DESCRIPTION & EVALUATION
OF THE
ALASKA PAVEMENT RATING
PROCEDURE

FINAL REPORT

by

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February 1982

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
DIVISION OF PLANNING AND PROGRAMMING
RESEARCH SECTION
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18. Abstract

This report describes and examines pavement condition rating methods used on Alaska's roadways since 1978. The methods were intended to provide the specific performance data necessary to optimize construction/maintenance planning and the allocation of available funds. Rating elements include simplified measurements of ride roughness, fatigue (alligator) cracking, patching and rut depth. These features are reported individually but are also combined with traffic data to indicate more general roadway serviceability levels.

Field evidence shows that a high degree of variability presently exists in the measurement of cracking, patching and rutting. Coefficients of variations above 20% were estimated for each type of rating element from experimentally repeated measurements. On a given road section, estimates of fatigue cracking made by 15 crews, differed by up to twice the calculated average. Rut depth measurements were typified by calculated standard deviations of about half the mean value.

Report findings suggest that great care be exercised on future pavement performance inventories. Standardization techniques are suggested which should improve manual rating methods; although mechanized or electronic data acquisition techniques must be developed to eliminate human error.

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Introduction:

The Alaska Department of Transportation and Public Facilities (DOTPF) initiated use of newly developed pavement rating procedures during its 1978 highway inventory. The purpose of this study is to describe the pavement rating method in detail and evaluate the individual measurements which comprise it. The Alaskan rating attempts to quantify surface cracking, patching and wheelpath rutting as an aid to design, construction and maintenance planning. This report examines the significant amount of error associated with measurements of pavement of distress, and suggests improvements which can be incorporated into future inventory work.

Principal topics addressed are:

- pavement ratings in the context of a pavement management system
- the development of Alaska's rating method for flexible pavements
- accuracy and reproducibility of field measurements for pavement ratings conducted by a two-man crew
- ways of improving observation and sampling methods

The research data base utilized in this study consisted of data and experience accumulated from two complete inventories of the Alaskan paved highway system conducted over the past three years. The study also examines results of repetitive sampling conducted specifically for this project on five typical pavement sections located near Fairbanks, Alaska.

The conclusions reached in this report will provide guidelines which can be incorporated into the State's future inventory work.

SUMMARY & CONCLUSIONS

This report describes the development and evaluation of Alaska's inventory rating procedure for flexible pavements.

Development of the system was based on the generally accepted principals of pavement rating practice as outlined in recent literature. The Alaskan rating method attempts to measure basic elements of road quality from two important viewpoints:

1) the highway user ---
   - * ride roughness
2) the highway engineer ---
   - * fatigue (alligator) cracking
   - * major (full lane width) patching
   - * wheelpath rutting

These rating features are reported on a mile-by-mile summary both individually and in terms of a composite servicability score. As the rating method was being developed, a concerted effort was made to keep all distress measurements as simple as possible while providing adequate information for pavement management needs.

The rating method was evaluated through a special field study and experience accumulated during the three years since its implementation. Findings indicate a large variation in the abilities of different rating crews to characterize the extent and severity of patching and cracking. The range of variation in crack and patch measurements obtained by 15 crews on 5 selected pavement sections was found to be as much as twice the mean measured value. These differences are apparently associated with the level of task-interest expressed by each crew and weather factors controlling visibility of pavement surface features. Examination of previous inventory ratings confirmed the data scatter indicated by the experimental pavement sections.

The variation in rut depth measurements was large enough to require very high sampling frequencies. A mechanized form of rut measuring device is suggested which is capable of more than 100 measurements per section in both inner and outer wheelpaths. Marked differences between average depths of inner and outer wheelpaths require data from both locations in order to define the worst-case condition.

Conclusions:

- The assumption that Alaska's pavement rating methods are simple enough to insure a high degree of reproducibility is not demonstrated with available data.
- A great deal of variation is apparent in the field measurement of cracking, patching and rutting. This is indicated through examination of experimental data as well as data collected from previous inventory work.
- The use of machine measurements is suggested wherever possible in all phases of the rating process.
- It is evident that pavement rating by "eyeball" methods is a difficult process requiring careful and rigorously standardized technique. Pavement rating instructions must be formalized to include guidelines for training rating crews and insuring acceptable performance. Specifications are necessary for standardization of viewing height, acceptable lighting conditions and vehicle speed.

RECOMMENDATIONS

The ability to successfully quantify pavement performance is a requirement of almost any approach to pavement management. It is therefore necessary to view Alaska's pavement rating method as a tool to be improved rather than discarded.

Recommendations for improvement include:

1) Phase out human "eyeball" measurements of pavement distress as reliable machines methods become available.

2) Except for very rough classification purposes, rut measurements should be discontinued until sampling rates of more than 100 per mile can be achieved.

3) Continue existing approach but with greatly increased/improved crew training and a strict standardization of observation technique.

An ideal form of instruction would include the use of "standard" road sections. On these sections, the crew would attempt to match the ratings performed by experienced personnel. The author suggests a five-day "tuning" period for new rating crews. Ratings performed during this first week would not be included in the inventory summary before being verified by a repeated observation.

Observation conditions for the inventory measurement of cracking and patching should be standardized:

1) vehicle speed at 6 mph or less
2) rating only completely dry road surfaces
3) utilization of optimal sun incidence whenever possible
    best illumination -- (See figure 10)
    * horizontal sun angle of +-70 degrees from head-on
    * vertical sun angle of more than 10 and less than 60 degrees from the horizontal

This point should be emphasized even if it requires that the direction of travel, i.e., direction of the rater's view, be changed.

4) standardized viewing height at 5 1/2 feet ± 1/2 foot
5) use of utility van-type vehicle with nearly vertical windshield

SECTION I

DESCRIPTION OF THE ALASKA DOTPF PAVEMENT RATING PROCEDURE

DEVELOPING AN ALASKAN
PAVEMENT RATING PHILOSOPHY

Background and Literature:

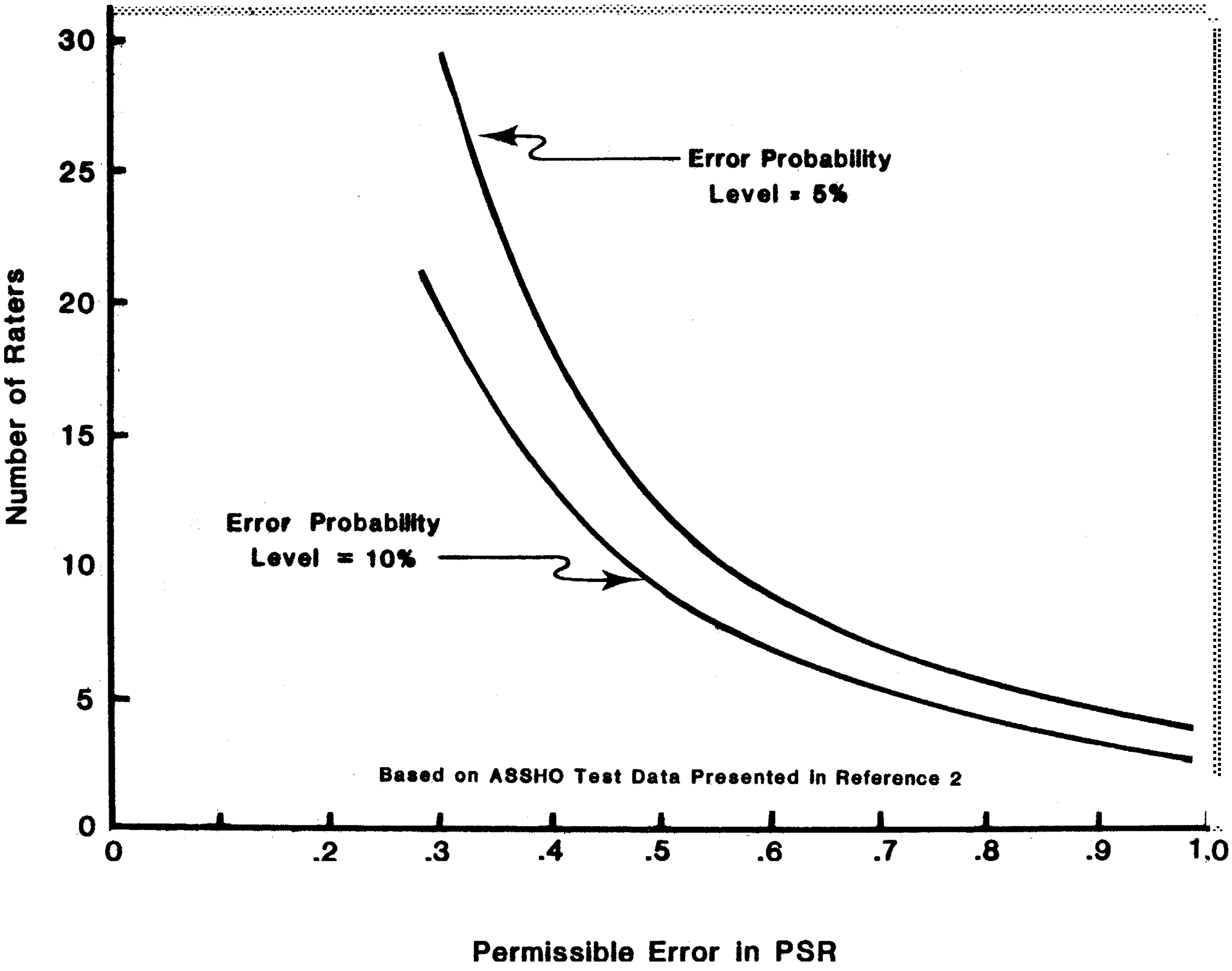
During the winter of 1977-78 the Planning Division of Alaska's DOTPF decided to revise its existing highway inventory procedure. The impetus behind this move was an increasing awareness of the need for accurate, quantitative data for programming highway maintenance and construction funds. The Department's Research Section was commissioned to produce a practical inventory system, one which would stand the scrutiny of statistical evaluation.

Before attempting to assemble an Alaskan highway inventory procedure, the literature was researched to see how other American states and foreign government transportation agencies had negotiated the same ground.

A method for rating pavements was first developed for use in the AASHO road test of the late 50's to early 60's era (1). The original idea behind the rating was to numerically classify pavements based on the subjective observations of engineering specialists and normal highway users. A rating scale was arbitrarily set between 0 and 5, where 0 is extremely poor and 5 is perfect. The key distress manifestations selected were; surface deterioration, ride roughness, rutting, cracking and maintenance patching. This rating technique produced a number termed "Present Serviceability Rating" (PSR) intended for classifying a given section of road. Figure 1 indicates the number of individual raters necessary, statistically, to estimate the "true" value of PSR using the completely subjective AASHO method. This figure indicates that for 1 or 2 raters the error associated with estimation of PSR is greater than 1. Since the error can range either t or - from the true value, the full range of possible estimation is therefore 2 which represents 1/3 of the total 0-5 scale.

The AASHO researchers then took the next logical step of converting the rating from a subjective to an objective method by deriving a regression equation closely matching PSR panel scores. Regression equation independent variables consisted of standardized measurements of fatigue cracking area, maintenance patch area, wheelpath rut depth and longitudinal surface variation (roughness). The road surface condition values

Figure 1
ESTIMATING PSR



calculated by the regression equation are termed "Present Serviceability Index" (PSI).

- AASHO Equation -

$$PSI = 5.03-1.91 \log (1+SV)-1.38RD^2-0.01 \sqrt{C+P}$$

Where :

SV = mean slope variance in the two wheelpaths as measured absolutely by a longitudinal profilometer (inches per mile x 10^6)

RD = mean rut depth (inches)

C+P = cracking + patching (square feet/1,000 square feet total surface)

Most pavement rating methods developed subsequent to the AASHO study, including Alaska's, are related in some degree to the original AASHO form and were intended to provide key performance feedback to the overall pavement management process. Generation of Alaska's rating scheme was expedited by a then recently complied summary and critique of highway agency pavement management practices. A federally sponsored workshop was held in Tumwater, Washington, in November of 1977 which examined the existing state-of-the-art in the field of Pavement Management Systems (PMS). U.S. and Canadian representatives were selectively invited providing they were actively implementing, and therefore experienced in a PMS program. At the time the ADOTPF was attempting to devise a rating method for asphalt concrete pavements, the Tumwater conference report was by far the most comprehensive source of information concerning rating schemes available. Although the Tumwater meeting addressed the general field of pavement management, a major topic of discussion concerned selection of methods for examining and rating pavements (3). The Tumwater report not only discussed various field methods but critically compared them. Rating system elements were suggested which provided the best input to the overall PMS.

The following discussion will indicate how pavement ratings **fit** into an overall PMS. **It** will also review some principal conclusions reached at Tumwater which were used in the development of Alaska's rating methods. Figure 2 is an idealized representation of the "systems" approach to pavement management **(10).** Pavement ratings within this scheme provide vital data to both project **(pl)** and network **(nl)** levels. Alaska presently uses its pavement ratings mostly at the network level for allocation of funding through the Division of Planning and Programming. There has been some use of inventory data, however, as a road classification tool in research projects. Also, at the regional level, maintenance analysts are beginning to look at road inventory data as an aid to manpower and equipment allocation. The idealized "Data File" shown at the center of Figure 2 does not exist in a comprehensive form within the ADOTPF at the present time. In Alaska, data concerning the highway inventory, maintenance expenditure, highway design, highway economics, etc. are stored on separate files in various computer systems. Additionally, little is compatible between different data files to allow their utilization as combinable PMS input.

Assuming that a PMS would be the ultimately intended use of pavement inventory data, the following consensus emerged from the Tumwater conference:

1. Ride roughness should be objectively rated,

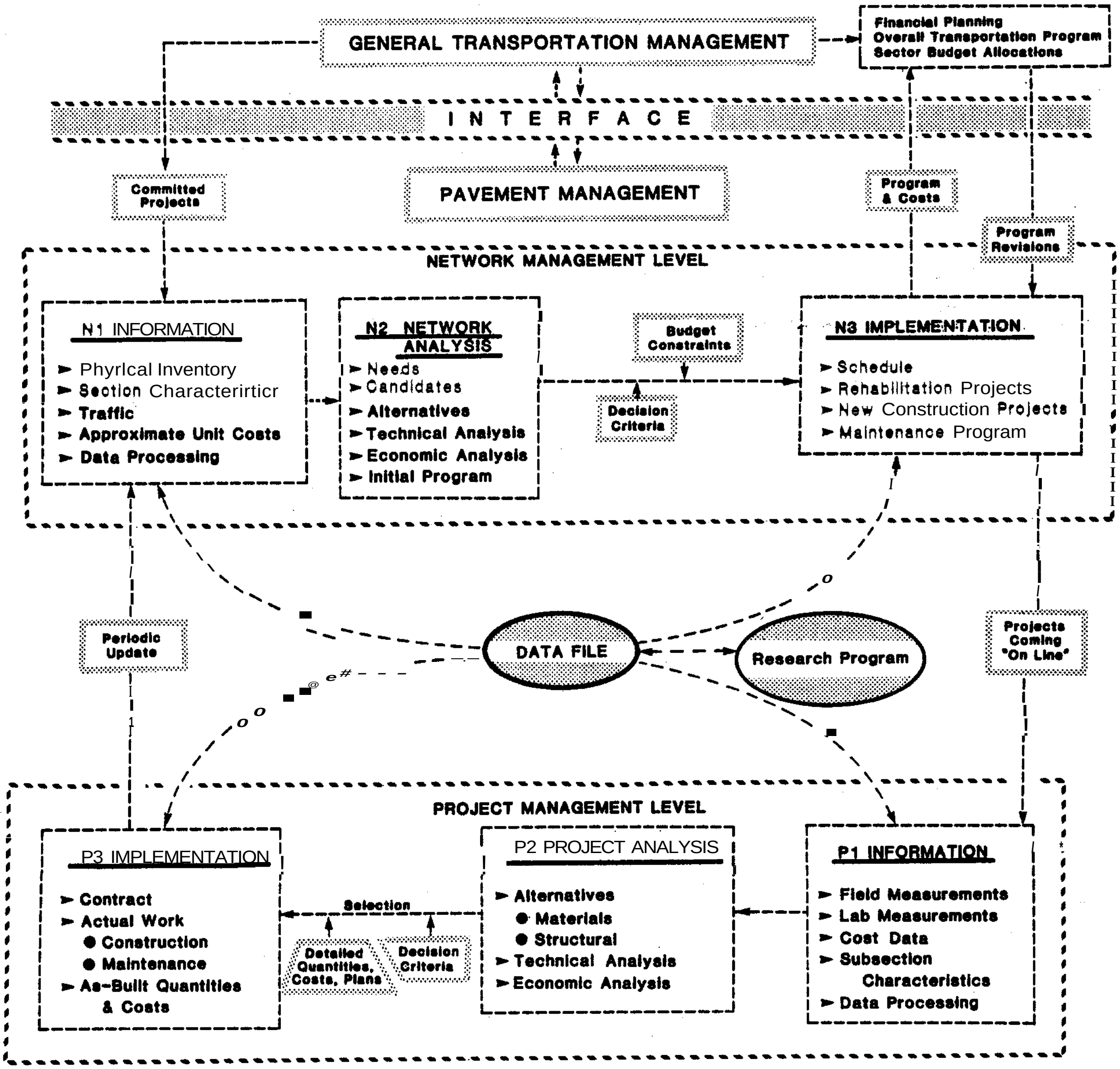
2. Structural capacity should be rated but **it** was not clearly decided whether to rate structural capacity on the basis of deflection tests or surface distress measurements.

