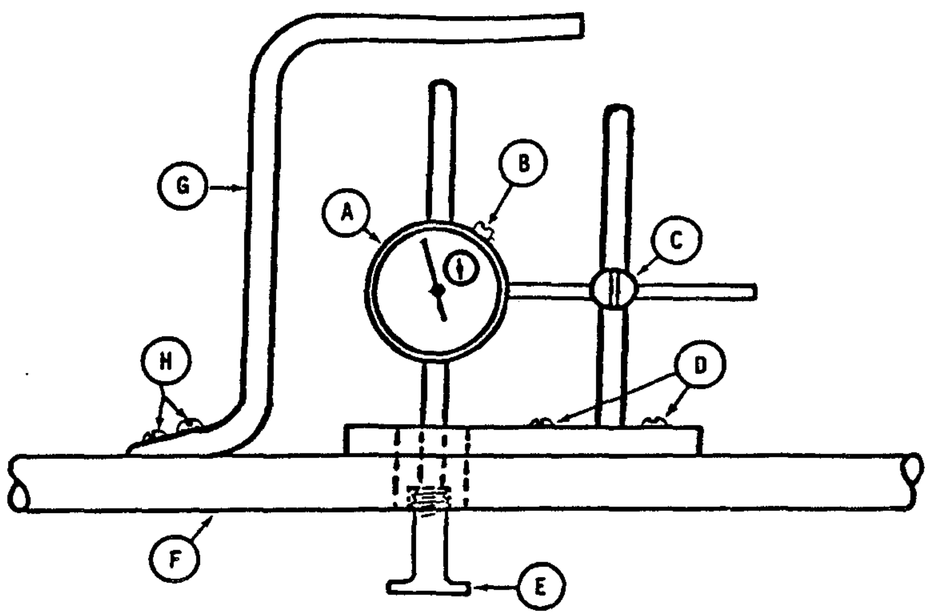
5. repeated loading of the road structure beyond design capacity

Rutting may become a safety hazard by causing difficult steering, driver fatigue and hydroplaning. Rutting may therefore be considered a type of pavement failure and should be an integral part in any pavement evaluation.

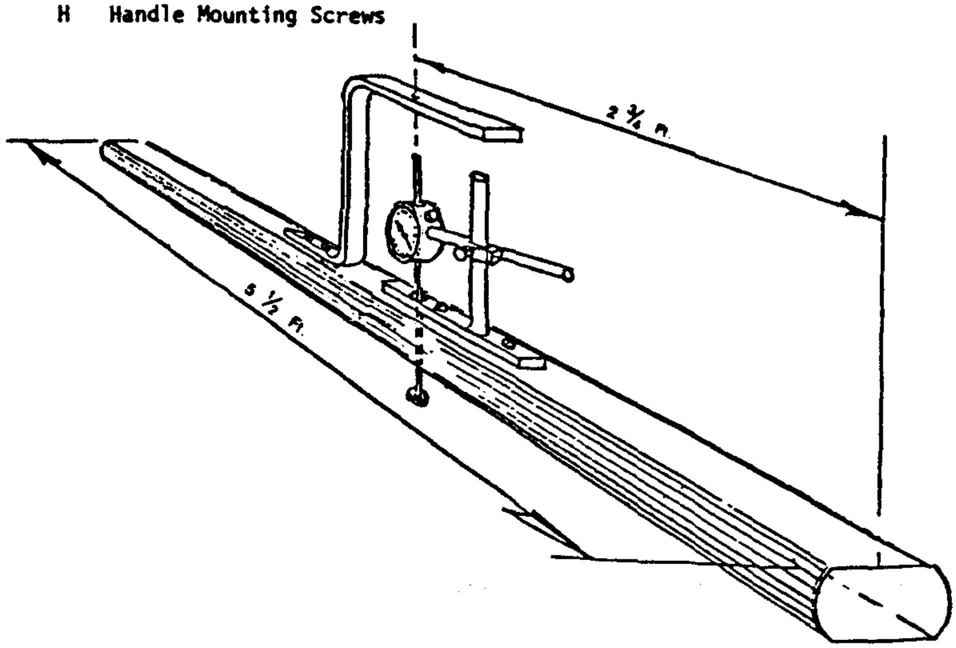
Rut depth is defined as the deviation of the pavement surface in the wheelpath from a $5\frac{1}{2}$ ft. straightedge. Figure 1 is a descriptive sketch of the Alaskan designed rut measuring device ("rut beam"). Readings are obtained by first placing the beam perpendicular to the traffic direction and centered over the deepest part of the rut. The dial indicator foot will extend below the beam to provide the depth measurement.

FIGURE 1

RUT DEPTH MEASUREMENT BEAM



A Dial indicator Assembly
B Dial indicator adjusting screw
C Vertical adjustment screw for indicator assembly
D Indicator assembly mounting screws
E Contact tip (large contact area)
F Beam
G Handle
H Handle Mounting Screws



Ruts are measured in both the inner and outer wheelpaths at eleven test locations randomly chosen within each section. The average and standard deviation is then calculated for each wheelpath and these values are considered representative of the section.

III. THERMAL CRACKING

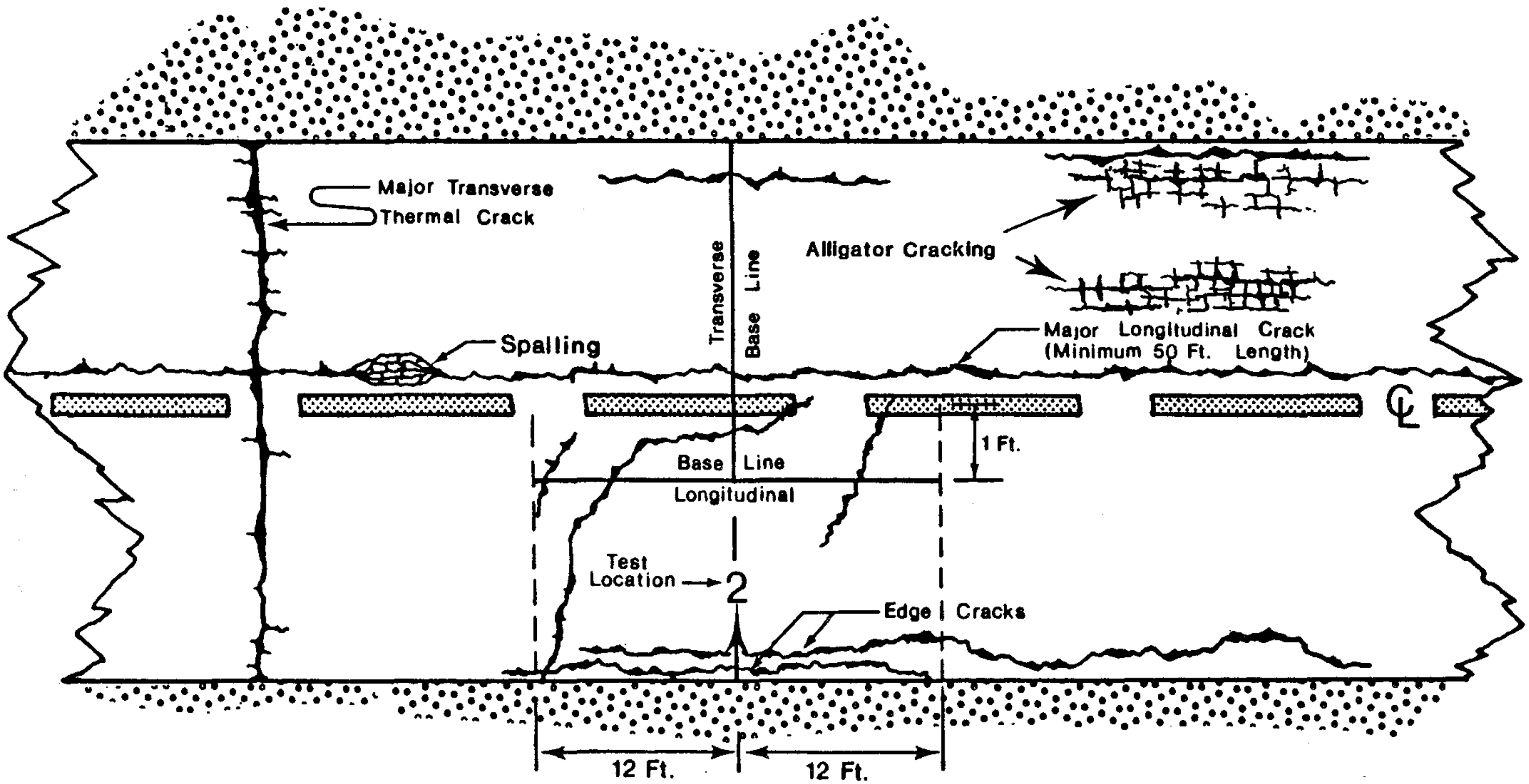
Thermal cracking is divided into four major divisions: major longitudinal, major transverse, miscellaneous longitudinal and miscellaneous transverse. Figure 2 illustrates the various crack types and should be referred to as the following explanations are read.

Major longitudinal cracks are those cracks which cross the transverse base line parallel to the centerline and have a length of greater than 50 feet. The count of major longitudinal cracking was made at each of the eleven test locations within the section.

Major longitudinal cracks are further subdivided as regular, spalled and edge cracks. "Edge" cracks occur within two feet of the outer edge of the pavement. "Spalled" cracks are those which exhibit a zone similar to alligator cracking around the parent crack. "Regular" cracks are those not classified as either spalled or edge types.

Major transverse cracks are those cracks which cross the entire width of the roadway at approximately 90° to the centerline. Each major transverse crack was counted and its exact location noted. These cracks were broken down into the subdivisions patched and unpatched. The number of major transverse cracks are normalized to

FIGURE 2


Major Transverse Thermal Crack
Transverse Base Line
Alligator Cracking
Spalling
Major Longitudinal Crack (Minimum 50 Ft. Length)
CL
1 Ft.
Base Line
Longitudinal
Test Location
2
Edge Cracks
12 Ft.
12 Ft.

PAVEMENT SURFACE SURVEY

Date: 9/14/78 Section Number 145

Location of Study Section: Richardson Hwy MP 256.0-257.0

Length of Study Section: 4699 Direction of Travel: North

Loc.	Longitudinal Cracks Regular	Longitudinal Cracks Spalled	Longitudinal Cracks Edge	Thermal Cracks Transver	Thermal Cracks Longit.	Mays Ride Meter		Rut Measurments Inner Wheel Path	Rut Measurments Outer Wheel Path
1	1	–	–	1	–	Total Inches of Axle Excursion/mile 112 (multiplier = 6.4)	Average IWP Rut Depth 102.3 Std. Dev. 55.0; Average OWP Rut Depth 145.0 Std. Dev. 67.2	079	155
2	1	–	1	1	–			095	176
3	–	–	–	–	1			252	123
4	–	–	–	–	–			068	083
5	1	–	1	–	1			101	066
6	–	1	–	–	–			092	065
7	1	–	–	–	–			039	200
8	1	–	1	1	1			086	072
9	–	–	1	–	–			102	175
10	–	–	–	–	–			077	220
11	1	–	–	1	2			134	260
Sum	6	1	4	4	5				

Alligator Cracked Areas
Linear feet/section

Inner W.P.	Outer W.P.
210	183

% of total outer W.P. 4

% of total inner W.P. 4

Major Transverse Cracks
Cracks/mile

Patched 0

Unpatched 79

Patches

Full Width (ft/mi) 241

Pothole (#/mi) 6

Remarks:

FIGURE 3

cracks/mile to facilitate statistical analysis.

Miscellaneous longitudinal and transverse cracks are those which respectively intersect the longitudinal and transverse base lines of the sampling grid (Figure 2). It should be noted that these crack types are named by the grid lines they intersect and not by the orientation of the cracks themselves. The same eleven randomly located grid locations are used for the counting of miscellaneous thermal cracks as are used for rut depth measurement.

Any of the previously described "major cracks" which happen to intersect the grid base lines are not included in this count. For example, in Figure 2 there are three minor longitudinal cracks. Miscellaneous transverse cracks are those cracks which cross the transverse base line and not included in major crack counts. In Figure 2, there are two miscellaneous transverse cracks.

IV. FATIGUE (ALLIGATOR) CRACKING

Alligator cracking is one of the most significant and recognizable distress features to be found on a pavement. This condition is often manifest as more or less continuous zones of interconnected, multisided blocks which look somewhat like the skin of an alligator. The presence of such cracking implies that total accumulated loadings have exceeded the fatigue capacity of the pavement system as it was constructed. For the purpose of the research performance survey, alligator cracking is measured continuously through each section. This measurement is recorded separately for both the inner and outer wheelpaths. Although thought was originally given to the differentiation of alligator cracking based on severity or block size. This approach was later abandoned as being technically correct but impractical as a repeatable field measurement.

Observation, especially of slight cracking, is best accomplished when lighting conditions consist of a low, head-on sun position. This provides a shadowing effect that results in maximum visibility. It is advised also that the rating procedure be done at walking speeds since this provides ample time for note taking and assures that subtle cracking is not overlooked.

V. PATCHING

In general, patching is the easiest form of pavement distress to recognize and measure. Although patching is done for a number of reasons, alligator cracking is a principle motive.

Two type of patching are recognized for the purpose of this survey:

1. pothole patching
2. major (full width) patching

Pot hole patches cover relatively small surface failures which are defined as being less than lane width. Patch lengths usually do not exceed 20 ft. in length. Longer examples, especially those which are nearly lane width, may be, at the discretion of the the rater, classed as full width patching.

Full width patching is defined as that which covers at least a total lane width. These features are commonly as wide as the total road surface and usually represent a considerable maintenance effort.

The rating sheet (Figure 3) provides a handy format for summarizing pavement rating information. Research sections are rated using the following measurement frequencies:

A. Continuous measurement

1. Mays Ride Meter
2. Fatigue (alligator cracking)
3. Pot hole patches
4. Full width patches
5. Major transverse cracks

B. Intermittent measurement utilizing 11 grid locations (Figure 2) per mile of road*

1. Rut depth
2. Thermal cracking (except major transverse cracks)

*In the event of sections shorter than one mile in length, it remains advisable to use 11 grid locations at evenly spaced intervals