3. Pavement distress should be rated. This includes measurement of rut depth, cracking and patching.

4. Rut Depth measurements were considered along with skid testing to provide an indication of road safety. Rut measurements should therefore be included in any highway rating scheme.

FIGURE 2

FRAMEWORK AND MAJOR SUBSYSTEMS FOR A TOTAL PAVEMENT MANAGEMENT SYSTEM



from NCHRP 216 (1979)

5. The use of a single classification number such as Present Serviceability Index (PSI) was said to provide a valid measure of pavement condition.

6. There is very little standardization of terminology and measurement technique among the available systems of pavement rating when these systems are examined in detail.

Each of the above points was seriously considered prior to development of the Alaskan rating system. Table 1, taken from the Tumwater conference report, indicates the salient features of the road rating methods of U.S. States and Canadian provinces in attendance.

In reviewing more recent literature (4,5) it appears that the rating procedures outlined in Table 1 have been basically continued. It is therefore concluded that Alaskan rating methods developed with the aid of pre-1978 literature sources still reflect contemporary thinking.

The objectives and basic rating elements listed below were chosen by the ADOTPF from background research and a definition of Departmental needs. They guided the development of Alaska's inventory rating by providing utilization "targets." Only the most recognized pavement condition indicators were selected for consideration as elements in Alaska's rating procedure.

Objectives:

Pavement condition (rating) data must——

1. Provide information for planning/prioritizing rehabilitative design and maintenance of existing pavements.

2. Provide information on the relative condition of total highway mileage within various jurisdictions for budgetary apportionment purposes.

3. Provide design feedback information.

TABLE 1 - Pavement Monitoring Features and Evaluation

AGENCY / FEATURE	Surface Condition	Roughness of Ride	Skid Resistance	Structural Capacity	Rating System	Primary Decision Criteria
Arizona	Crack survey	Mays Ride Meter on annual basis	MU Meter 500' at each mile post	Dynaflect - 3 locations per mile	Pavement Management Information System PMIS	Compares major maintenance alternatives
California	Pavement condition survey based on alphanumeric rating	Ride scores compared to pavement distress	Measured periodically		Alpha-numeric rating combines severity and extent of defects	Defects compared to repair strategies and costs
Florida	Structural defects of cracking, rutting and patching	Mays Ride Meter correlated with CHLOE Profilometer			Combined ride rating and defect rating	Adjusted Pavement Rating evaluated for priority programming
Kentucky	Used as feedback for design deficiencies	Roughness Index, RI, correlated to PSI. Use ride quality meter or GM Profilometer		Road Rater for specific design evaluation	Correlation of several factors for redesign input	Input used to develop overlay design
New York		Vehicle response on profiler is part of system			Pavement Serviceability System, PSS. Based on correlation w/known serviceability levels	Aimed at identifying budget needs, failed pavements, effectiveness of expenditures
Pennsylvania		Mays Meter used to develop serviceability	ASTM Skid trailer	Road Rater		
Texas	Distress survey based on vehicle mounted camera-visual distress rating	Mays Meter correlated with Surface Dynamics Profilometer	Skid trailer	Dynaflect or critical locations	Relative Design. Ratio of allowable 18K axle loads to those predicted for next 20 years	All highways must carry their traffic safely and comfortably
Utah	Pavement distress based on 11 observed parameters	PCA Roadmeter on 1 mile increments	MU Meter, ½-mile sections tested every 2 miles	Dynaflect For predicting remaining life	Present Serviceability Index PSI	Overall priority ranking for preventative rehabilitation
Washington ✡	Pavement condition survey every 2 years covering entire network	PCA Roadmeter on all sections	ASTM Skid trailer for high accident locations-considered separataly	Limited use of Benkelman Beam	Combined structural rating and ride score	Tabulate rehabilitation strategies and costs based on pavement condition
Ontario	Pavement Condition Rating, PCR 1-2 year cycle	Subjective Riding Comfort Index, RCI		Dynaflect Random sample locations in need of rehabi-	Subjective Pavement Condition Rating, PCR	Require overlay prediction based on expected pr-
Saskatchewan	Annual surface condition rating	PCA Roadmeter on intervals of 1 month to 1 year		Benkelman Beam data used for overlay design	Condition Rating system used to priortize projects for overlay or scaling, etc.	Preventative maintenance is primary goal
	✡ Photo logging of entire system					

Pavement Distress Indicators:

1. <u>Structural condition</u>

   a. surface distress

      cracking
      - fatigue (traffic load related "alligator" cracks)
      - thermal (major transverse and "map" cracks)
      - longitudinal

      deformation
      - shoving (slippage of asphalt concrete layer on the base course)
      - wheelpath rutting

      surface deterioration
      - plucking (loss of coarse aggregate)
      - ravelling (loss of fine aggregate)
      - bleeding
      - potholes

   b. pavement layer strength, usually interpreted from deflection test data

2. <u>Functional condition</u>

   a. ride roughness - produced by combined effects of surface distress and embankment/foundation movements

      - cracking and rutting (surface distress features)
      - frost heave (embankment)
      - differential thaw settlement (foundation)

   b. pavement surface frictional coefficient

Any of the pavement damage terms which may be unfamiliar to the reader are explained with photographic examples in Ontario, Canada's excellent pavement rating manual (6). The Ontario manual (available as of this writing on request from the provincial government) is suggested as a standardizing source for detailed pavement distress terminology. Figure 3 illustrates distress types most commonly seen on Alaska's paved roadway system.

Alaska's Rating Method - The Development Process:

Literature review plus common sense pointed to the need for a rating method which would adequately characterize the road condition while allowing a high degree of reproducibility. The data must provide true reproducible characterization of pavement condition changing from year to year in a rational manner, e.g., pavements should not anomalously appear to heal with time unless maintenance has actually been done. The rating technique therefore had to be as simple as possible, and include the largest practical sampling of each road section.

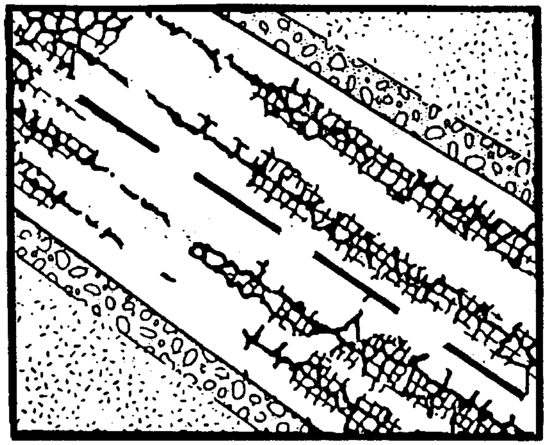
The following were chosen as rating parameters by Alaskan researchers:

1) fatigue cracking (alligatoring)
2) major patching (at least full lane width)
3) wheelpath rut depth
4) ride roughness as measured by the Mays Ridemeter

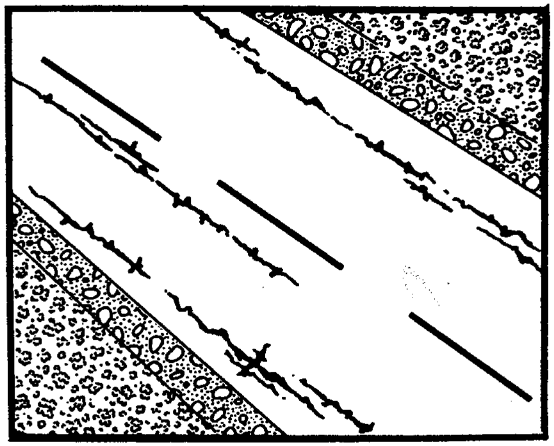
Fatigue cracking was selected as a rating parameter because it serves as an excellent indicator of structural condition and load-life potential. The pavements design-life vehicle load capacity is said to be reached when significant alligatoring becomes apparent. Fatigue cracking is also often associated with unacceptable rutting, vehicle ride roughness and pavement surface disintegration.

Major patching, necessitated to repair a host of problems including fatigue cracking, embankment settlement, rutting, etc., gives a general picture of the maintenance effort required on a given road section. It is

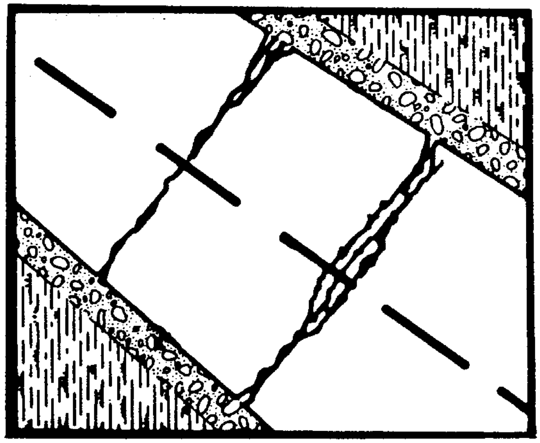
Illustration Of Typical Pavement Damage Types



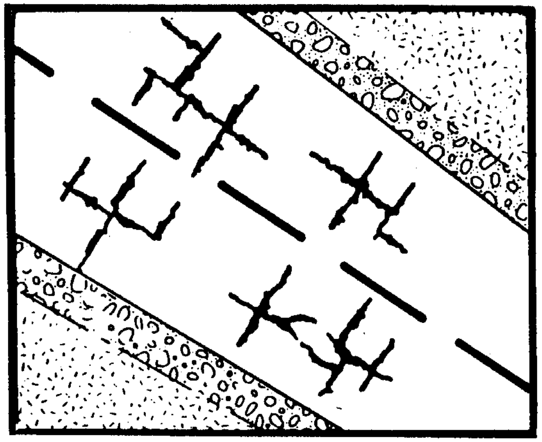
Alligator Cracking



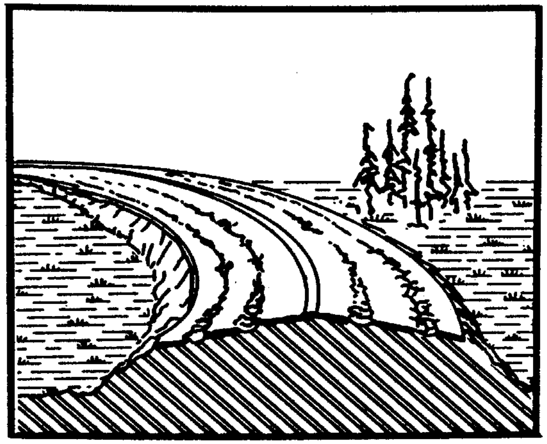
Longitudinal Cracking



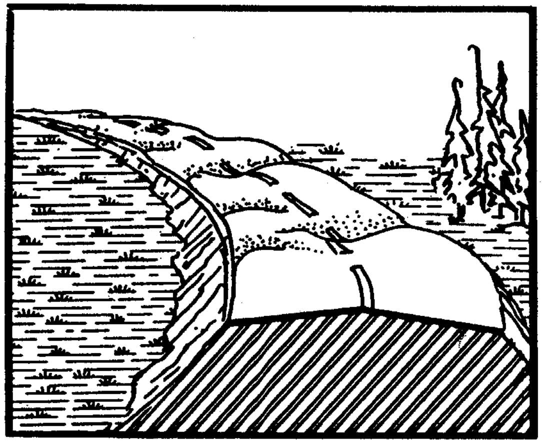
Transverse Cracking



Map Cracking



Wheel Path Rutting



Differential Settlement

also a principal source of surface roughness and usually becomes cracked and potholed with time.

Wheelpath rutting is important in terms of driver safety and travel costs. A consensus of available literature indicates that rutting deeper than approximately 1/2 inch is a safety hazard which can cause hydroplaning at high vehicle speeds. Rutting also has an effect on vehicle steering and reduces the mechanical life of chassis components. Deep rutting usually accompanies advanced alligator cracking and signifies that pavement structural soil layers (base and/or subbase) have been loaded beyond capacity. This condition is aggravated through use of materials subject to extensive moisture related softening (thaw weakening).

Ride roughness is measured because it is that characteristic of the pavement which is of primary concern to the driving public. The combination of differential settlement and leveling patches are common to all parts of Alaska and together are the major cause of roughness felt by the driving public. Ride roughness is easily measured on a continuous basis.

Some recognized surface distress features were disregarded in order to simplify the rating process for the following reasons:

Difficult to Identify --
- plucking (popping) of coarse aggregate
- ravelling

Difficult to Quantify --
- plucking
- ravelling
- longitudinal cracks (all types)
- thermal cracking (map type cracking)
- shoving
- bleeding

Rare Occurrence in Alaska --
(or considered of relatively minor importance)
- shoving
- bleeding
- plucking

Justification for Not Including Other Distress Indicators --

pothole patches/pot holes

Easily recognized and quantified by individual count but a very time consuming measurement for routine inventory work

thermal cracking (major transverse type)

Easily counted but their number is apparently more controlled by climate-area than by materials type and pavement condition (7). An inventory is not made of these features because they are not meaningful indicators of design-dependent pavement performance

pavement frictional coefficient

Recent measurements (Statewide in 1975) have indicated that the materials used in Alaskan roadbuilding provided consistently high skid numbers. Reasons for this include a high degree of aggregate hardness and limited potential for asphalt bleeding because of Alaska's relatively cool air temperatures.

deflection testing

These data provide valuable basic information concerning the mechanical nature of the pavement structure. It has been proposed that deflection testing ultimately become part of the normal inventory process. According to present planning, a deflection inventory process will begin in 1982 and will require approximately 5 years per statewide cycle. The falling weight deflectometer will be used to collect inventory data.

DESCRIPTION OF RATING AND SCORING
PROCEDURES USED SINCE 1978

This chapter outlines pavement rating methods used by Alaska DOTPF since 1978 and shows how the acquired field data are munipulated for purposes of scoring and reporting. Figure 4 illustrates the manner in which raw field data are transformed into a useful pavement inventory report.