APPENDIX C

CUMULATIVE DISTRIBUTION

PLOTS FOR ENVIRONMENTAL AND

DISTRESS INDICATOR VARIABLES

APPENDIX C FIGURES

Figure 1

FREQUENCY DISTRIBUTION ENVIRONMENTAL FACTORS

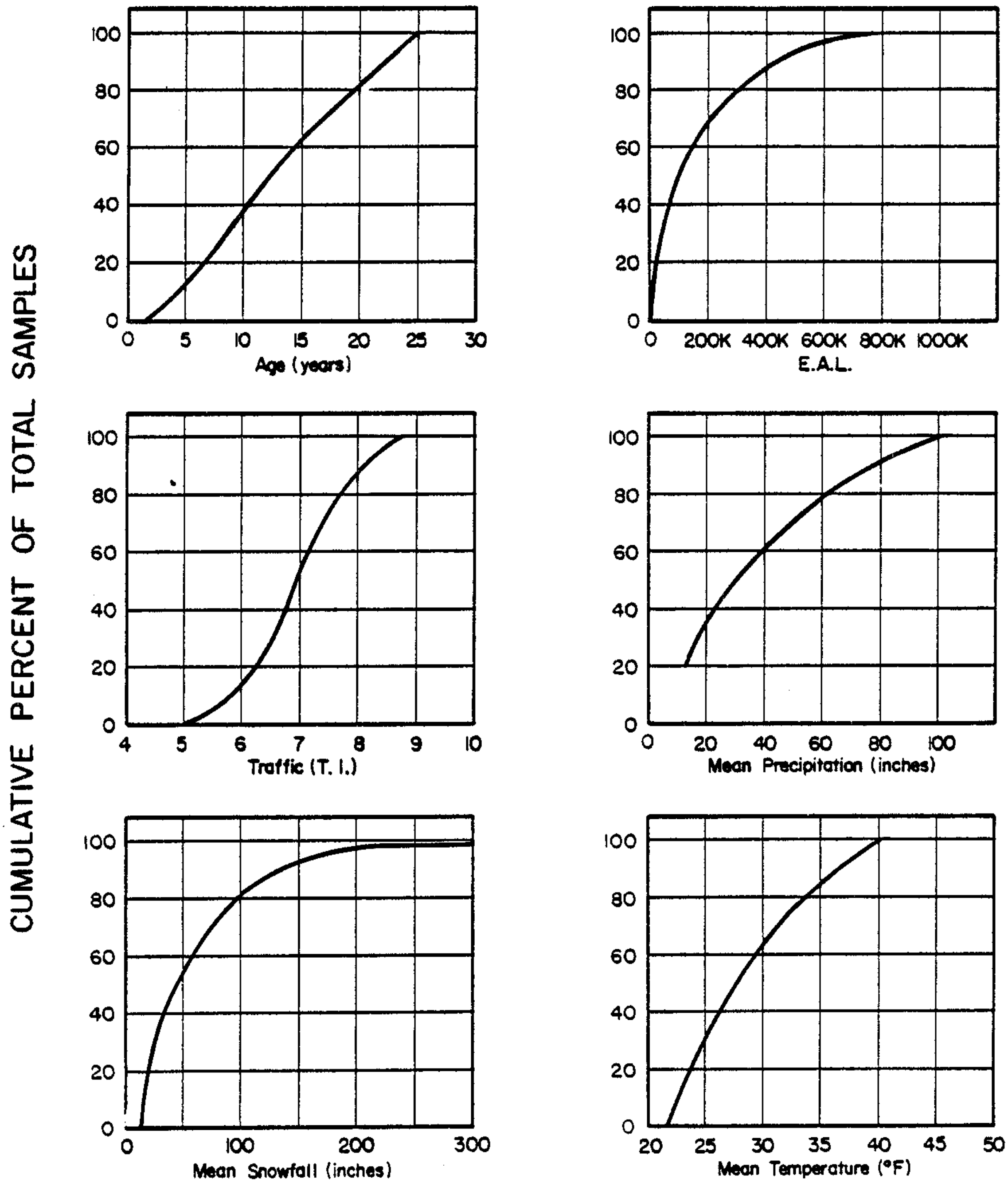


Figure 2

FREQUENCY DISTRIBUTION ENVIRONMENTAL FACTORS

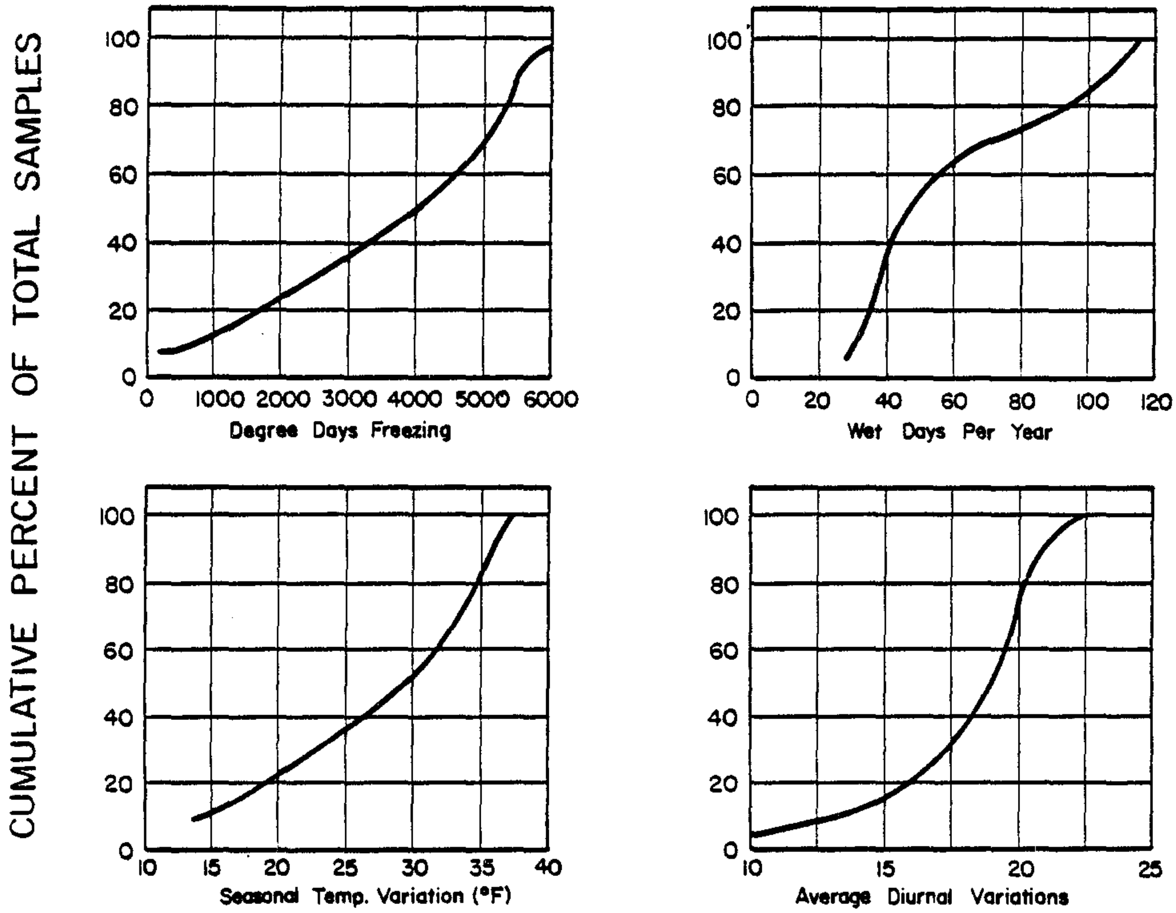


Figure 3

FREQUENCY DISTRIBUTION PERFORMANCE FACTORS

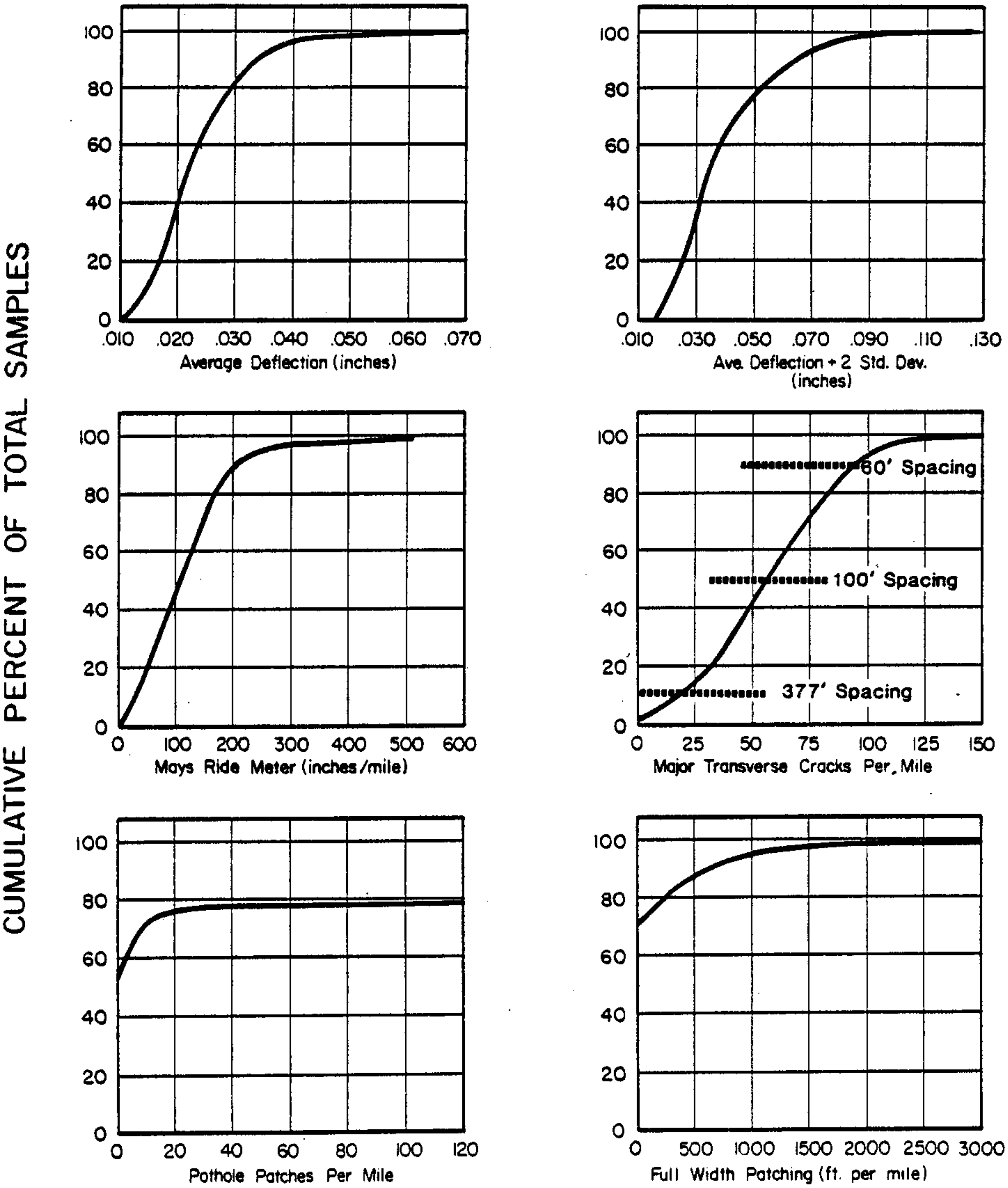


Figure 4

FREQUENCY DISTRIBUTION PERFORMANCE FACTORS

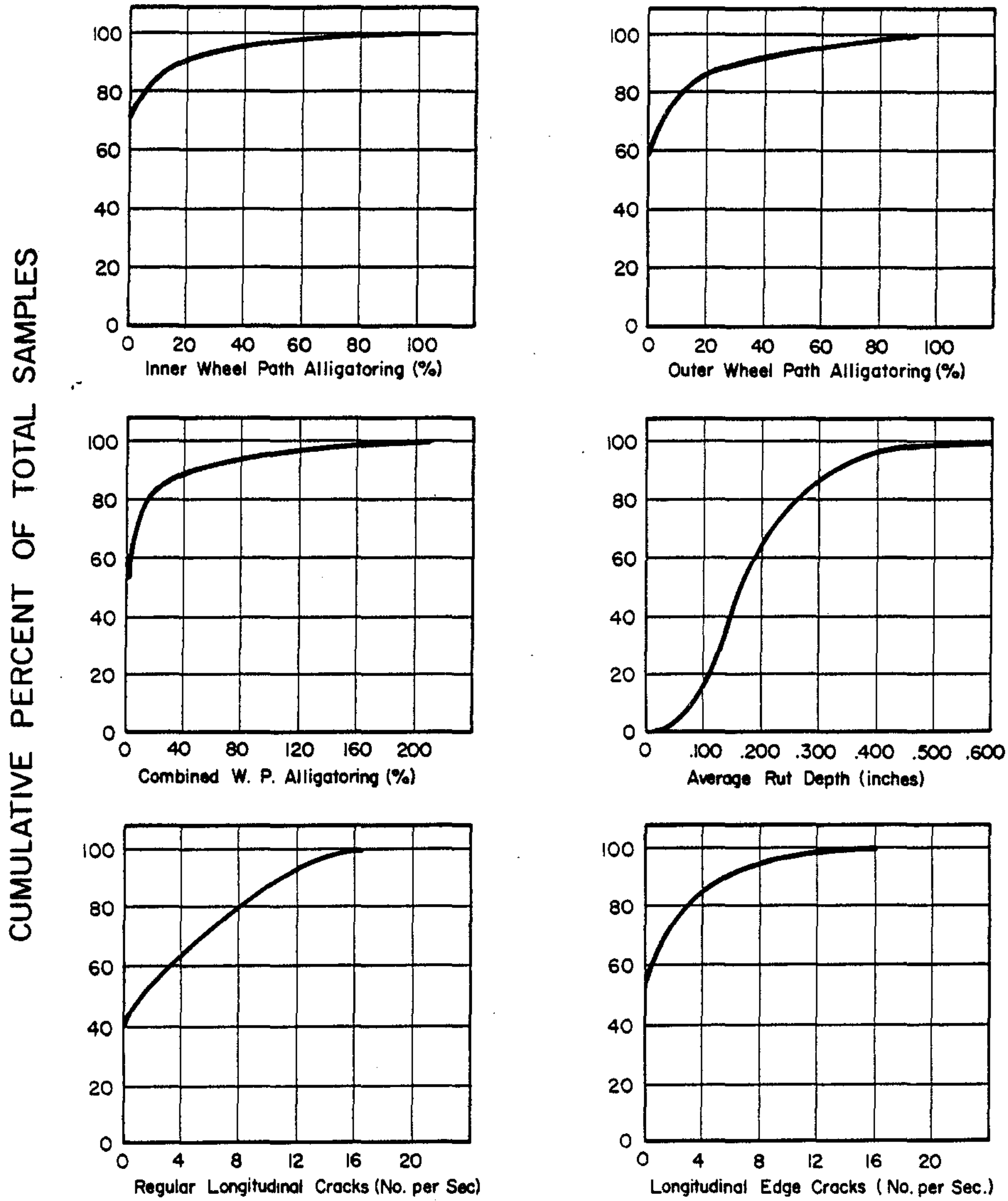
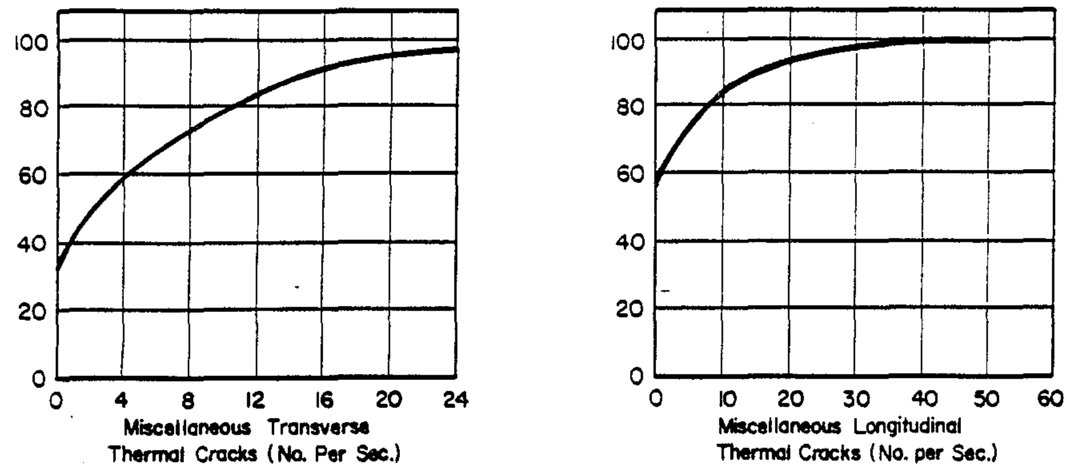