Summary of Field Methods:

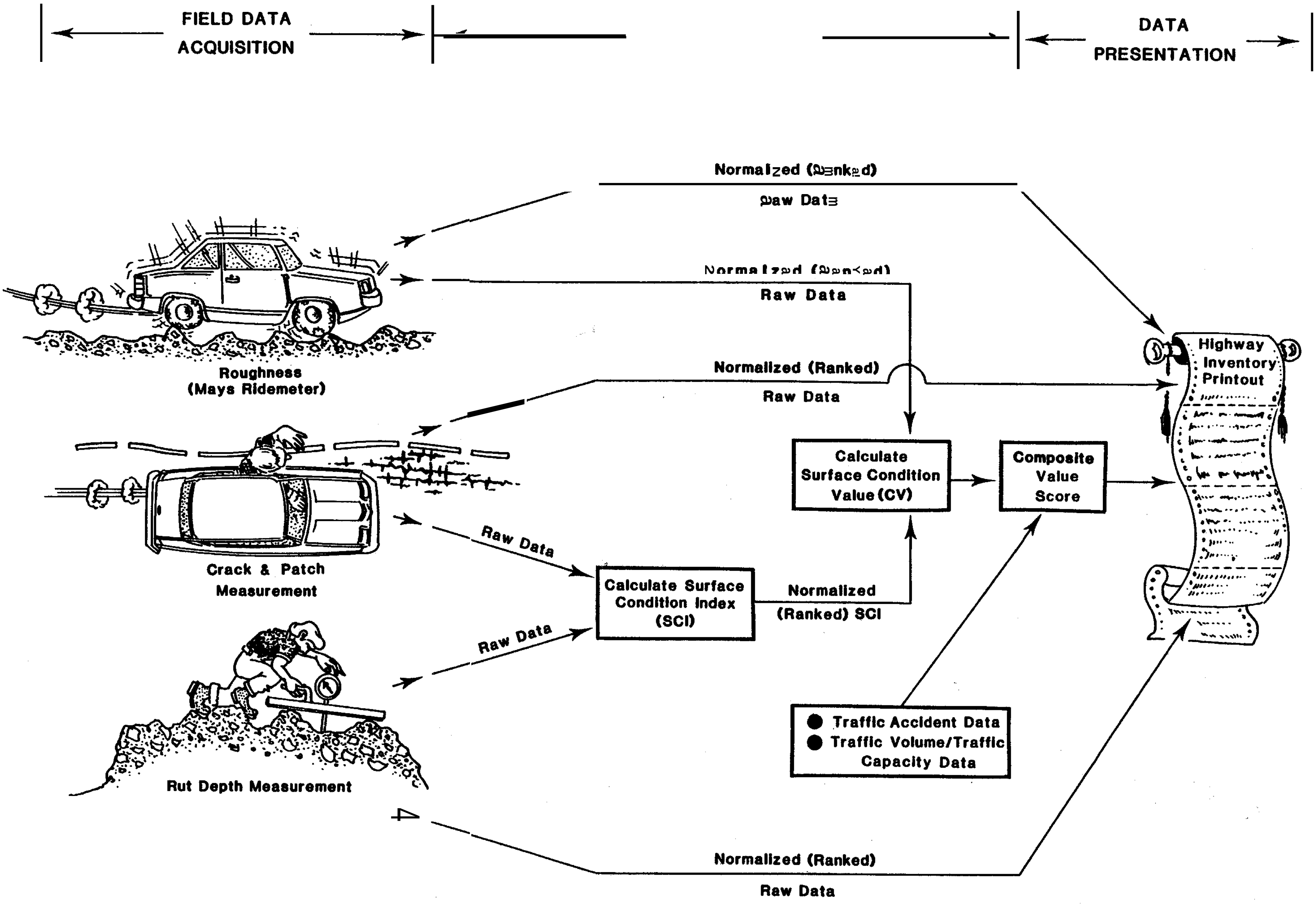
The rating process is done as two separate operations, each requiring the use of a two-man crew. A detailed description of the inventory rating procedure is presented in Appendix A.

Phase I Mays Ridemeter Evaluation (mile by mile, continuous measurement)

1. Minimum 2 man crew
2. Mays Ridemeter, Model 890 with rotary transmitter
3. Standardized operation
    a. vehicle operating speed
    b. standardized vehicle, suspension and tire type
4. Required Calibration
    a. periodically
    b. with tire, suspension, vehicle changes

Phase II Surface Distress Rating

1. Minimum 2 man crew
2. Distress features measured
    a. alligator cracking (mile by mile, continuous measurement). Appearance or absence of cracking is defined by the raters detection abilities at minimum allowable vehicle speed--no estimation of severity is necessary except type I, type II classification.
        1. severity measured subjectively as type I or type II
        2. density (extent) measured as total % of section length exhibiting alligatoring in any or all wheel paths (see Appendix A).



Elements Of The Alaskan Pavement Inventory

Figure 4

        3. detection limit is defined by observation speed (7 - 10 mph)
    b. full width patching (mile by mile, continuous measurement)
        1. defined as having a minimum 1 lane width
        2. no measurement of severity
        3. density (extent) measured as a % of total section length
        4. detection limit is defined by observation speed (7 - 10 mph)
    c. rut depth measurement (measured at raters discretion one or more times per mile)
        1. rut depth is derived by averaging all wheelpaths
        2. magnitude of rut depth determines total number of readings required (see Appendix A), with deeper rutting requiring more measurements

Road Condition Scoring Utilizing Alaska's Pavement Rating:

Alaska utilizes its pavement inventory data to construct a mile by mile summary report listing individual condition scores (% cracking, rut depth, % patching and ride roughness) and also a combined Condition Value (CV) score. The CV is analogous to the AASHO PSI and provides a single numerical descriptor of a given road section. The purpose behind Alaska's summarization in terms of both the individual and composite (CV) scoring is explained:

mile by mile
summary of CV ______

used mostly by administrative level personnel for general pavement serviceability classification and funding allocation.

mile by mile
summary of individual distress features _____

used mostly by those at the technical level for detailed evaluation of the pavement sections; this method of summarization is necessary, for example, to descriminate between functional and structural problems in maintenance planning.

The CV is calculated from the inventory data in the following way:

$$CV=\frac{\text{Mays Ridemeter Score(Ranked)+Surface Condition Index(Ranked)}}{2}$$

"Ranked" data indicates that the data has been mathematically transformed into a percent-worse-than score before calculation of C.V. This provides a normalizing of raw scores on a 0-100 (worst to best) scale.

$$\%\text{-worse-than}=[(1/2E+L)/N]X100$$

where: E=number of statewide sections rated the same
L=number of statewide sections rated worse
N=total number of statewide sections rated

Mays Ridemeter score as shown in the CV equation is derived directly through the ranking equation from raw Mays Ridemeter data. Surface Condition Index (SCI) is calculated by means of the following equation and then transformed to a %-worse-than ranking through the ranking formula.

$$SCI=1.38R^2+0.01(A+P)$$

Where: R=average rut depth (inches)
A=% of road section which is alligator cracked
P=% of road section which is covered by full width patching

In addition to reporting a summary of the previously discussed information the pavement inventory report also includes, for multiple mile sections, the ranked scores describing a volume/capacity ratio and the section's accident rating value. Finally, the CV plus capacity and accident scores are combined in a final step to produce a "Composite Value" calculated as:

Composite Value Score=$(C.V.\ X\ \text{Capacity(ranked score)}X\ \text{accidents(ranked score)})^{1/3}$

This composite score, like the CV is used mostly for generalized administrative planning and programming purposes. Figure 5 is an example page from the 1979 inventory summary.

Figure 5

Example Of Pavement Inventory Printout

LOCATION			CONDITION ELEMENTS					PERFORMANCE VALUES			
TERMINI	SECTION LENGTH	CDS MILE	ADT	RIDE (in/mi)	CRACKING (%/mi)	PATCHING (%/mi)	RUTTING (in/1000)	CONDITION VALUE	SERVICE VALUE	ACCIDENT VALUE	COMPOSITE VALUE
FAP 35 Parks Highway		312		24	0	0	72 ✡	85			
(State Route 170000)		313		63	5	0	83 ✡	52			
		314		35	0	0	62 ✡	82			
JCT Old Nenana Hwy. Ester JCT	20	315									
SECTION AVERAGES			30[illegible]	23	1	1	87	73	32	7	8
		316		132	41	15	137	16			
		317		154	16	29	119	15			
		318		129	4	14	188	26			
		319		166	27	21	169	13			
JCT RS [illegible]43 GEIST ROAD	5	320		88	0	36	29	29			
SECTION AVERAGES			23[illegible]2	134	13	23	128	20	1	[illegible]0	11
JCT FAU AIRPORT SPUR	1	321		61	o	1	65	67			
FAP 35 PARKS HIGHWAY (STATE ROUTE 1[illegible]000) SECTION AVERAGES			4090	[illegible]	0	1	65	[illegible]7	[illegible]	72	66
		322		6	0	1	116	63			
		323		[illegible]	0	3	220	33			
		324		1 2	0	0	138	43			
JCT STEESE AND RICHARDSON HWYS 4		325		6	0	0	340	43			
SECTION AVERAGES			17319	80	0	1	204	43		42 [illegible]	

SECTION II

EVALUATION OF THE ALASKA DOTPF PAVEMENT RATING PROCEDURE

EVALUATING THE ORIGINAL PLAN

Criteria Used in the Initial Development of the 1978 Pavement Rating Method:

The reporting of mile by mile data is an expedient settled upon because larger sections were not sufficiently locative of specific problems, while smaller sections result in extremely voluminous summary reports. After deciding on one mile as the basic section length for rating purposes, **it** was necessary to settle on a sampling frequency which could properly characterize each mile.

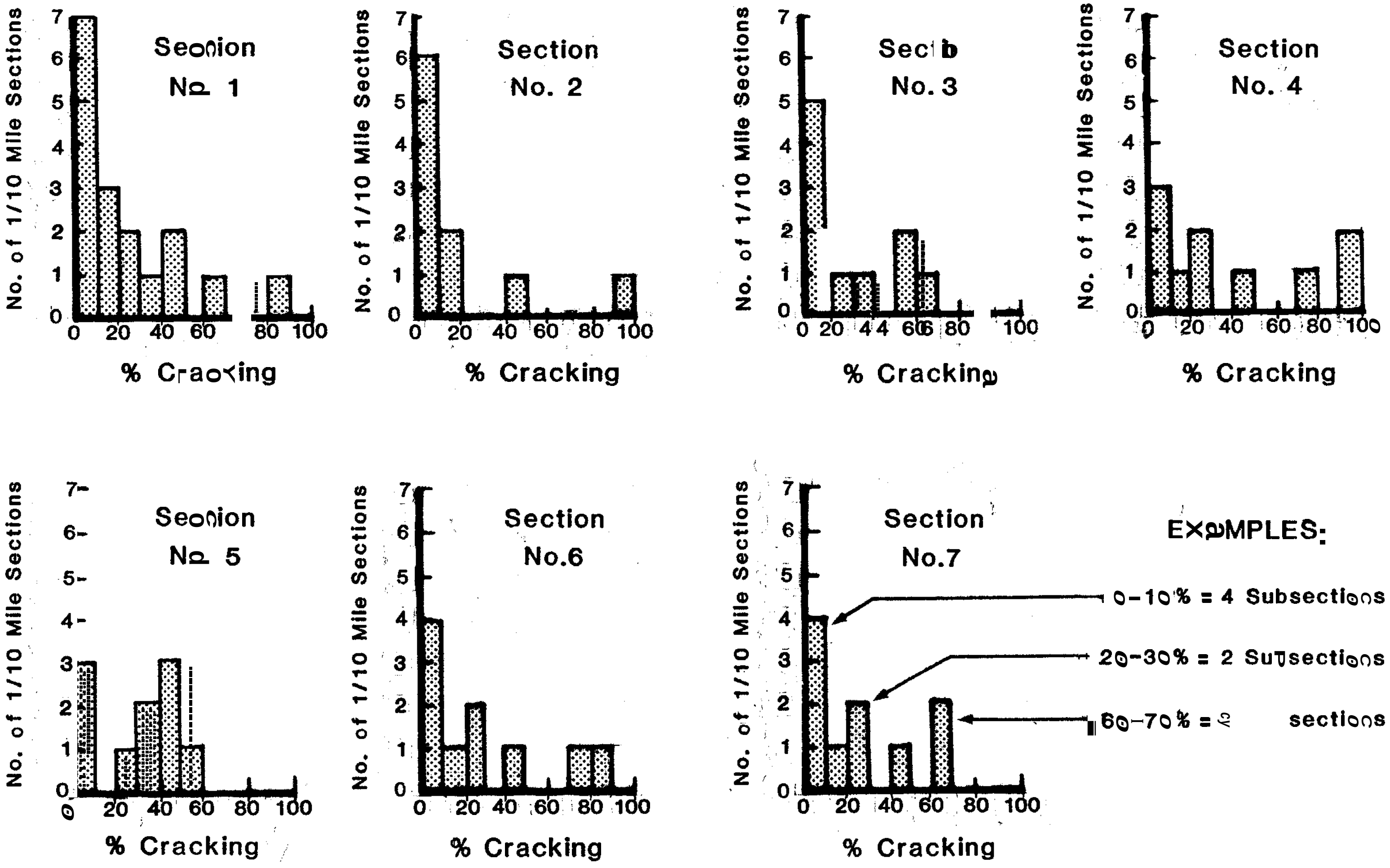
The Mays Ridemeter can automatically provide a one hundred percent sampling density at 50 mph so sections of less than a mile in length were not considered. Studies of the repeatibility of this test have been made by others and were beyond the scope of this report. Becasue of its relatively good repeatability the Mays meter is considered the most reliable part of the present inventory procedure.

Methods for measuring alligator cracking and major patching were initially evaluated on seven sections of roadway near Fairbanks. Each section was divided into tenth mile subsections which were independently rated. Full width patching was characterized on the basis of total length patched (density), while fatigue cracking was typified by both density and severity. A type 1 or type 2 classification was adopted for cracking of lesser or greater severity as described in Appendix A.

Alligator Cracking was defined as that visible while slowly driving (7-10 mph) along each tenth mile interval and measuring the percent of the total distance in which cracking occurred. Histograms were constructed (Figure 6) to show the frequency distribution of fatigue cracking for the subsections within each mile. The distribution of cracking is strongly poly-modal (showing no single mean value) and bounded at both the 0 and 100 percent occurrence level. Distributions of fatigue cracking are obviously non-Gaussion in character. In view of these data **it** was apparent that a one, two, three or more mile length of paved road could not accurately be rated for fatigue cracking based on measurements in a random subsection several hundred feet long. The normal assumption of a 10-20

ALLIGATOR CRACK FREQUENCY DISTRIBUTION

(variation in amount cracking in subsection measurements within 7 test sections)



EXAMPLES:

0-10% = 4 Subsections

20-30% = 2 Subsections

60-70% = 2 sections

NOTE: Except for section No. 1, all were 1 mile in length and included 10-1/10 mile subsections.

Section No. 1 was 1.7 miles in length and included 17-1/10 mile subsections.

Figure 6

percent sampling density is of no value in this case. As a result of this initial trial, it was apparent that fatigue cracking must be measured by continuous observation through each mile of roadway.

Full Width Patching was observed to be similar in distribution of occurrence to fatigue cracking and it was similarly decided that this feature could be properly characterized only by continuous observation.