Figure 5

FREQUENCY DISTRIBUTION PERFORMANCE FACTORS



FREQUENCY DISTRIBUTION PAVEMENT SURFACING MATERIALS

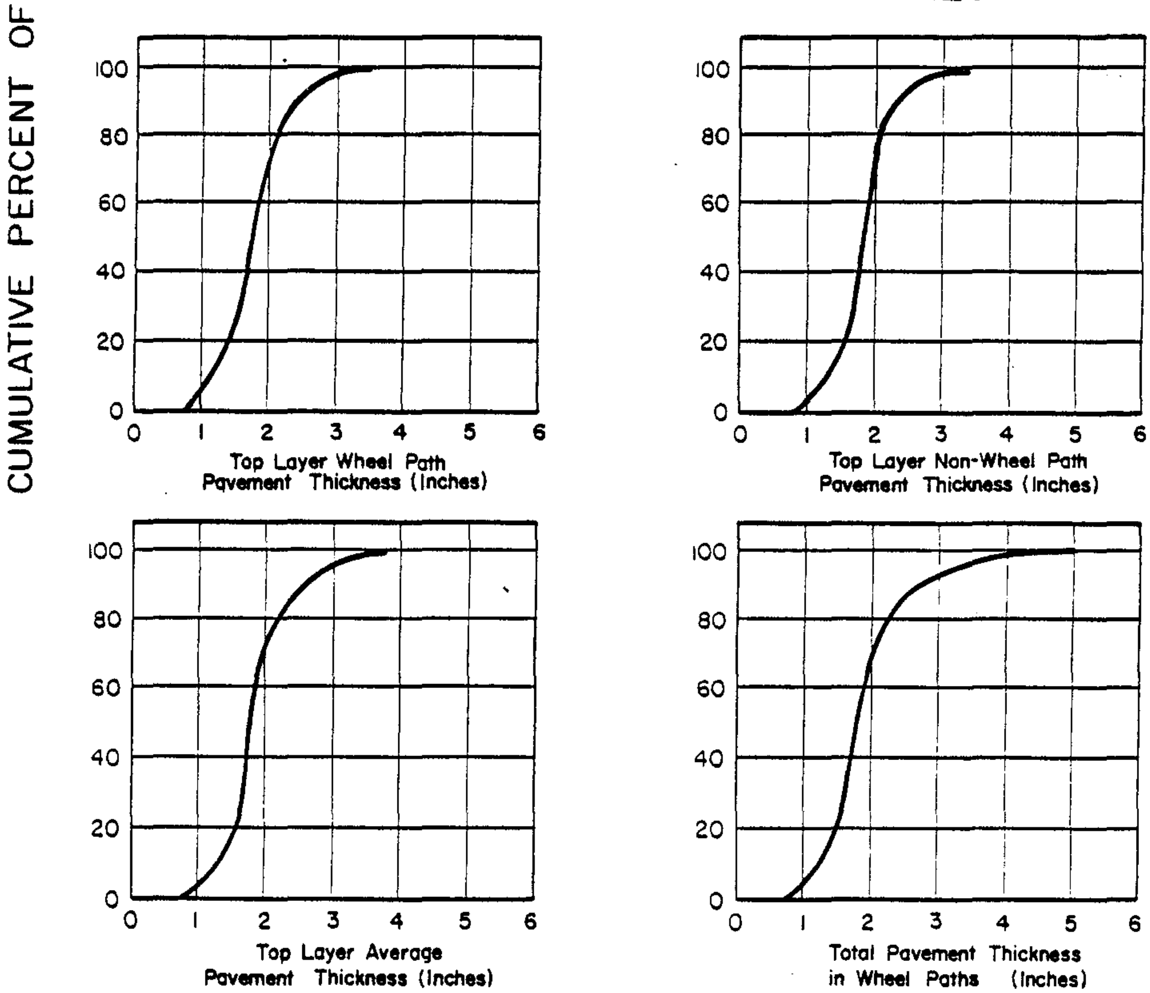


Figure 6

FREQUENCY DISTRIBUTION PAVEMENT SURFACING MATERIALS

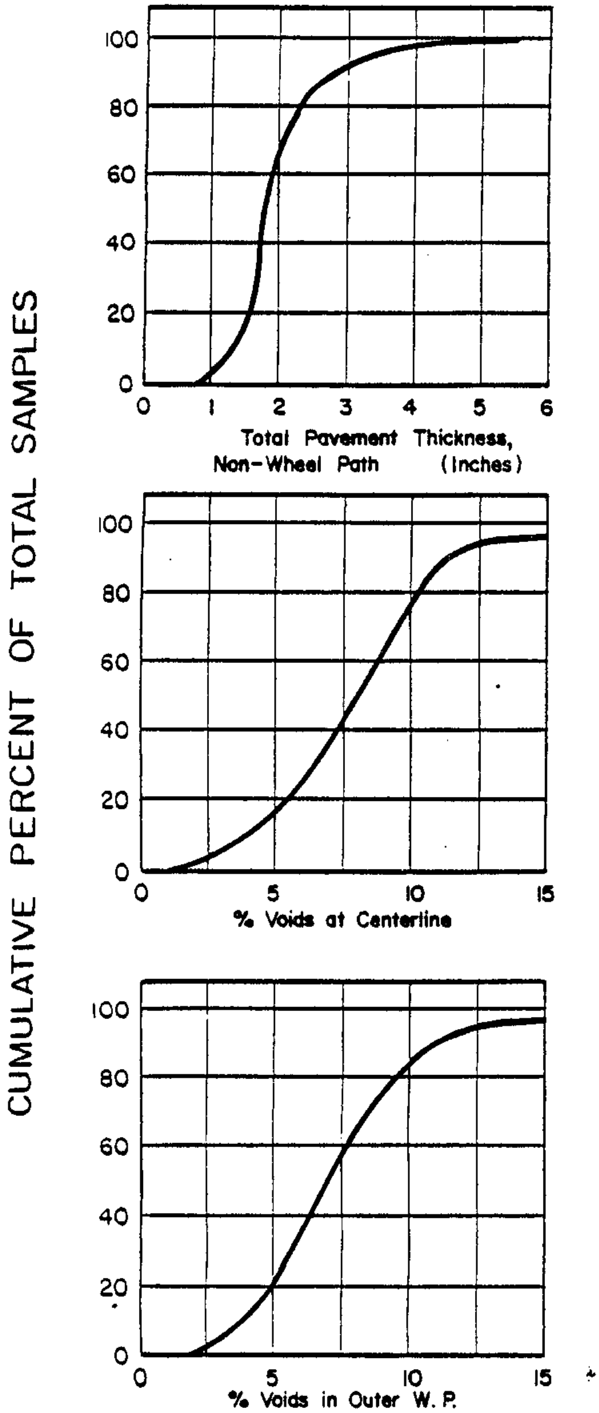


Figure 7

FREQUENCY DISTRIBUTION PAVEMENT SURFACING MATERIALS

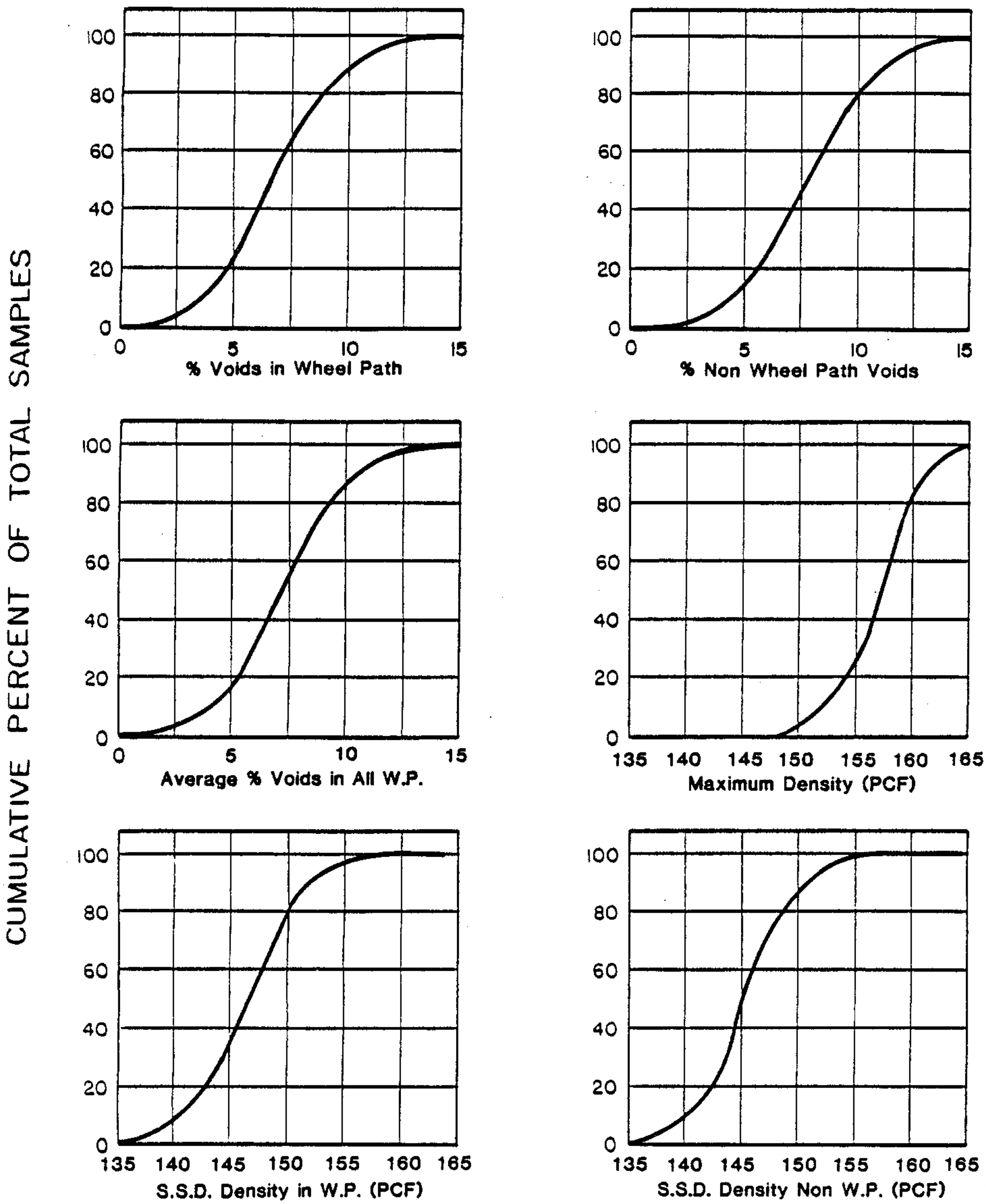