Rut Depth measurement frequency was also briefly examined prior to development of the rating method through multiple readings taken on each of eight one-mile long pavement sections near Fairbanks. Rut depth averages ranged from 0.185 inch to 0.244 inch. The sample standard deviations ranged between 16 and 35 percent of the sample means and the plotted frequency distributions of rut depth measurements appeared reasonably indicative of normal (Gaussian) behavior. It was assumed from these trials that rut depth measurement could be evaluated by normal statistical techniques. Sampling frequency was addressed through the statistical method used for estimating a true mean value from a small sampling. An estimation of true population average is given by:

$$\mu_o = \bar{X} \pm S\,T\sqrt{N}$$

where: o = true population average, i.e., true average rut depth
X = average rut depth as determined from sample
S = standard deviation of sample
N = number of measurements constituting the sample
t = "students t" value for a given confidence level and N

This formula is an expression of the Central Limit Theorem which describes the distribution of sample means about a true mean. In modified form, the equation can be expressed as follows:

$$(\mu_o - \bar{X})/S = T/\sqrt{N}$$

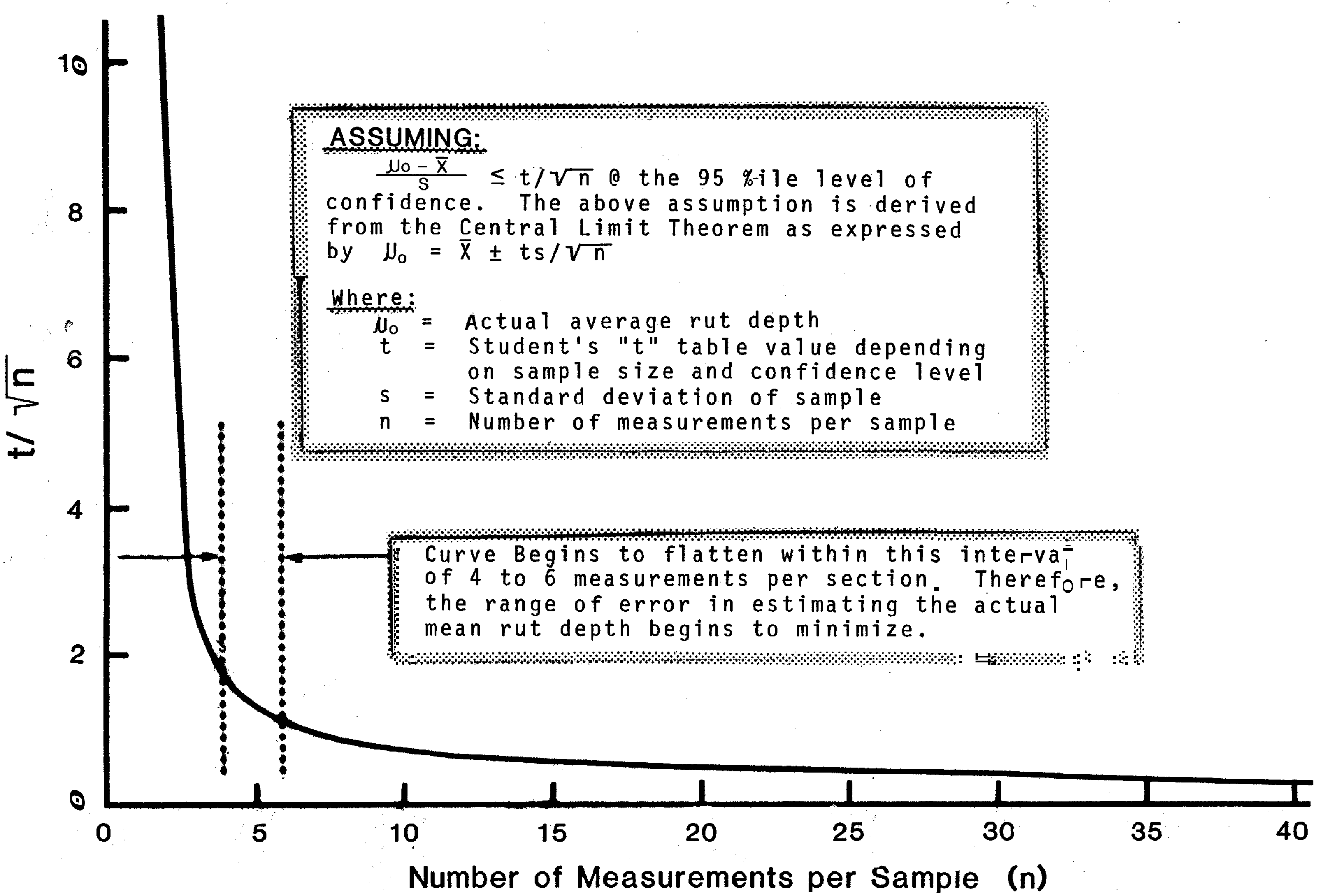
The error in estimating true rut depth average, i.e., $\mu_0 - \bar{X}$ is small in relation to the sample standard deviation (at a given level of confidence) when the term $t/\sqrt{N}$ is minimized. Figure 7 is a plot of N versus $t/\sqrt{N}$ used to select sampling frequency for the initial inventory runs in 1978. Flattening of the curve beginning between **N=4** and N=7 suggested that a sampling of at least 4 locations would be necessary to insure that the error in estimating true mean rut depth would be less than 2 standard deviations of the sample. Figure 7 indicates that the error of estimating true mean rut depth is about 1.6 X S for **N=4.** Since S of the trial road sections averaged approximately 0.05 inches, it was expected that the errors in estimating rut depth during inventory work would be no larger than + or - 1.6 X 0.05, i.e., 0.08 inches. This accuracy was considered good enough for beginning the pavement inventory process. As indicated in the description of rating methods (Appendix A), less than **4** readings per mile were required in the 1978 rating method if rutting was generally observed to be less than 0.25 inch.

Summary of the Original Plan:

It was decided on the basis of very limited field trials previously described that pavement distress, except for rut depth measurement, should be characterized by continuous observation of the entire road. Three field seasons of field data collection have absolutely reinforced the idea of utilizing a 100% sampling.

The frequency of measurements necessary to adequately determine average rut depth was calculated from a preliminary statistical assessment, Measurement of ruts was known to be a disproportionately time consuming job when compared to other distress observations. It was hoped that accumulating experience would show that no more than 4 sets of readings would be required per mile of road.

PLOT OF RELATIVE ERROR FACTOR ($t/\sqrt{n}$) VERSUS SAMPLE NUMBER (n)



ASSUMING:

$\frac{\mu_o - \overline{X}}{s} \leq t/\sqrt{n}$ @ the 95 %-ile level of confidence. The above assumption is derived from the Central Limit Theorem as expressed by $\mu_o = \overline{X} \pm ts/\sqrt{n}$

Where:

μ_o = Actual average rut depth
t = Student's "t" table value depending on sample size and confidence level
s = Standard deviation of sample
n = Number of measurements per sample

Curve Begins to flatten within this interval of 4 to 6 measurements per section. Therefore, the range of error in estimating the actual mean rut depth begins to minimize.

Figure 7

A REVIEW OF ALASKA'S PAVEMENT RATING METHODS BASED ON RECENT FIELD STUDIES

Introduction:

The Alaskan pavement rating method had been in use for 2 years when it was decided that a more detailed evaluation of its constituent measurements was needed. A field study was begun in 1980 to investigate the repeatability of cracking and patching measurements made by different rating crews. Frequency of measurements necessary to estimate rut depth was also reviewed.

Method of Study and Data Acquisition:

Five roadway sections were selected near Fairbanks, to reflect the average range of road surface conditions commonly encountered. Each of the sections were rated, using the standard Alaskan procedure, by 15 different 2-member crews. Members were drawn mostly from the middle level professional and technical ranks of road design, maintenance, right-of-way and materials sections, but only four had prior pavement rating experience. Raters with previous experience were drawn from the Department's Research and Development section.

Each crew of raters was given the same introduction to pavement rating and directed from one pavement section to another by the instructor. Ratings by each crew required a full day and the sequence of pavement sections remained constant throughout the duration of the study. It was considered important that the sequence of sections not change because this assured that the sun angle relative to the viewer remained consistant for each crew, for each section. Sun illumination was known through accumulated field experience to greatly affect pavement crack visibility. In order to maximize the observational abilities of each rating crew, all ratings were performed from a vehicle of light truck "van" configuration. A nearly vertical windshield combined with a relatively high seating position allowed the most advantageous pavement surface view of any standard vehicle type. Each section was inspected at under 10 mph in order to identify and measure cracking. Rut depths were measured in each of the four wheelpaths every two-tenths mile. Distances were measured with an electronic odometer capable of one (1) foot resolution.

The Field Data:

Appendix B is a section by section summary of the pavement distress measurements made by each crew. An indication of measurement variabilities between crews is given through the Coefficient *of* Variation (Cv) associated with each distress type.

Cv=(std.deviation/mean value)X100

In general, a small Cv of around 5-10% indicates that a good estimate of a true mean value is possible from relatively few individual measurements. Cv values associated with measurement of all pavement distress indicators were considered very high. This tends to contradict the initial hypothesis that, because of the rating method's simplicity, reproducibility of ratings between crews could be taken for granted. The following estimates of Cv were calculated from project data:

Type I Alligatoring	cv average = 43%
Rut Depth (calculated average)	cv average = 25%
Rut Depth (Calculated std. deviation)	cv average = 40%

The significance of the above listing should not be understated as the uniformity of Cv from section to section indicates (See Appendix B).

Type II (severe) alligatoring and full width patching are not listed because their infrequent occurrence within the test sections did not provide an adequate sampling to allow a good evaluation of differences between rating crews. Based on these limited observations it is fairly apparent, however, that the variability in measuring patching length is somewhat lower than for alligatoring with a Cv of perhaps 10-20%. A clear distinction between type I and type II alligatoring was not easily made by the rating crews. A tendency, except in the most obviously severe cases, was to place all cracking into the type I category. Most crews apparently selected a lower severity classification whenever the question of degree of damage arose. This problem can probably be remedied to some extent during the instruction process by specifically advising that pavements be critically rated.

The large amount of variability observed in the collected data is shown in table 2. Considering the similarity in training and background between these "experimental" raters and previous inventory crews, these variabilities could be expected on pavement sections throughout the State.

The last two columns of Table 2 indicate different perspectives from which measurement variations can be viewed.

Interpretation No. 1: - variation in measurements expressed as a percent of the total road section length - Referring to the next-to-last column of Table 2, the variation between crews in measuring alligator cracking was as high as 13% of the total section length (where length of sec. 2 = 2 miles). It is also as low as 2% as indicated for sections 1 and 4. On sections where patching was present, the range of its measurement varied from 0.4 to almost 6% of the total section lengths. Set in a context of percent total length of section, these measurement variabilities would probably not be termed excessive.

Interpretation No. 2: - variation in measurements expressed as a percent of the mean measurement value - This approach evaluates variation within the measurement itself rather than considering it a percent of some arbitrary variable such as length of road section. Examples of this calculation are shown below where the extreme difference in measurements is divided by the average value:

Examples: (max.-min.)/average

Type I alligatoring

Section 1 100 x (187-29)/ 40 = 110%

Section 2 100 x (1,434-35 /820 = 170%

Table 2
Observed Variation in Pavement Distress Measurements

	Section #	Low-High	Range	Average	Range as % of Section Length	Range as % of Mean Value
Type I						
Alligator Cracking	1	29-187 ft	158'	140'	2.0%	113%
	2	35-1,434	1,399'	820'	13.0	171
	3	69-700	631'	300'	6.0	210
	4	54-218	164'	120'	2.0	137
	5	190-505	315'	340'	6.0	93
Type II						
Alligator Cracking	1	none detected	0'	0'	0%	0%
	2	4-19 ft	15'	12'	0.1	123
	3	0-13	13'	0'	0.1	--
	4	none detected	0'	0'	0	0
	5	none detected	0'	0'	0	0
Full Width Patching	1	350-382 ft	32'	360'	0.4%	9%
	2	439-1,042	603'	820'	5.7	74
	3	91-197	106'	100'	1.0	106
	4	none detected	0'	0'	0	0
	5	none detected	0'	0'	0	0
Rut Depth Average Inner Wheelpath	1	.016-.059 inch	.043"	.040"	--%	108%
	2	.110-.393	.283"	.210"	--	135
	3	.114-.289	.175"	.180"	--	97
	4	.100-.257	.157"	.170"	--	92
	5	.134-.271	.137"	.210"	--	65

Table 2 (Continued)

Observed Variation in Pavement Distress Measurements

Type II	Section #	Low-High	Range	Average	Range as % of Section Length	Range as % of Mean Value
Rut Depth Std. Deviation Inner Wheelpath	1	.005-.055 inch	.050"	.020"	--	250%
	2	.051-.601	.550"	.160"	--	344
	3	.040-.198	.158"	.080"	--	198
	4	.023-.263	.240"	.080"	--	300
	5	.060-.241	.181"	.110"	--	165
Rut Depth Average Outer Wheelpath	1	.050-.167 inch	.117"	.090"	--	130%
	2	.116-.410	.294"	.240"	--	123
	3	.089-.248	.159"	.150"	--	106
	4	.062-.272	.210"	.180"	--	117
	5	.172-.445	.273"	.270"	--	101
Rut Depth Std. Deviation Outer Wheelpath	1	.022-.105 inch	.083"	.055"	--	151%
	2	.069-.596	.527"	.240"	--	220
	3	.040-.322	.282"	.090"	--	313
	4	.032-.184	.152"	.080"	--	190
	5	.098-.257	.159"	.160"	--	99

Section 3 100 x (700-69)/300 = 210%
Full Width Patching
Section 1 100 x (382-350)/360 = 10%
Section 2 100 x (1,042-439)/820 = 70%
Section 3 100 x (197-91)/100 = 110%

Most of the above examples show measurement differences which are actually larger than the average value itself.

Considering interpretation No. 2 and the high coefficient of variation (Cv) values previously noted, it would appear that very serious rating errors could occur on sections of pavement where alligatoring (or patching) would cover a large percent of the total section length. In other words, as the actual total length of alligatoring (or patching) increases within a particular road section, the importance of an accurate, reproducible measurement becomes very important.

Because it is a more statistically correct assessment of measurement variability, the author favors interpretation No. 2 and notes with concern the apparent inability of rating crews to match each others measurements. These results are particularly surprising since alligatoring is classified and measured in what is thought to be the simplest possible manner.

The overall effect of crew measurement variations on rut depth determinations is magnified by the fact that the DOTPF usually reports "maximum" rut depth in terms of average plus 2 standard deviations.

Examples: the mean, mean t 1 standard deviation and mean t 2 standard deviations are given for the following sections:

*Section 1	mean = 0.090"	mean t s = 0.145"	mean t 2s = 0.200"
Section 2	0.240"	0.480"	0.720"
Section 3	0.150"	0.240"	0.330"
Section 4	0.180"	0.260"	0.340"

*Note--Using Table 2, outer wheel path data.

The above examples demonstrate a wide range of uncertainty as to the measured depth of rutting even though calculated mean values are quite low.

Discussion of Alligator Cracking Measurements:

In several of the following figures the variations in measurements have been "normalized." This normalization step is used so that various road sections can be directly compared even though each has a different mean rut depth or length of alligatoring. Normalization of scoring, e.g., % alligatoring, average rut depth, etc'. is accomplished as in the following example:

Normalized % alligatoring = (A-B)/C

where: A = % alligatoring as measured by an individual crew on a specific road section.
B = average % alligatoring calculated from the measurements of all crews on the above section.
C = standard deviation value calculated from the measurements of all crews on the above section.

Figure 8 shows how normalized scores of individiual crews rank in relation to calculated average values on all 5 pavement sections. This plot indicates the ability of certain crews, e.g., 7 and 8 to see more damage than others. Conversely, crew number 14 saw much less cracking in all 5 pavement sections than the calculated average. Figure 8 includes the instructor's subjective assessment of each crew in terms of: communication between crew members [rated: low (L), moderate (M) and high (H)], and initial impression of rating ability (rated: fair, good, expert). It should be noted that crews 2 and 10, rated "expert" by the instructor, had at least a full season's rating experience and were included for purposes of comparison with the other crews. Although figure 8 indicates that some crews could apparently see more pavement damage than others, this difference was not particularly accounted for in obvious attitudes or abilities. It is interesting to note, however, that crew 8, which saw much more pavement damage than crew 14, also rated higher in the instructor's opinion. It is suggested that best results are obtained when active conversation concerning the rating process is encouraged between crew members, especially during the first few days of inventory.

RANGE OF VARIATION IN EACH CREW'S MEASUREMENT OF TYPE I ALLIGATOR CRACKING (In Units of Standard Deviation)

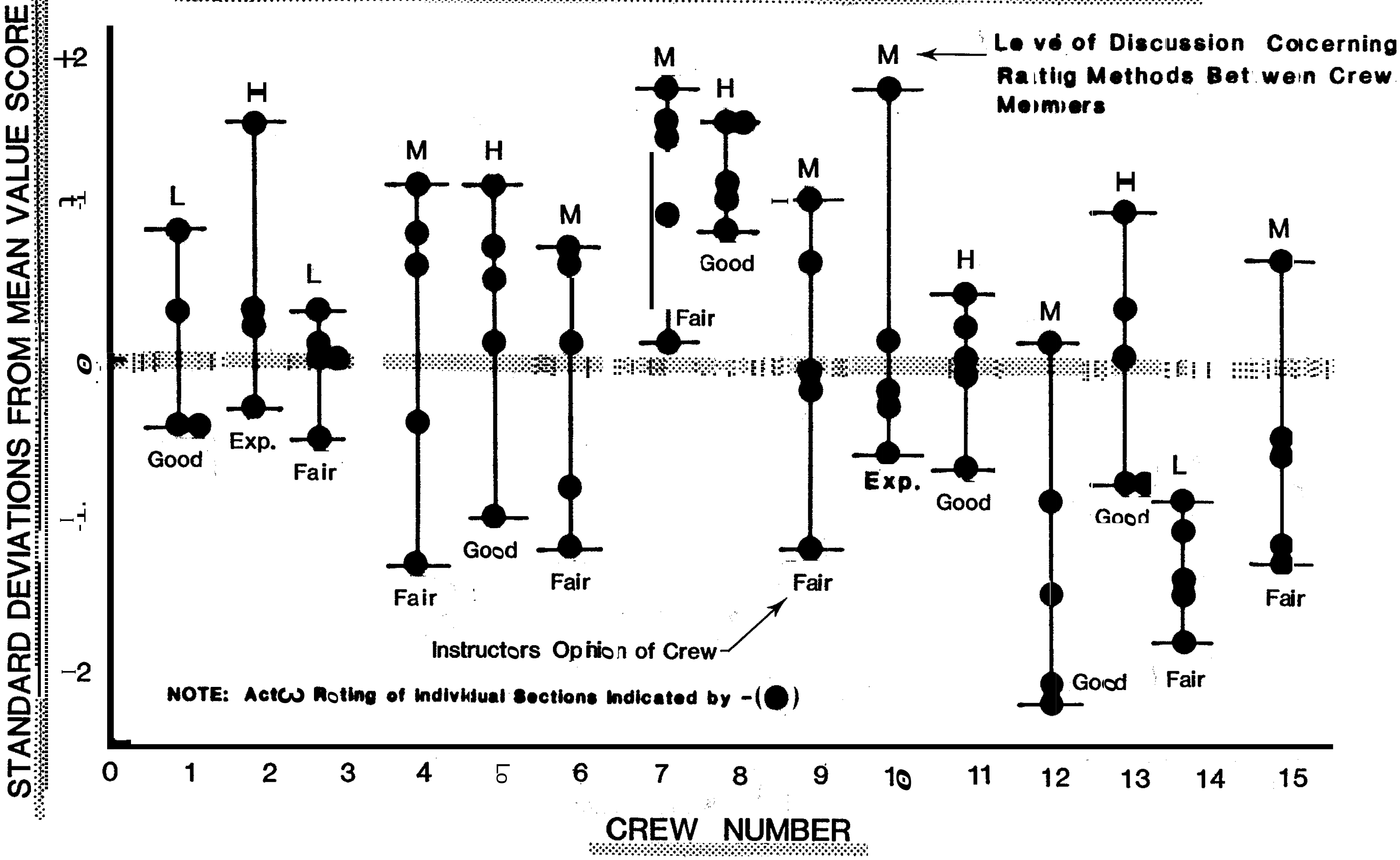


Figure 8

Table 3 attempts to delineate reasons for differences between crew ratings. The samples have been broken down into a stratified format and cross indexed in terms of crew communication and weather/pavement surface condition at the time of rating. The numbers shown in table 3 as X (characteristic sample average) and S (characteristic sample standard deviation) have been "normalized" as previously described, thus allowing all 5 pavement sections to be considered in the same analysis. The combination of a SW (slightly wet) pavement surface and a highly communicative crew resulted in more visible cracking with a characteristic average of +0.8 std. deviations above the overall sample average. Also, in examining the weighted (for sample number) averages of both rows and columns, good crew communication and a slightly wet road surface are individually associated with increased damage observation.

Surface Wetness: The effect of a slightly wet surface in optimizing the visibility of alligator cracking is fairly obvious to even the casual observer and can often cause the most hairline alligatoring to stand out in vivid detail. On the other hand, a very wet road surface such as obtained during or shortly after a rainstorm camouflages all but severe cracking. It is strongly suggested that observations of cracking be discontinued during rainstorms or other periods when the pavement surface is covered by "free" water. Table 3 generally associates the least observed cracking with a very wet (VW) surface condition. The ideal slightly wet surface condition is created when the road surface is dry except in and around individual cracks. In this case, water stored in the cracks during a rain will keep the adjacent pavement wet longer than in areas of no cracking.

From the previous discussion, it would appear that pavement ratings could best be done shortly after a rainstorm. Although a slightly wet surface allows highest crack visibility, a dry road condition represents the more normally encountered situation. Because of the need for a standard rating procedure the author strongly suggests that crack measurements be made only on dry pavement.

Sun Angle: Illumination effects due to variations in vertical and horizontal sun angle are known to strongly affect crack visibility. The author's experience indicates that optimal lighting conditions are pro-

ANALYSIS OF TYPE I ALLIGATOR CRACKING

	S	C	SW	VW	.WEIGHTED AVERAGE OF ROWS
H	$\bar{x}$ = -0.1 s = 0.5 n = 7	0.5 0.7 5	0.8 0.8 8	0.2 0.9 4	x = 0.4 s = 0.7
M	$\bar{x}$ = 0 s = 0.8 n = 7	0.3 1.1 19	-0.3 0.6 5	-1.7 0.5 4	x = -0.1 s = 0.9
L	$\bar{x}$ = 0.1 s = 0.6 n = 4	-0.7 0.8 10	No Samples	No Samples	$\bar{x}$ = -0.5 s = 0.7
WEIGHTED AVERAGE OF COLUMNS	$\bar{x}$ = 0 s = **0.6**	$\bar{x}$ = 0 s = **1.0**	$\bar{x}$ = 0.4 s s = **0.7**	$\bar{x}$ =-0.8 s s = 0.7	

COMMUNICATIONS BETWEEN CREW MEMBERS	WEATHER CONDITIONS:
H = Active discussion of rating methods M = Moderate discussion of rating methods L = Little discussion of rating methods	S = Sunny C = Cloudy SW = Cloudy, Road Surface Slightly Wet VW = Rain, Road Surface Very Wet

Table 3

vided by a more or less head-on sun incidence as indicated in figure 9. Frontal light tends to shade and therefore darken the visible side of crack segments which are perpendicular to the observer and most easily viewed. This has the net effect of maximizing apparent tone and texture differences between cracked and uncracked pavement. The travel direction chosen for the experimental ratings produced "over-the-shoulder" lighting on 4 of the 5 pavement sections which is usually considered a worst-case viewing condition. However, each test section was examined at approximately the same time of day by each crew to assure a consistent sun angle.

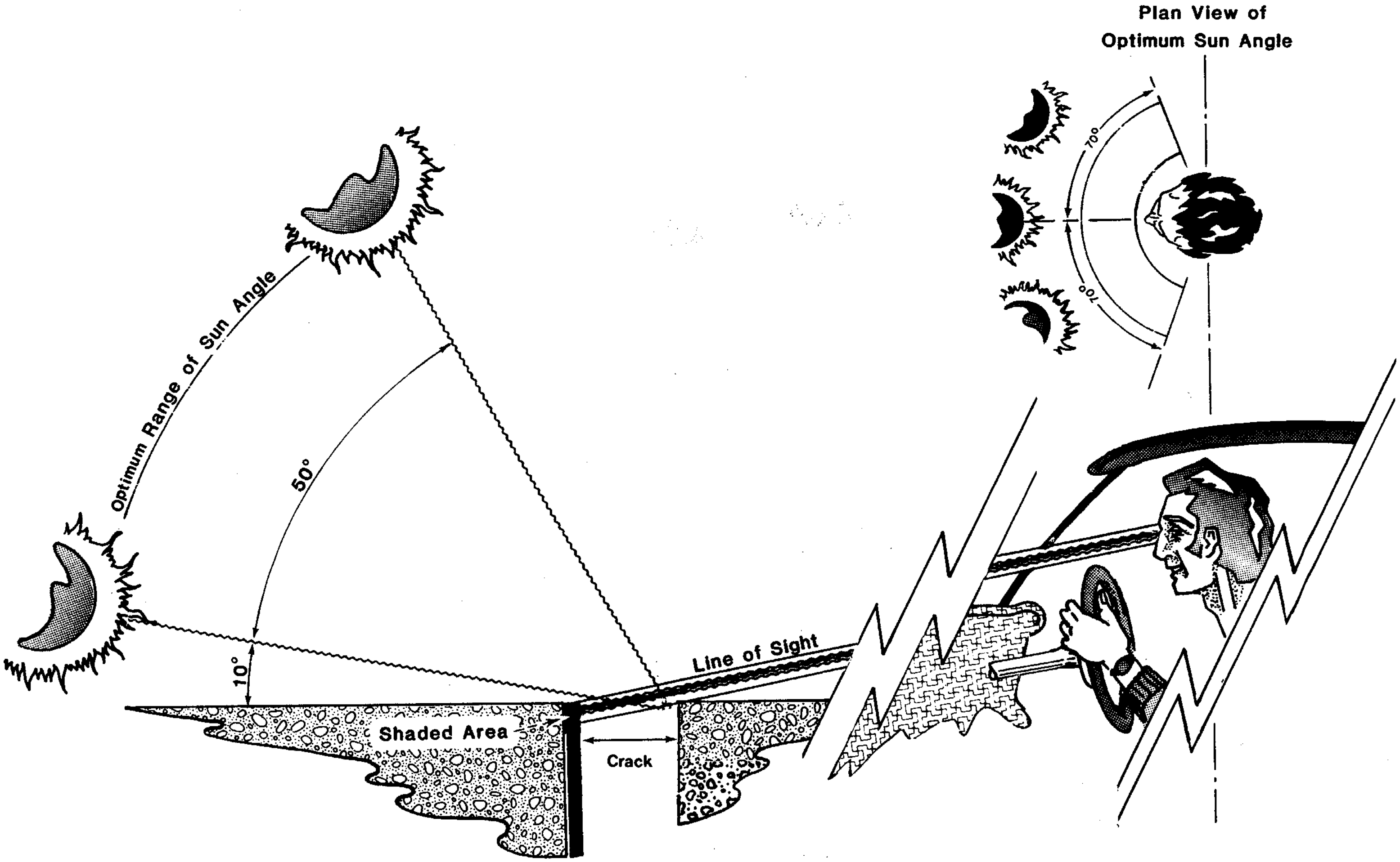
Discussion of Full Width Patching Measurements:

The occurrence of full width patching within the test sections was somewhat limited. Data from section 3 indicate that patching measurement differences between crews may be about half those expected from observations of cracking. The distribution of normalized scores indicated in figure 10 represent only the 3 test sections which actually contained patching. The variation between crews is markedly less pronounced than for alligator cracking. An exception to this observation is crew number 2, one of the ''expert'' crews which included the author. No explanation is apparent for this anomaly except that the "experts" were obviously not attuned to patching at the time.

It is concluded that patching is more easily measured than alligator cracking even though both are evaluated in a similar way. In most cases, patching, at least new patching, is actually quite easily seen. Observation conditions which provide the best view of alligator cracking also tend to make patched areas stand out. Again, very wet surfaced roads resulted in the most variable measurements between crews.

Discussion of Rut Depth Measurement:

The approach initially taken to determine a sample number (as indicated in figure 7) was a rough attempt to limit the possibility of gross errors. Sufficient field data has since been collected to allow a much more valid estimation of rut depth.

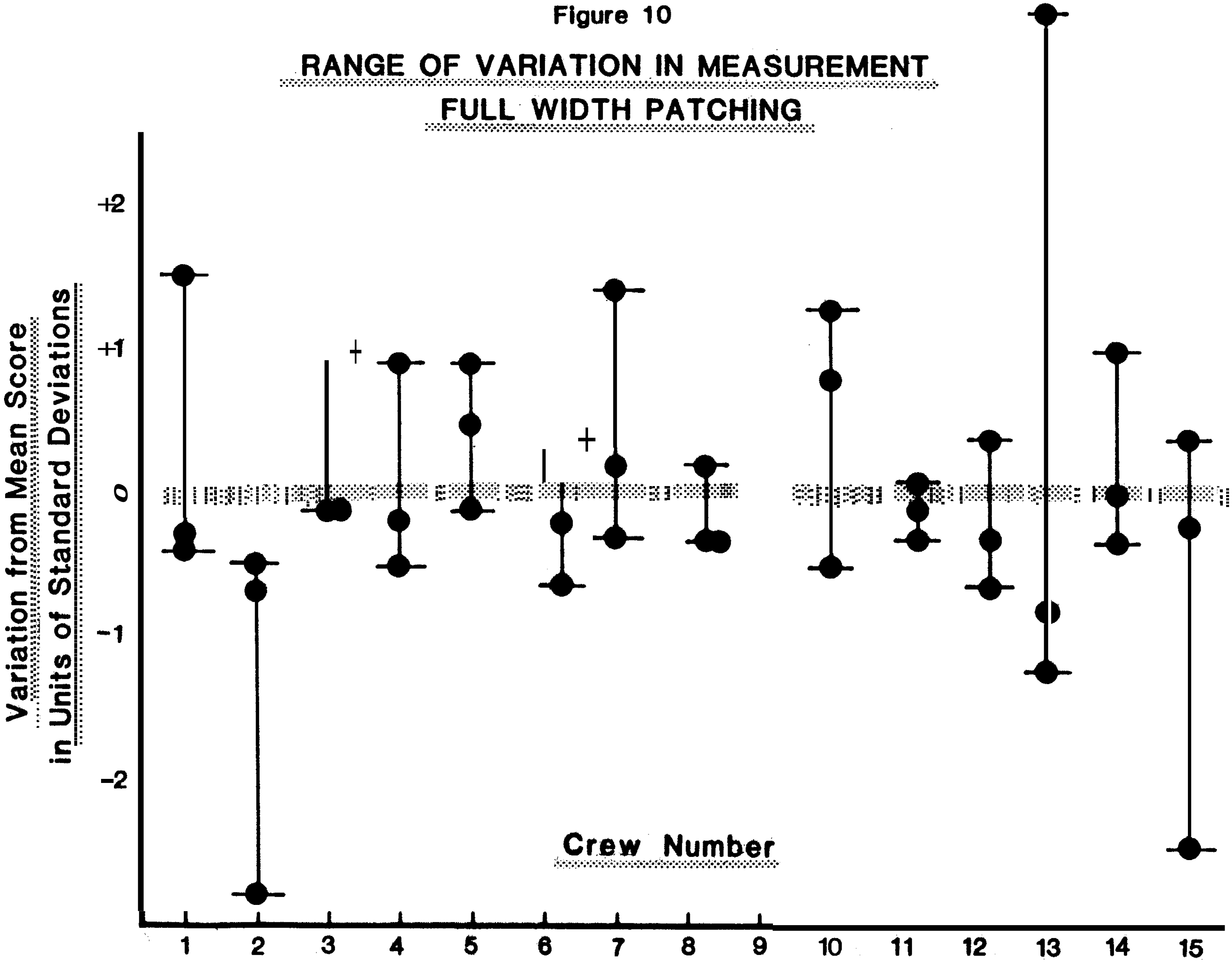


OPTIMAL SUN INCIDENCE RELATIVE TO VIEWER

Figure 9

Figure 10

RANGE OF VARIATION IN MEASUREMENT
FULL WIDTH PATCHING



As stated previously, the problem of rut depth measurement can be addressed by normal statistical methods. The principal questions asked are:

1. How frequently must rut depth measurements be taken?
2. Must rut depth measurements be taken in both inner and outer wheel paths?