Figure 8

FREQUENCY DISTRIBUTION
PAVEMENT SURFACING MATERIALS

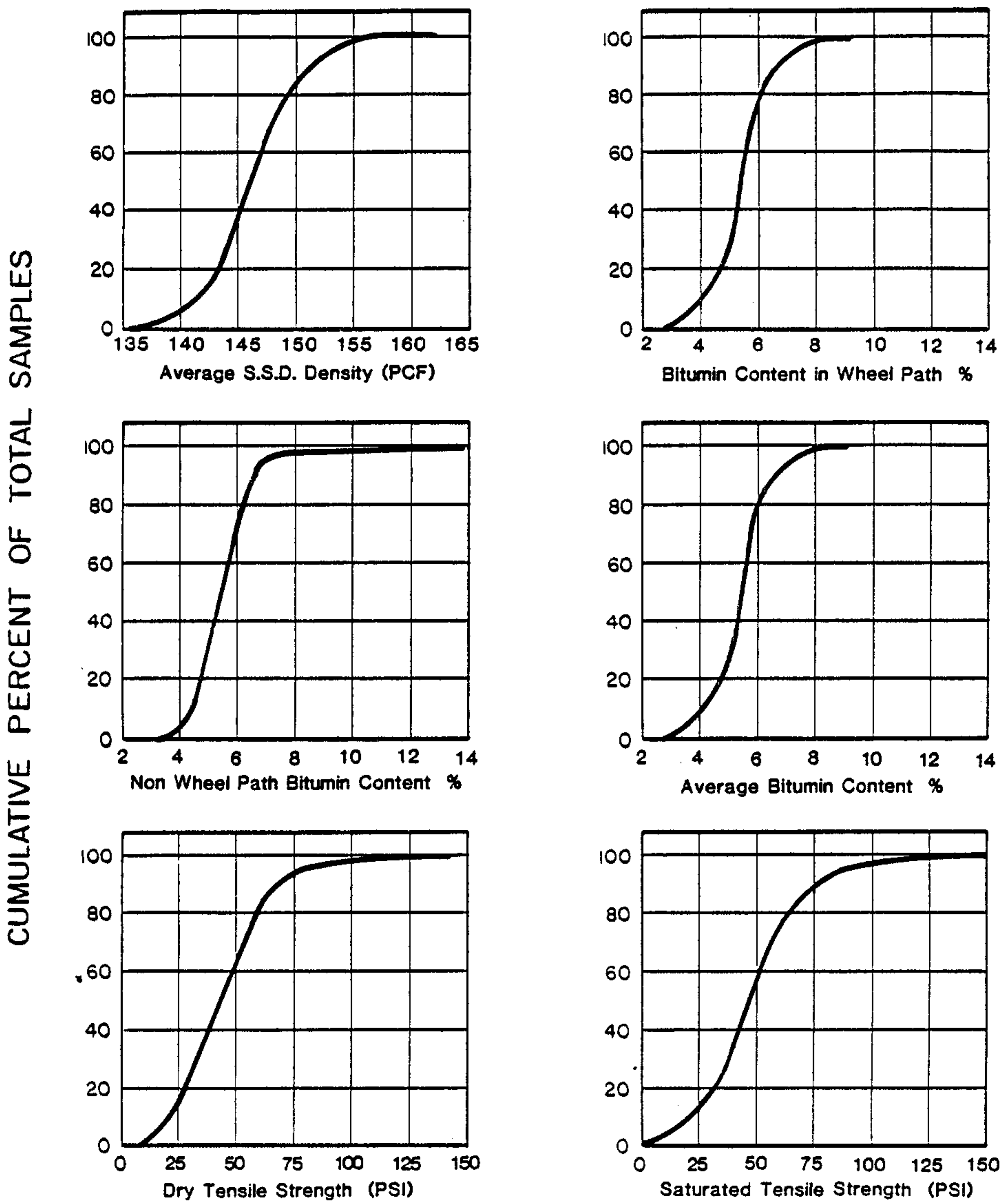


Figure 9

FREQUENCY DISTRIBUTION
PAVEMENT SURFACING MATERIALS

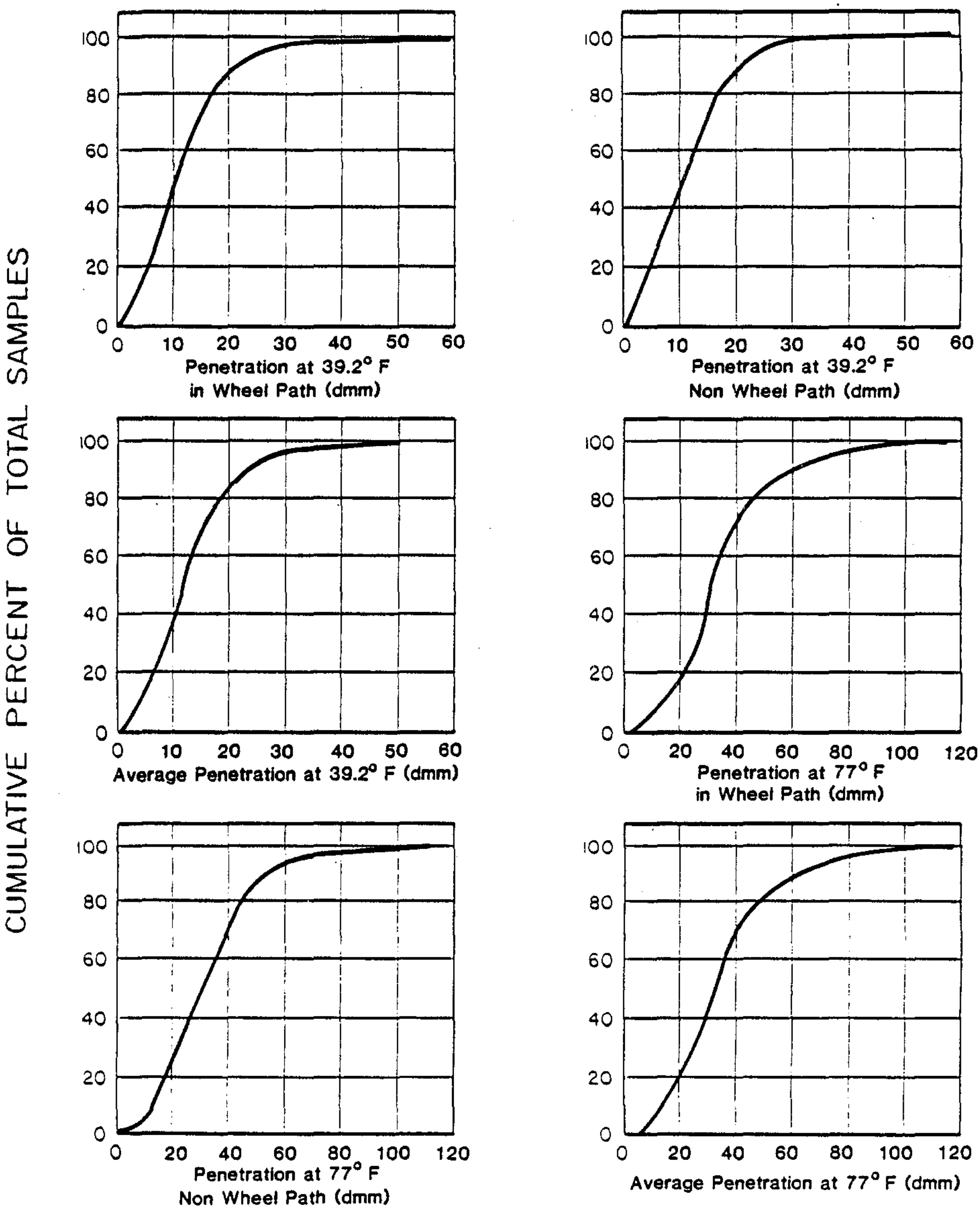


Figure 10

FREQUENCY DISTRIBUTION
PAVEMENT SURFACING MATERIALS

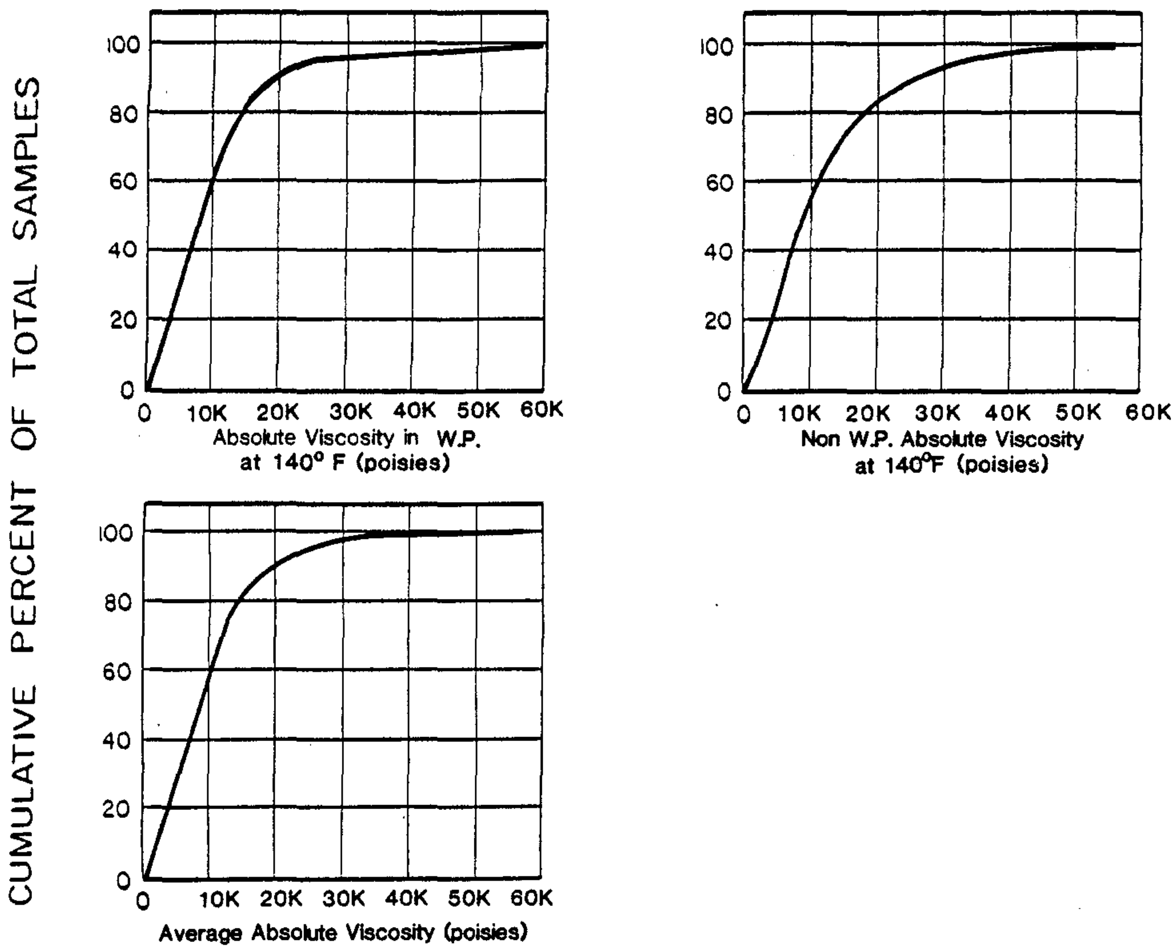
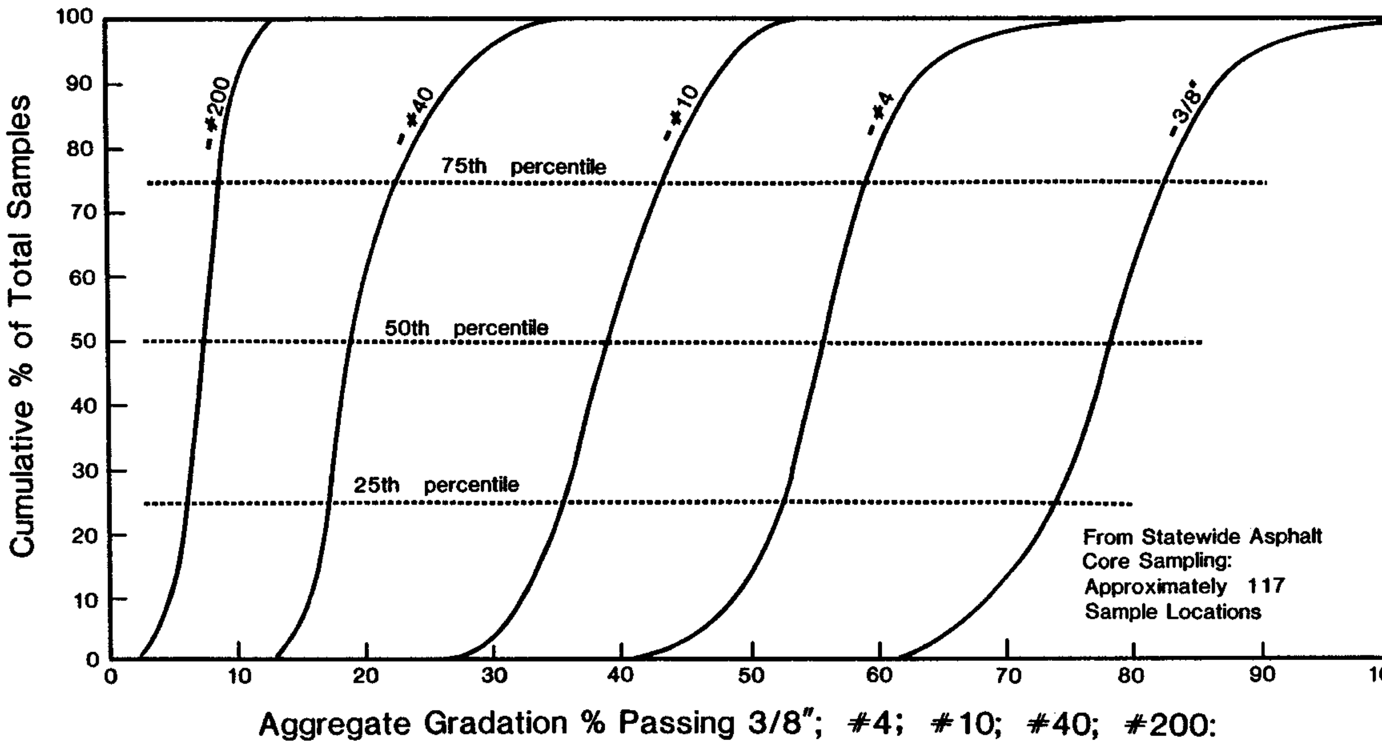