Sampling Frequency: Without becoming involved in a detailed explanation of statistical sampling methods and hypothesis testing, it can be stated that the sampling frequency must be high enough to insure (to some specified confidence level) that a calculated mean rut depth is reasonably close to the actual mean rut depth. Actual or "population" average in this case, is that value which would be measured from an infinitely large sampling. Sampling tables which are available in references such as the CRC statistical handbook (8) indicate minimum sample numbers necessary to attain specific levels of confidence against either a type 1 or type 2 error being committed. Figure 7 only addressed the possibility of type 1 error. A type 1 error occurs if statistical calculations indicate that the sample mean is not representative of the population mean, when in fact it is. Conversely, a type 2 error occurs when statistics indicate that the sample mean is representative of the population mean when it is not.

Figure 11 was derived from tabulated values and used to determine minimal rut depth sampling locations per section. It was assumed that for predicting the actual rut depth average from sample data, an error of no more than ±0.05 inch would be allowable. In order to use figure 11, a sample standard deviation is first assumed or calculated from trial measurements. A solution line is then selected based on the desired confidence level against type 1 and 2 errors. A horizontal line is drawn from the estimated standard deviation to the selected line and minimum sample size is read directly below the point of intersection.

Example

assumed standard deviation = 0.05 inches
selected confidence against
type 1 error = 95%

Sample Number Versus Sample Standard Deviation

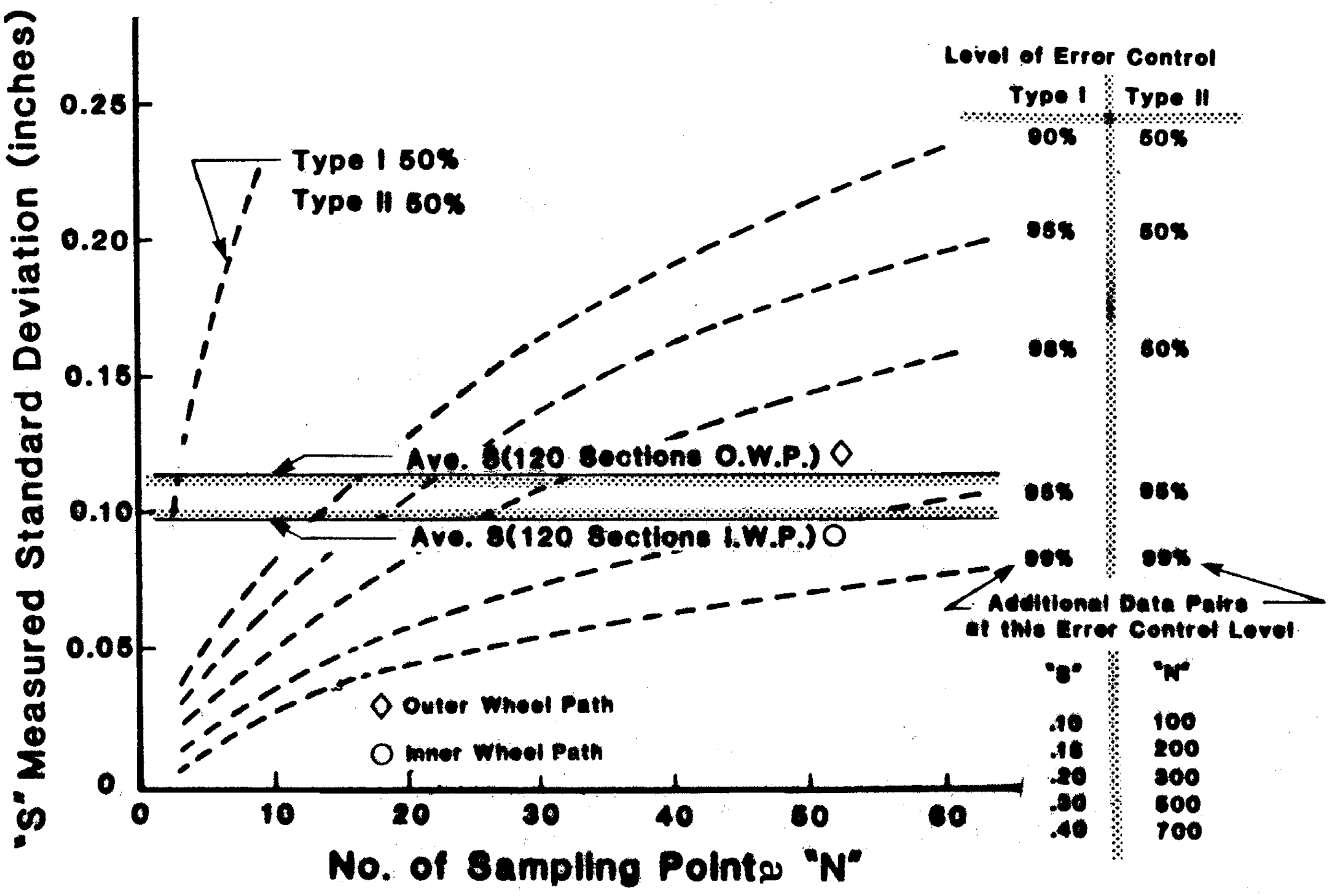


Figure 11

selected confidence against
type 2 error = 95%

obtained by graphical solution:
minimum sample number = 17 measurements per section

In most sampling situations, little concern is expressed over type 2 errors. This philosophy leads to the use of solution lines having only a 50% level of type 2 error control, i.e., no control and a significantly reduced sample size.

Since determination of sample size is dependent upon expected standard deviation, it is important to consider the magnitude of values which might commonly be encountered. Rut measurements made on the 5 Fairbanks test sections indicated standard deviations ranging from about 0.02 to more than 0.35 inches associated with average rut depths between 0.02 and 0.40 inches. Indications of rut measurement variability derived from the Fairbanks test section data suggest that minimum sampling be based on a standard deviation perhaps as high as 0.30-0.35. This magnitude of deviation plus 90-95% confidence level against error results in a minimum sample size much larger than can be shown in figure 11. Extrapolation suggests a minimum sample size exceeding one hundred. The job of rut depth measurement therefore begins to appear impossible except through an automatic rut measuring device capable of high density sampling.

Further evidence for requiring a large number of rut measurements per section was obtained by examining data from 120 statewide pavement sections which were part of a previous DOTPF research study (7). The cumulative plot shown as figure 12 indicates standard deviations calculated from both inner and outer wheelpath measurements were generally less than 0.3 inches. Plots 13A and B were constructed to show how standard deviations in the inner and outer wheelpaths respectively, tend to increase with average rut depth. The standard deviation value of 0.3 inch is reached on the upper confidence levels (a std. error of estimate) of both figures at an average rut depth of approximately 0.32-0.34 inches. In other words, fairly large standard deviation values are associated even with moderate rut depths, a factor which would again strongly suggest a high sample frequency.

Cumulative Frequency Distribution of Rut Measurement Standard Deviations (from 120 Pavement Sections)

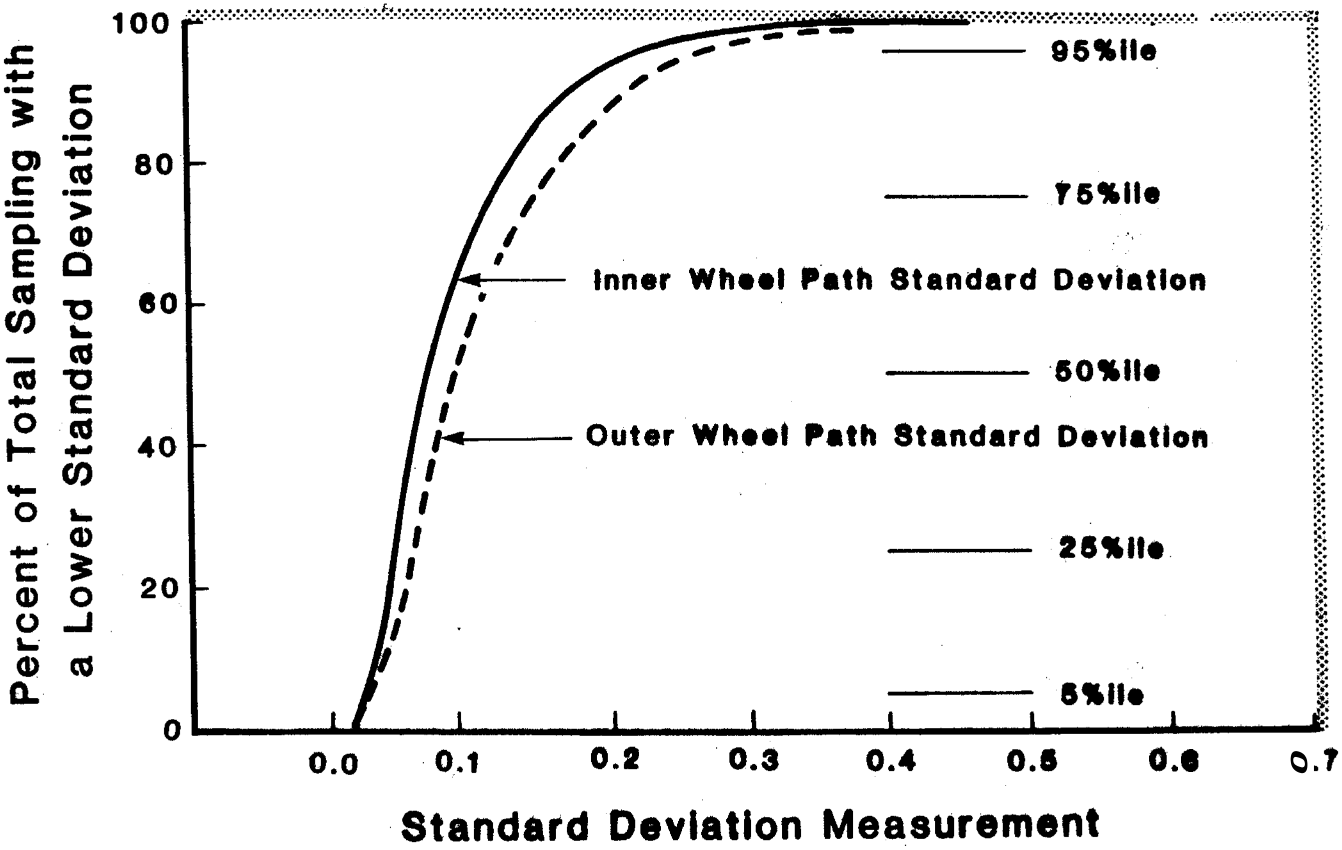


Figure 12

Figure 13A

Rut Depth Average Versus Standard Deviation (inner wheel path)

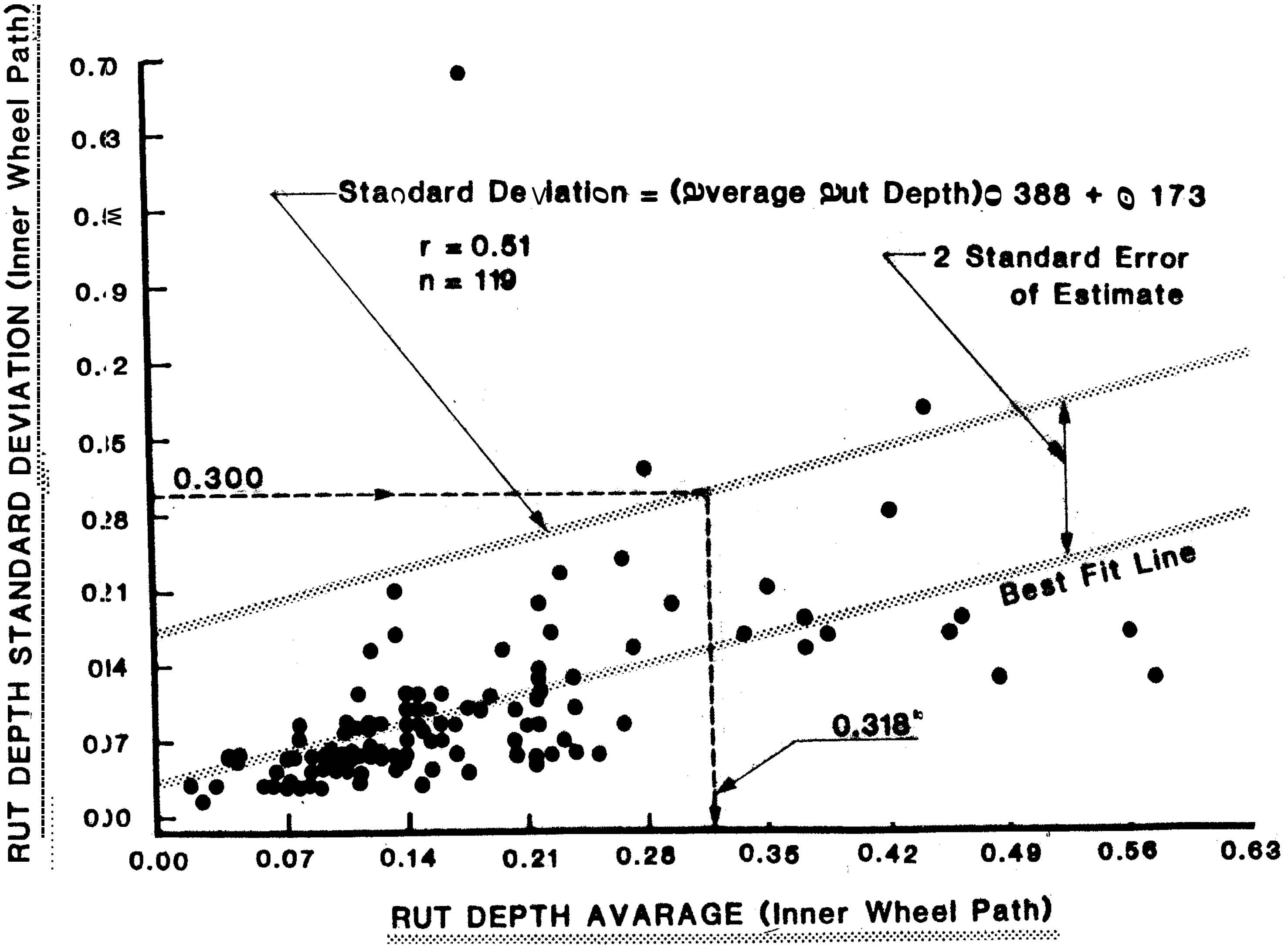
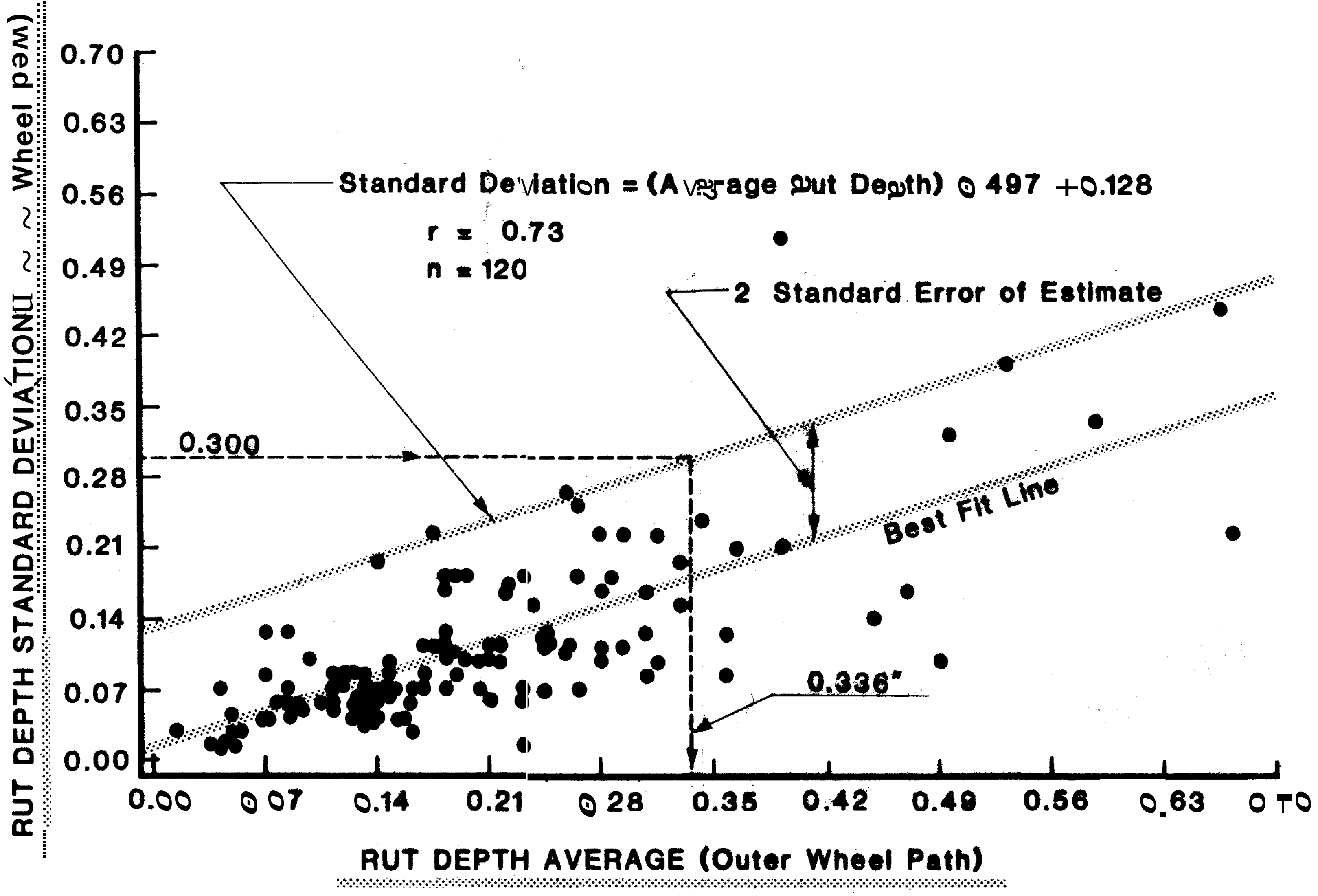


Figure 13B

Rut Depth Average Versus Standard Deviation (outer wheel path)



Wheelpath Location: Figure 14 answers the question of whether both inner and outer wheelpath locations must be measured individually. Data scatter about the line of best fit is large, with only a 0.72 regression coefficient. The usually practiced assumption that rutting is deeper in the outer wheelpath proves to be a shaky proposition. A very significant number (28%) of the field sections examined were found to exhibit deepest rutting in the inner wheelpath areas. The primary conclusion from this analysis that the "worst case" rutting condition can be determined only after looking at both wheelpaths.

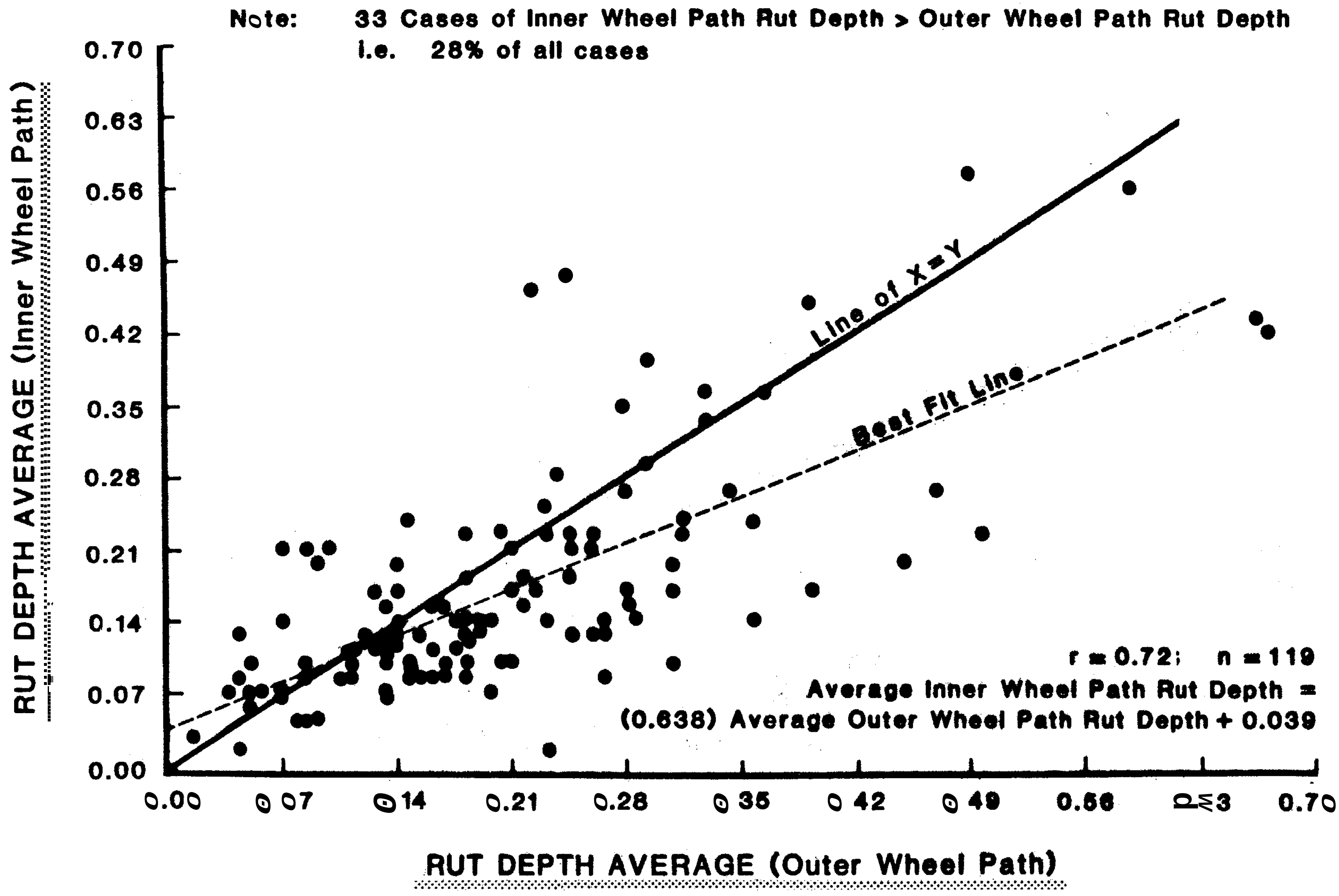
Alternatives: Several sources of rut measurement data were used to construct functional relationships between average rut depth, calculated standard deviation and required number of sampling points. This report substantiates previous contentions (9) that true mean rut depth can be accurately characterized only through a very large sampling. Problem rut depths on the order of 0.4-0.5 inch would require an assumed standard deviation value, using figures 12 and 13, of at least 0.3 inch and with reasonable error confidence levels, figure 11 would indicate a sampling obviously greater than 100 per section. Furthermore, the inability to predict whether inner or outer wheelpath represents the worst case condition would require doubling of the sampling effort. In dealing with this question, the choices are:

1. assume rutting to not be a problem and cease measurement,
2. perform a few random measurements per mile at locations which appear from general observation to represent worst case conditions,
3. purchase or build an automatic rut measuring device as described in reference 9.

Since deeply rutted sections are usually associated with severe alligatoring on most Alaskan road sections, it would seem reasonable to suggest that the measurement of both is not necessary. It is further known that rutting within the state is rarely as deep as the ½ inch + figure termed critical in most literature sources. The author would favor the first of the above alternatives. Alternative 2 provides "numbers" and the "numbers" can, of course, be included in subsequent discussions of

Figure 14

Inner Versus Outer Wheel Path Rut Depth Average



Note: 33 Cases of Inner Wheel Path Rut Depth > Outer Wheel Path Rut Depth
i.e. 28% of all cases

r = 0.72; n = 119
Average Inner Wheel Path Rut Depth =
(0.638) Average Outer Wheel Path Rut Depth + 0.039

pavement condition. However, the numbers generated from alternative 2 have no basic statistical validity and might be thought of as inventory garbage. Alternative 3 is preferred if departmental policy requires a rut depth determination. A 1981 cost estimate for purchase of an automatic rut measuring device was $30,000-$50,000.

A COMPARATIVE LOOK AT
PREVIOUS INVENTORY DATA

This report section looks at actual pavement inventory data in view of the preceeding findings of this report. Mindful of the rather gross variability evident in the experimental measurement of cracking and patching, a direct mile by mile comparison between two previous inventories is made.

Figure 15 shows the apparent variation in pavement distress between 1978 and 1980/81. As shown, these data have been normalized to provide a total scoring range of 0-100 (worst-best). The reader should note that data at coordinates (0%, 0%) and (100%, 100%) are often repeated in figure 15 accounting for the appearance of fewer than expected individual points on plots of cracking and patching.

A line of x = y has been included in each plot and differentiates pavement sections which apparently or actually improved with time (points above the line) from those which became worse (points below the line). Examination of plotted data indicates:

1) a very high degree of overall scatter

2) an unusually large number of data points lie above the line of x = y, i.e., performance improvement with time.

Taken together, these findings demonstrate a marked degree of randomness inherent to the rating process. The implication of point number two is especially significant in view of the common sense assumption that pavement condition deteriorates with time. This assumed generality could, of course, be altered by reconstruction, overlay or careful patching, and no attempt was made to remove specific points representing reconditioned pavement sections from the plots. This should, however, account for only a minor percentage of total rated mileage. A significant degree of randomness is suggested because even sections scoring better than average in 1978 show a very high rate of apparent improvement with time. The likelihood of initially good pavements (scoring 50-100) being substantially improved within a period of three years through maintenance, etc., is slight.

COMPARISON OF 1978 PAVEMENT INVENTORY DATA WITH 1980181 DATA

NOTE: All numbers have been normalized to a 0–100 (worst–best) scoring system

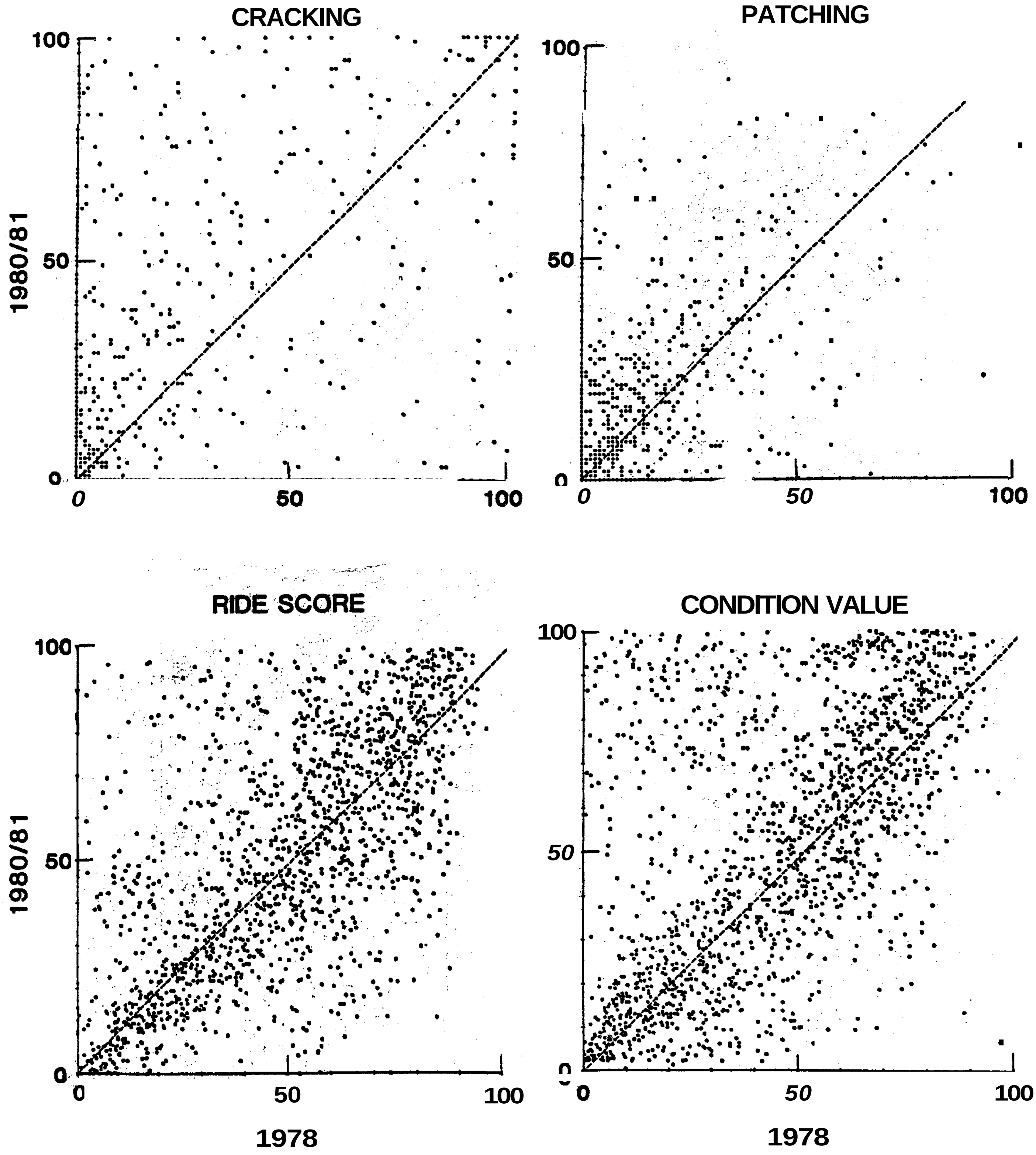


Figure 15

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Appendix A

Description of the State of Alaska's Field Rating Precedure for Bituminous Pavements

(Method Used 1978-81)

Phase I Mays Ridemeter

Mays Ridemeter data is collected at 50 mph as a continous summation of actual vehicle rear axle vertical movements on each mile-long section of highway. Measurement of ride roughness throughout the state produced the following values:

statewide minimum ride -- 11 inches/mile
statewide average ride -- 78 inches/mile
statewide maximum ride -- 500 inches/mile

Minimum roughness was measured on a very newly paved surface. Roads in condition at or near the maximum roughness value of 500 inches/mile cannot be safely driven at 50 mph. (With proper driving technique, the variations associated with this measurement are outside the subjective influence of the equipment operator. A complete analysis of road roughness measurements is therefore outside the scope of this report.