Figure 11

RANGE OF AGGREGATE GRADATION EXIBITED BY STATEWIDE PAVEMENT SAMPLING



APPENDIX D

Description of Correlated Variable

374 average measured rut depth VERSUS:		W/o Climate control	W/ Climate control
355	% 3/8 inch aggregate	-0.0036	-0.0288
356	%-#4 aggregate	0.0761	0.0497
357	%-#10 aggregate	0.0994	0.0359
358	%-#40 aggregate	0.1896	0.1201
359	%-#200 aggregate	0.1937	0.2104
352	% average top layer pvmt. thickness	-0.1346	-0.2109
353	average total pvmt. thickness	0.0646	-0.0155
368	saturated tensile strength	0.4958	0.4132
369	dry tensile strength	0.3788	0.2837
360	maximum density	-0.1263	-0.033
364	surface saturated density	0.0062	0.0722
375	average % voids	-0.0983	-0.1013
363	bitumen % w/ash correction	0.0036	-0.0621
365	average absolute viscosity	0.3034	0.3284
366	average penetration at 39.2°F	-0.2321	-0.2469
367	average penetration at 77°F	-0.2240	-0.2381
370	% voids @ centerline	-0.0324	-0.0701
371	% voids @ inner wheelpath	-0.0887	-0.0924
372	% voids @ outer wheelpath	-0.1153	-0.0992
373	% voids @ shoulder	-0.1122	-0.0825
380	% voids on wheelpath	-0.1068	-0.1039
381	% voids, non wheelpath	-0.0807	-0.0827
376	top layer pvmt. thickness, wheelpath	-0.1785	-0.2544
377	top layer pvmt. thickness, non wheelpath	-0.0874	-0.1604
378	total pvmt. thickness, wheelpath	0.0169	-0.0692
379	total pvmt. thickness, non wheelpath	0.1062	0.0450
382	bitumin % w/ash correlation, wheelpath	0.0150	-0.0535
383	bitumin % w/ash correlation, non wheelpath	-0.0060	-0.0535
384	surface saturated density, wheelpath	0.0137	0.0715
385	surface saturated density, non wheelpath	-0.0014	0.0610
386	penetration @ 77°F, wheelpath	-0.1814	-0.1893
387	penetration @ 77°F, non wheelpath	-0.2539	-0.2766
388	penetration @ 39.2°F, wheelpath	-0.1956	-0.1903
389	penetration @ 39.2°F, non wheelpath	-0.2279	-0.2580
390	absolute viscosity, wheelpath	0.3140	0.3249
391	absolute viscosity, non wheelpath	0.2829	0.3230

024 Misc. thermal cracks (longitudinal line) VERSUS:			
355	% 3/8 inch aggregate	-0.0510	-0.0593
356	%-#4 aggregate	-0.0766	-0.0354
357	%-#10 aggregate	0.1391	0.01831
358	%-#40 aggregate	0.3208	0.2756
359	%-#200 aggregate	-0.1308	-0.1197
352	average top layer pvmt. thickness	-0.0361	-0.0366

353	average total pvmt. thickness	-0.0747	-0.0726
368	saturated tensile strength	0.0779	0.0126
369	dry tensile strength	0.1783	0.1622
360	maximum density	-0.2333	-0.1561
364	surface saturated density	0.0088	0.0653
375	average % voids	-0.1894	-0.1883
363	bitumin % w/ash correction	0.0786	0.0908
365	average absolute viscosity	-0.0890	-0.1025
366	average penetration @ 39.2°F	0.0156	-0.0468
367	average penetration @ 77°F	-0.0647	-0.0575
370	% voids @ centerline	-0.0804	-0.0888
371	% voids @ inner wheelpath	-0.1642	-0.1731
372	% voids @ outer wheelpath	-0.1994	-0.1929
373	% voids @ shoulder	-0.2067	-0.1873
380	% voids in wheelpath	-0.1872	-0.1881
381	% voids in non wheelpath	-0.1720	-0.1648
376	top layer pvmt. thickness wheelpath	-0.0303	-0.0331
377	top layer pvmt. thickness, non wheelpath	-0.0145	-0.0120
378	total pavmt. thickness wheelpath	-0.0723	-0.0692
379	total pvmt. thickness, non wheelpath	-0.0696	-0.0611
382	bitumin % w/ash correlation, wheelpath	0.1075	0.1329
383	bitumin % w/ash correlation, non wheelpath	0. 0418	0.0428
384	surface saturated density, wheelpath	0.0236	0.0799
385	surface saturated density, non wheelpath	0.0024	0.0545
386	penetration @ 77°F, wheelpath	-0.0760	-0.0647
387	penetration @ 77°F, non wheelpath	-0.0394	-0.0359
388	penetration @ 39.2°F, wheelpath	-0.0137	-0.0624
389	penetration @ 39.2°F, non wheelpath	0.0465	-0.0077
390	absolute viscosity, wheelpath	-0.0417	-0.0549
391	absolute viscosity, non wheelpath	-0.1158	-0.1323

023	Misc. Thermal Cracks (transverse line)	W/o Climate Control	W/ Climate Control
VERSUS:			
355	% 3/8 inch aggregate	-0.0716	-0.0791
356	%-#4 aggregate	-0.0517	-0.0031
357	%-#10 aggregate	0.0228	0.0649
358	%-#40 aggregate	0.2307	0.1865
359	%-#200 aggregate	-0.0921	-0.0749
352	average top layer pvmt. thickness	-0.0607	-0.0730
353	average total pvmt. thickness	-0.0972	-0.0963
368	saturated tensile strength	0.1410	0.1210
369	dry tensile strength	0.1982	0.2018
360	maximum density	-0.0027	0.1028
364	surface saturated density	0.0902	0.1585
375	average % voids	-0.0902	-0.0902
363	bitumin % w/ash correct	-0.1087	-0.0981
365	average absolute viscosity	0.1075	0.1001
366	average penetration @ 39.2°F	-0.0889	-0.1755
367	average penetration @ 77°F	-0.2085	-0.2107
370	% voids @ centerline	-0.0231	-0.0331

371	% voids @ inner wheelpath	-0.0623	-0.0636
372	% voids @ outer wheelpath	-0.1278	-0.1250
373	% voids @ shoulder	-0.0878	-0.0740
380	% voids in wheelpath	-0.1017	-0.1026
381	% voids non wheelpath	-0.0638	-0.0605
376	top layer pvmt. thickness, wheelpath	-0.0631	-0.0778
377	top layer pvmt. thickness, non wheelpath	-0.0539	-0.0647
378	total pvmt. thickness, wheelpath	-0.1012	-0.0999
379	total pvmt. thickness, non wheelpath	-0.0794	-0.0727
382	bitumin % w/ash correlation, wheelpath	-0.0783	-0.0554
383	bitumin % w/ash correlation, non wheelpath	-0.1128	-0.1117
384	surface saturated density, wheelpath	0.1122	0.1790
385	surface saturated density, non wheelpath	0.0781	0.1425
386	penetration @ 77°F, wheelpath	-0.1528	-0.1474
387	penetration @ 77°F, non wheelpath	-0.2410	-0.2490
388	penetration @ 39.2°F, wheelpath	-0.0645	-0.1294
389	penetration @ 39.2°F, non wheelpath	-0.0947	-0.1754
390	absolute viscosity, wheelpath	0.0709	0.0677
391	absolute viscosity, non wheelpath	0.1376	0.1233

		W/o Climate Control	W/ Climate Control
022	edge longitudinal cracks		
VERSUS:			
355	% 3/8 inch aggregate	-0.0841	-0.0840
356	%-#4 aggregate	0.0308	0.0415
357	%-#10 aggregate	0.0196	0.0130
358	%-#40 aggregate	-0.0525	-0.1178
359	%-#200 aggregate	-0.1059	-0.0927
352	average top layer pvmt thickness	-0.0903	-0.1433
353	average total pvmt. thickness	-0.0843	-0.1671
368	saturated tensile strength	0.1837	0.1615
369	dry strength (tensile)	0.0463	-0.0282
360	maximum density	0.1383	0.1807
364	surface saturated density	0.0433	0.0764
375	average % voids	0.0519	0.0342
363	bitumin % w/ash correction	-0.1286	-0.1274
365	average absolute viscosity	0.1116	0.1197
366	average penetration @ 39.2°F	-0.3203	-0.3049
367	average penetration @ 77°F	-0.3205	-0.3082
370	% voids @ centerline	-0.0628	-0.0931
371	% voids @ inner wheelpath	0.0481	0.0358
372	% voids @ outer wheelpath	0.0338	0.0248
373	% voids @ shoulder	0.1420	0.1471
380	% voids wheelpath	0.0444	0.0300
381	% voids non wheelpath	0.0503	0.0374
376	top layer pvmt. thickness, wheelpath	-0.1293	-0.1785
377	top layer pvmt. thickness, non wheelpath	-0.0466	-0.1017
378	total pvmt. thickness, wheelpath	-0.1146	-0.1954
379	total pvmt. thickness, non wheelpath	-0.0577	-0.1286
382	bitumin % w/ash correlation, wheelpath	-0.2170	-0.2268
383	bitumin % w/ash correlation, non wheelpath	-0.0362	-0.0300

384	surface saturated density, wheelpath	0.0498	0.0783
385	surfae saturated density, non wheelpath	0.0526	0.0805
386	penetration @ 77°F, wheelpath	-0.2818	-0.2709
387	penetration @ 77°F, non wheelpath	-0.2984	-0.2861
388	penetration @ 39.2°F, wheelpath	-0.2592	-0.2381
389	penetration @ 39.2°F, non wheelpath	-0.3303	-0.3201
390	absolute viscosity, wheelpath	0.1104	0.1209
391	absolute viscosity,, non wheelpath	0.1210	0.1254