Phase II Surface Distress Ratina

A two-man crew is recommended for both safety and efficiency of operation. All measurements of cracking, patching and rut depth are made in one pass through the section. The average time required to rate a particular mile of roadway is completely dependent upon factors of:

1. light condition
2. variability of surface quality
3. severity and density of cracking
4. safety considerations

Optimum lighting conditions consist of low angle, head-on sun position. This tends to shadow the far (facing) edge of crack segments running more or less perpendicular to the line of sight and results in maximum visibility. It is sometimes advisable to choose the direction of travel on the basis of light conditions alone, especially if cracking is sporadic and/or of low severity. An observation speed of 7 - 10 mph should be used to insure that all detectable distress is seen. This, of course, does not preclude occasional stops which are used to make comment notes and to keep the "feel" of the road as conditions change.

Alligator Cracking

A brief description of alligator cracking is presented to aid the differentiation of this from the multitude of other common crack types.

Description - after: Manual for Condition Rating of Flexible Pavement, Ontario, Canada (1975).

Alligator Cracks

> Cracks which form a network of multisided (polygonal) blocks resembling the skin of an alligator. The block size can range from a few inches to about two feet (block size may be somewhat indicative of the depth of which failure is taking place with larger blocks corresponding to problems deeper in the structure).

A field survey summary sheet (see Figure 1) is used to record all aspects of the surface distress. Alligator cracking is divided, for the purpose of our evaluation scheme, into type I and II classifications which are subjectively based on severity. An attempt has been made to estimate severity level because the rate of further deterioration is assumed to be accellerated with increasing crack width and spall.

type I alligator cracking
- first formed alligator pattern
- definite polygon blocks with slightly spalled edges

type II alligator cracking
- definite polygon blocks with slightly spalled edges
- non-interlocking, spalled blocks: incipient pavement disintigration

Figure 1

Pavement Inventory Field Rating Form

CDS ROUTE NAME: Parks Hwy. CDS ROUTE NUMBER: 170000 Page 14

CREW: McHattie E Harwood WEATHER: DATE: 8/21/78

MILE	ALLIGATOR CRACKING				FULL WIDTH PATCHING		RUT DEPTH MEASUREMENT						REMARKS
	TYPE I		TYPE II										
	begin	end	begin	end	begin	end						mile	
218 → 219					218.231	18.292	0.010	0.071		0.157	0.137	218.25	
					18.944	19.000	0.132	0.079		0.050	0.110	218.75	Ravelling
						12%							Ave. 0.093
													SD 0.050
219 → 220	219.303	19.346			219.000	19.192	0.122	0.143		0.089	0.178	219.25	Very rough Patch
		4%			19.227	19.300	0.179	0.069		0.058	0.095	219.75	Section. Bad —
					19.343	19.661	Ave. 0.117			SD 0.047			Surface most of
						59 %							this patch.
220 → 221					220.186	20.228	0.084	0.052	centerline	0.146	0.153	220.25	...is due to embank-
					20.266	20.340	0.168	0.128		0.113	0.203	220.75	ment problems rather than pavement
					20.471	21.000	Ave. 0.131			SD 0.048			Structure inadequ-
						17%							acy.
221 → 222	221.157	21.223			221.000	21.158	0.083	0.051		0.091	0.163	221.25	
	21.312	21.400			21.260	21.312	0.166	0.103		0.070	0.225	221.75	Poor road surface
	21.434	21.471			21.404	21.436	Ave. 0.119			SD 0.059			also.
	21.783	21.829			21.618	21.625							Shows significant
	21.866	21.884			21.732	21.781							ravelling in the
	21.992	22.000			21.822	21.867							non-patched
		27%			21.889	21.930							portions.
					21.972	21.998							The patches are
						41%							also generally
222 → 223	22.000	22.036			222.061	22.263	0.185	0.120	centerline	0.150	0.200	222.25	ravelling.
	22.375	22.466			22.312	22.339	0.225	0.219		0.090	0.114	222.75	
	22.524	22.592			22.597	22.621	Ave. 0.153			SD 0.052			
	22.626	22.698				25%							
	22.756	22.871											
		41.00											

Figure 1 also exemplifies a completed rating form covering (5) 1-mile sections. The location of the 1-mile section is noted in the first column, **e.g.,** mile 218-9, etc. Columns 2-4 are used to measure total crack length and to classify as to type I or 11. In the example of Figure 1, no type II gatoring is indicated. A continuous length of gatoring is entered by listing begin and end points in the appropriate columns. The numbers as shown on the example sheet (columns 2 and 3) are route miles (Alaska C.D. S. system) read directly to the 1/1000 mile from an electronic odometer.

It is important to realize that a segment of road is considered continuously cracked **if** alligatoring remains visible within any portion of the traveled way, **i.e.,** the idea of a "continuously" cracked segment does not imply anything about the width or x- sectional distribution of the crack networks. When fillng out the field rating sheets, **it** is necessary to leave a space after each completed mile's data entry. This will allow sufficient room for the initial data conversions and averaging. All individual length increments within a given mile are eventually summed and converted to total % per mile, **e.g.,** 4% alligatoring is indicated for mile 219-20 of Figure 1.

Patching

Patching, for the purpose of this survey, is defined as that which is at least full lane width. The usual generic implication of the "major" patch is of pavement structure failure or settlement problems and a definite high level of maintenance requirement. Columns 6 and 7 of the field survey sheet (see Figure 1) are used to record the beginning and end of patches (to 1/1000 mile). The survey of patching and alligatoring is a simultaneous operation where the maximum driving speed is usually determined by the more difficult crack observations. Where patching and **alligatoring** occur together, **e.g.,** cracked patches or a single patched lane with the opposite lane cracked, both are indicated.

Since the basic rating interval is by the mile, no continuous occurrence of resurfacing material which is greater than 1 mile in length is termed "patch." Individual patch increments within a given mile are summed and converted to total % per mile, **e.g.,** 12% patching is indicated for mile 218-19 of Figure 1.

Rut Depth Measurement

Rut depth is standardized in this rating method by measurement from a 5 1/2 ft. reference straight edge. All wheelpaths are utilized for determining rut depth instead of the usual practice of using only the outside tracks. This decision was based on the observed variability of Alaskan roads, where the more severe rutting is often found on the inside wheelpath.

Rut measurements are taken as a series of "sets" per mile, where a set is defined as a series of readings from all wheelpaths at a given location. It is assumed that a maximum of 4 sets of rut depth readings will characterize even the more variable or deeply rutted surface types. The following is a suggested frequency of measurement based on very limited experience.

1. new pavement w/ 0.150" rut depth; 1 set/mile
2. pavements w/ 0.250" rut depth; 2 sets/mile
3. pavements w/ 0.250" rut depth; 4 sets/mile

All pavement types should be measured at 4 sets/mile if rutting appears to average more than 0.250" in depth. Rut depth information is entered in columns 8-12 of the rating sheet (Fig. 1) as shown in the example. All rut measurements are given to 0.001 inch and the appropriate location of the data set is recorded in column 12. The depth measurement entered in columns 8-11 should correspond to the actual wheelpaths (as viewed in the chosen direction of travel). The time required to perform the entire distress rating is generally determined by the number of rut measurements required; this is by far the slowest single operation. Estimated average time requirements for crack, patch and rut measurements will generally allow an advance rate ranging from less than 4 mph to 10+ mph.

-Other Distress Features-

Miscellaneous Subjective Observations

A column is provided on the field rating sheet for special remarks or amplifying comments. Unusual defects should be noted if they appear to be a major component of overall surface quality. Longitudinal, transverse/thermal and meandering cracks are commonly described, and additionally, such features as ravelling and bleeding (if severe and persistent).

Appendix B

Section by Section Summary of Experimental Ratings

Rating Crew #	Total/Ft. of Cracking		Total/Ft. of Full Width Patching	Rut depth in Raters Lane (in)				Rut depth in Opposing Lane (in)			
				$\bar{X} \times 10^3$		$S \times 10^3$		$\bar{X} \times 10^3$		$S \times 10^3$	
	Type I	Type II		IWP	OWP	IWP	OWP	IWP	OWP	IWP	OWP
1	145	0	369	57	88	55	56	39	160	49	86
2	109	0	350	30	124	19	105	16	74	5	45
3	142	0	380	38	118	19	61	45	89	23	53
4	171	0	379	26	152	13	98	37	67	17	22
5	167	0	379	43	110	12	78	23	70	12	41
6	158	0	375	24	103	23	80	21	50	26	43
7	174	0	370	37	55	14	28	19	50	11	29
8	187	0	370	32	132	17	41	26	82	19	61
9	183	0	370	40	167	27	65	32	54	37	38
10	91	0	382	48	103	26	79	36	69	27	25
11	138	0	371	59	92	29	51	57	70	26	29
12	8	0	367	44	147	14	65	42	79	27	33
13	84	0	366	45	141	33	85	17	74	19	56
14	29	0	380	25	126	12	62	44	50	30	39
15	100	0	375	36	156	35	48	40	86	38	44
$\bar{X}$ of Measurements	126	0	372	39	121	23	67	33	75	24	43
S of Measurements	55	0	8	11	30	12	21	12	27	11	16
coefficient of Variation (CV)	44	0	2	28	25	52	31	36	36	46	37

SUMMARY OF PAVEMENT RATING

DATA FOR SECTION NUMBER 1

Rating Crew #	Total/Ft. of Cracking		Total/Ft. of Full Width	Rut depth in Rater s L ne				Rut de Opposi			
				x		>		X			
	Type I	Type II	Patching	IWP	OWP	IW	OWI	IWI	OWP		
1	680	16	1042	156	215	94	170	254	245	179	250
2	912	19	697	295	331	199	280	149	231	123	142
3	819	13	799	209	284	240	224	179	208	129	195
4	1032	14	727	166	145	89	89	124	116	80	69
5	1202	13	889	270	287	203	290	190	315	143	301
6	1085	11	785	231	177	276	197	135	192	100	144
7	1434	12	1023	274	266	141	226	208	349	156	352
8	1097	10	834	279	264	265	221	161	306	119	279
9	1040	12	821	299	184	271	147	146	211	88	245
10	747	11	935	248	231	259	212	182	236	112	202
11	593	12	828	199	228	116	225	138	271	51	263
12	35	9	870	260	338	167	348	156	302	85	351
13	814	10	622	393	151	601	227	122	307	62	310
14	316	8	810	287	410	269	596	260	371	158	340
15	609	4	439	267	119	339	81	110	341	85	419
$\bar{X}$ of Measurements	828	12	808	256	242	236	236	167	267		
S of Measurements	355	3	151	59	81	125	122	45	69		
co-efficient Variation	43	25	19	23	33	53	52	27	26	33	37

SUMMARY OF PAVEMENT RATING

DATA FOR SECTION NUMBER 2

Rating Crew #	Total/Ft. of Cracking		Total/Ft of Full Width	Rut depth in Raters Lane				Rut depth in Opposing Lane			
				$\bar{X}$				$\bar{X}$		S	
	Type I	Type II	Patching	IWP	OWP	IWP	OWP	IWP	OWP	IWP	OWI
1	252	0	100	226	178	99	51	114	155	76	93
2	361	0	93	164	123	131	77	237	133	81	65
3	237	0	105	125	105	51	43	190	142	48	83
4	255	0	101	119	89	66	40	211	143	40	78
5	396	0	105	150	152	104	89	233	166	80	104
6	190	0	91	121	94	79	80	219	177	65	154
7	700	0	112	130	248	44	149	289	155	76	83
8	470	0	100	184	143	124	65	223	201	140	233
9	128	0	102	128	170	97	104	280	175	114	127
10	338	10	94	230	192	86	135	192	175	198	97
11	296	13	98	142	149	78	74	212	145	79	144
12	169	0	99	196	183	128	121	268	219	130	282
13	459	4	197	125	183	79	158	263	185	67	233
14	69	0	98	164	231	88	139	249	224	70	322
15	404	10	103	115	114	92	67	188	117	84	91
$\bar{X}$ of Meas'ure-ments	315	2	107	155	157	90	93	225	167	90	146
S of Measure-ments	160	5	26	38	47	26	39	44	31	40	82
co-efficient of Variation (CV)	51	250	24	25	30	29	41	10	19	44	56

SUMMARY OF PAVEMENT RATING

DATA FOR SECTION NUMBER 3

Rating Crew #	Total/Ft. of Cracking		Total/Ft of Full Width	Ra X							
	Type I	Type II	Patching	IWP	~~OWP~~	~~IWP~~	OWP	IWP	OWP	IWP	OWF
1	170	0	0	156	160	93	89	199	232	58	90
2	207	0	0	192	245	99	71	231	190	121	184
3	125	0	0	100	212	23	51	153	62	41	40
4	541	0	0	169	237	90	.13	169	111	78	93
5	132	0	0	206	258	105	.29	167	140	86	79
6	58	0	0	152	208	66	82	142	119	74	38
7	130	0	0	205	233	106	83	120	159	71	81
8				174	217	83	62	127	123	42	55
9	116	0	0	201	235	90	.15	140	141	77	32
10				201			170	158	144	63	85
11				192			77	139	115	77	79
12	130	0	0	221			83	150	152	84	81
13	82	0	0	257			110	185	147	204	103
14	64	0	0	196	272	56	114	162	158	78	81
15	60	0	0	129	117	80	98	111	81	60	53
$\bar{X}$ of Measurements	125	0	0	183	220	95	96	157	138	81	78
S of Measurements	56	0	0	38	39	55	30	31	41	39	36
Coefficient of Variation (CV)	45	0	0	21	18	58	31	20	30	48	46

SUMMARY OF PAVEMENT RATING

DATA FOR SECTION NUMBER 4

Rating Crew #	Total/Ft. of Cracking Type I	Total/Ft. of Cracking Type II	Total/Ft. of Full Width Patching	Rut depth in Raters Lane $\bar{X}$ IWP	Rut depth in Raters Lane $\bar{X}$ OWP	Rut depth in Raters Lane S IWP	Rut depth in Raters Lane S OWP	Rut depth in Opposing Lane $\bar{X}$ IWP	Rut depth in Opposing Lane $\bar{X}$ OWP	Rut depth in Opposing Lane S IWP	Rut depth in Opposing Lane S OWP
1											
2											
3	357	0	0	173	172	207	102	134	334	63	213
4	461	0	0	205	186	143	101	213	294	241	187
5	244	0	0	271	233	107	152	210	331	153	153
6	353	0	0	180	260	84	98	222	445	76	216
7	505	0	0	247	233	111	125	252	294	186	190
8	501	0	0	185	210	136	133	175	314	73	171
9	338	0	0	260	202	165	187	199	386	103	257
10	311	0	0	186	427	101	116	204	225	173	119
11	381	0	0	216	257	137	137	203	350	108	201
12	190	0	0	260	235	132	143	204	352	82	151
13	372	0	0	236	236	108	149	204	337	108	200
14	249	0	0	230	215	111	156	175	277	95	110
15	207	0	0	191	178	117	182	136	259	60	187
$\bar{X}$ of Measurements	344	0	0	218	234	128	137	195	323	117	181
S of Measurements	104	0	0	34	64	32	29	33	57	55	40
Coefficient of Variation (CV)	30	0	0	16	27	25	21	17	18	47	22

SUMMARY **OF** PAVEMENT **RATING**

DATA FOR SECTION NUMBER 5