020 regular longitudinal cracks
VERSUS:

355	% 3/8 inch aggregate	0.0797	0.0306
356	%-#4 aggregate	0.0856	0.0536
357	%-#10 aggregate	0.2156	0.1691
358	%-#40 aggregate	0.3119	0.2958
359	%-#200 aggregate	-0.0303	-0.0449
352	average top layer pvmt. thickness	0.0047	0.0002
353	average total pvmt. thickness	-0.0832	-0.0612
368	saturated tensile strength	0.2370	0.1572
369	dry tensile strength	0.2821	0.1965
360	maximum density	-0.1343	0.0190
364	surface saturated density	-0.0192	0.0938
375	average % voids	-0.0753	-0.0695
363	bitumin % w/ash correction	0.0079	-0.0478
365	average absolute viscosity	0.1274	0.0974
366	average penetration @ 39.2°F	0.0170	-0.1020
367	average penetration @ 77°F	-0.1184	-0.1618
370	% voids @ centerline	0.0398	0.0088
371	% voids @ inner wheelpath	-0.0760	-0.0942
372	% voids @ outer wheelpath	-0.0668	-0.0386
373	% voids @ shoulder	-0.1046	-0.0720
380	% voids wheelpath	-0.0832	-0.0766
381	% voids non wheelpath	-0.0415	-0.0397
376	top layer pvmt. thickness, wheelpath	0.0264	0.0172
377	top layer pvmt. thickness, non wheelpath	-0.0190	-0.0138
378	total pvmt. thickness, wheelpath	-0.0665	-0.0468
379	total pvmt. thickness, non wheelpath	-0.0716	-0.0479
382	bitumin % w/ash correlation, wheelpath	0.0269	-0.0184
383	bitumin % w/ash correlation, non wheelpath	-0.0083	-0.0609
384	surface saturated density, wheelpath	0.0031	0.1123
385	surface saturated density, non wheelpath	-0.0297	0.0814
386	penetration @ 77°F, wheelpath	-0.1299	-0.1607
387	penetration @ 77°F, non wheelpath	-0.0799	-0.1339
388	penetration @ 39.2°F, wheelpath	-0.0364	-0.1164
389	penetration @ 39.2°F, non wheelpath	0.0528	-0.0863
390	absolute viscosity, wheelpath	0.2118	0.1762
391	absolute viscosity, non wheelpath	0.0633	0.0488

144 total % alligator cracking
VERSUS:

355	% 3/8 inch aggregate	-0.0470	-0.0773

356	%-#4 aggregate	0.0209	-0.0361
357	%-#10 aggregate	-0.0361	-0.1120
358	%-#40 aggregate	0.0468	0.0473
359	%-#200 aggregate	0.3635	0.3652
352	average top layer pvmt. thickness	-0.0058	-0.0353
353	average total pvmt. thickness	-0.0616	0.910
368	saturated tensile strength	0.4923	0.5442
369	dry tensile strength	0.6226	0.6577
360	maximum density	0.0067	0.0334
364	surface saturated density	-0.0281	0.0131
375	average % voids	0.0313	0.0174
363	bitumin % w/ash correction	0.0017	-0.0245
365	average absolute viscosity	0.5172	0.5178
366	average penetration @ 39.2°F	-0.2725	-0.3000
367	average penetration @ 77°F	-0.2831	-0.3067
370	% voids @ centerline	0.0374	0.0033
371	% voids @ inner wheelpath	0.0104	-0.0118
372	% voids @ outer wheelpath	-0.0139	-0.0165
373	% voids @ shoulder	0.0590	0.0584
380	% voids in wheelpath	0.0002	-0.0108
380	% voids in non wheelpaths	0.0545	0.0356
376	top layer pvmt. thickness, wheelpath	-0.0080	-0.0368
377	top layer pvmt. thickness, non wheelpath	-0.0042	-0.0284
378	total pvmt. thickness, wheelpath	-0.0607	-0.0904
379	total pvmt. thickness, non wheelpath	-0.0648	-0.0964
382	bitumin % w/ash correlation, wheelpath	0.0272	0.0082
383	bitumin % w/ash correlation, non wheelpath	-0.0239	-0.0442
384	surface saturated density, wheelpath	0.0027	0.0408
385	surface saturated density, non wheelpath	-0.0434	-0.0038
386	penetration @ 77°F, wheelpath	-0.2092	-0.2268
387	penetration @ 77°F, non wheelpath	-0.3182	-0.3485
388	penetration @ 39.2°F, wheelpath	-0.2324	-0.2371
389	penetration @ 39.2°F, non wheelpath	-0.2513	-0.2993
390	absolute viscosity, wheelpath	0.5005	0.4980
391	absolute viscosity, non wheelpath	0.4743	0.4845

		W/o Climate Control	W/ Climate Control
143	major transverse thermal cracks		
VERSUS:			
355	% 3/8 inch aggregate	0.0135	0.0157
356	%-#4 aggregate	-0.0539	0.0868
357	%-#10 aggregate	-0.1759	-0.0711
358	%-#40 aggregate	-0.0949	-0.2327
359	%-#200 aggregate	-0.0918	-0.0899
352	average top layer pvmt. thickness	-0.1087	0.0044
353	average total pvmt. thickness	-0.2195	-0.0539
368	saturated tensile strength	0.1757	0.3070
369	dry tensile strength	0.0604	0.1707
360	maximum density	0.1280	0.3014
364	surface saturated density	-0.0176	0.0558
375	average % voids	0.1132	0.1381
363	bitumin % w/ash correction	-0.2952	-0.2381

365	average absolute viscosity	0.2859	0.2829
366	average penetration @ 39.2°F	0.0012	-0.1777
367	average penetration @ 77°F	-0.2332	-0.2421
370	% voids @ centerline	0.0422	0.0798
371	% voids @ inner wheelpath	0.1715	0.1725
372	% voids @ outer wheelpath	0.1085	0.1229
373	% voids @ shoulder	0.0772	0.1254
380	% voids in wheelpath	0.1482	0.1542
381	% voids in non wheelpath	0.0661	0.1121
376	top layer pvmt. thickness, wheelpath	-0.0947	0.0053
377	top layer pvmt. thickness, non wheelpath	-0.1100	0.0115
378	total pvmt. thickness, wheelpath	-0.2128	-0.0549
379	total pvmt. thickness, non wheelpath	-0.2197	-0.0480
382	bitumin % w/ash correlation, wheelpath	-0.3112	-0.2241
383	bitumin % w/ash correlation, non wheelpath	-0.2293	-0.2044
384	surface saturated density, wheelpath	-0.0535	0.0298
385	surface saturated density, non wheelpath	0.0127	0.0722
386	penetration @ 77°F, wheelpath	-0.1724	-0.1585
387	penetration @ 77°F, non wheelpath	-0.2977	-0.3305
388	penetration @ 39.2°F, wheelpath	0.0057	-0.1241
389	penetration @ 39.2°F, non wheelpath	-0.0143	-0.2078
390	absolute viscosity, wheelpath	0.2550	0.2491
391	absolute viscosity, non wheelpath	0.3202	0.3185

		W/o Climate Control	W/ Climate Control
035	full width patching		
VERSUS:			
355	% 3/8 inch aggregate	-0.0406	-0.0564
356	%-#4 aggregate	-0.0441	-0.0553
357	%-#10 aggregate	-0.0862	-0.0935
358	%-#40 aggregate	0.0559	0.0982
359	%-#200 aggregate	0.3027	0.2948
352	average top layer pvmt. thickness	-0.0795	-0.0326
353	average total pvmt. thickness	-0.1125	-0.0377
368	saturated tensile strength	0.1084	0.1621
369	dry tensile strength	0.1024	0.1816
360	maximum density	0.0199	0.0423
364	surface saturated density	-0.0260	-0.0307
375	average % voids	0.0766	0.1009
363	bitumin % w/ash correction	-0.0036	-0.0159
365	average absolute viscosity	0.0820	0.0690
366	average penetration @ 39.2°F	-0.0287	-0.1143
367	average penetration @ 77°F	-0.0875	-0.1171
370	% voids @ centerline	0.0756	0.1020
371	% voids @ inner wheelpath	0.0928	0.1051
372	% voids @ outer wheelpath	0.0413	0.0581
373	% voids @ shouldelrl	0.0464	0.0604
380	% voids in wheelpath	0.0730	0.0916
381	% voids in non wheelpath	0.0672	0.0883
376	top layer pvmt. thickness wheelpath	-0.1096	-0.0730
377	top layer pvmt. thickness, non wheelpath	-0.0433	0.0163
378	total pvmt. thickness, wheelpath	0.1330	-0.0672

379	total pvmt. thickness, non wheelpath	-0.0961	-0.0255
382	bitumin % w/ash correlation, wheelpath	-0.0042	-0.0131
383	bitumin % w/ash correlation, non wheelpath	-0.0025	-0.0151
384	surface saturated density, wheelpath	-0.0255	-0.0247
385	surface saturated density, non wheelpath	-0.0303	-0.0322
386	penetration @ 77°F, wheelpath	-0.0408	-0.0622
387	penetration @ 77°F, non wheelpath	-0.1288	-0.1636
388	penetration @ 39.2°F, wheelpath	-0.0136	-0.0734
389	penetration @ 39.2°F, non wheelpath	-0.0287	-0.1258
390	absolute viscosity, wheelpath	0.0702	0.0511
391	absolute viscosity, non wheelpath	0.0801	0.0766