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16. Abstract

This study was initiated in an effort to assist the department in responding to nationwide trends that are directed toward the desire to construct mainline Jointed Portland Cement Concrete Pavements to an as-built Serviceability Index (SI) of 4.5 or greater. At the beginning of this study it was clear that existing specifications and procedures were not resulting in the level of pavement smoothness desired. It was felt that combined improvements in construction procedures, roughness measurement and specifications may allow an SI level of 4.5 or greater to be routinely achievable on rural interstate rigid pavement construction. This study primarily compares the ability of several roughness measuring devices to measure and locate roughness and the ability of grinding to lessen roughness and presents recommendations for changes in current roughness measurement specifications. It was found through this study that the California Style profilograph is the preferred instrument (of the instruments evaluated) to utilize on mainline JPCC pavements for construction control, grinding and acceptance. It was also observed that an SI level of 4.5 will not routinely be achievable even though the profilograph is utilized and roughness specifications are set much lower (tighter) than the nationwide norm. Additionally it was observed that grinding will not provide substantial increases in pavement serviceability levels. To obtain smooth pavements they must be constructed smooth without resorting to extensive grinding.

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PAVEMENT ROUGHNESS AND RIDE CORRECTION PROCEDURES FOR JOINTED CONCRETE PAVEMENTS

FINAL REPORT

BY

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LTRC RESEARCH PROJECT NO. 87-1P(B)

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Conducted By

LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
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ABSTRACT

This study was initiated in an effort to assist the department in responding to nationwide trends that are directed toward the desire to construct mainline Jointed Portland Cement Concrete Pavements to an as-built Serviceability Index (SI) of 4.5 or greater. At the beginning of this study it was clear that existing specifications and procedures were not resulting in the level of pavement smoothness desired. It was felt that combined improvements in construction procedures, roughness measurement and specifications may allow an SI level of 4.5 or greater to be routinely achievable on rural interstate rigid pavement construction. This study primarily compares the ability of several roughness measuring devices to measure and locate roughness and the ability of grinding to lessen roughness and presents recommendations for changes in current roughness measurement specifications. It was found through this study that the California Style profilograph is the preferred instrument (of the instruments evaluated) to utilize on mainline JPCC pavements for construction control, grinding and acceptance. It was also observed that an SI level of 4.5 will not routinely be achievable even though the profilograph is utilized and roughness specifications are set much lower (tighter) than the nationwide norm. Additionally it was observed that grinding will not provide substantial increases in pavement serviceability levels. To obtain smooth pavements they must be constructed smooth without resorting to extensive grinding.

IMPLEMENTATION STATEMENT

As a result of the work conducted through this study, data collected concurrently with this study and through decisions by the administrators of the LA DOTD, the Ames profilograph is now utilized as the primary roughness quality control and acceptance device for not only interstate JPPC pavements, but all pavement (rigid and flexible) constructed in Louisiana. Data collected during this study and concurrently with this study were utilized to formulate current specifications for urban and rural rigid pavements and flexible pavement construction both new and overlay. Appendix B of this report presents a report titled "Pavement Roughness and Profilograph Specifications" prepared for the LA DOTD. This report also summarizes the data collected during this study and also documents data collected and analyzed concurrently with this study. The purpose of the report was to provide the department with information concerning the use of the profilograph for specification development for both rigid and flexible pavements. Appendix C of this report includes the current roughness specifications as adopted by the department for rigid and flexible pavement construction.

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INTRODUCTION

The ability of a pavement structure to serve automobile and truck traffic is described or quantified as the facilities performance. The performance of a highway facility may be envisioned as the area under that facilities serviceability vs. loading curve with the Serviceability Index (SI) being the primary measure of a pavement's serviceability. The new AASHTO design procedures for Jointed Portland Cement Concrete pavements (JPCC) require an estimation to be made of the initial SI of the pavement to be constructed and to the level to which an agency will let the SI fall. In design theory, if the as-built (initial) SI of a JPCC pavement is decreased, the performance of the pavement will decrease and, conversely, an increase in SI will result in an increase in performance. Louisiana, for many years, has acknowledged the relationship between initial as-built SI and performance and has initiated (and continues to initiate) design and specification changes in an effort to increase the initial SI of their interstate and primary JPCC pavements.

These efforts resulted in an evolution of major changes in specifications and acceptance procedures for JPCC pavements in the areas of construction of transverse contraction joints and acceptable, as-built, surface (roughness) tolerance limits. Transverse contraction joints were specified to be formed by sawing rather than the traditional method which utilized plastic removable inserts. The level of acceptance for surface tolerance determined by the 10-foot rolling straightedge, (linear percent exceeding a 1/8 inch setting) was first lowered from 4.0 percent to 0.0 percent. The next major step by Louisiana in an effort to reduce roughness was to replace the straightedge with the profilograph.

This study was initiated prior to the department changing from the straightedge to the profilograph for as-built roughness measurement, control, correction and project acceptance. The department adopted the profilograph as its primary roughness measuring device for interstate JPCC pavements as the result of previous work and research conducted in Louisiana and elsewhere and the belief that this instrument was superior to the straightedge. As a result of this study and departmental directives, the California Style Profilograph (Ames) has now become the primary roughness measuring instrument for all rigid and flexible pavements constructed in Louisiana.

Before and after these specification and acceptance procedure changes were instituted, questions concerning what causes roughness in JPCC pavements and how best to identify, control, and correct roughness have been raised. This study was undertaken in an effort to answer these questions.

OBJECTIVE

The objective of this study is to examine roughness occurring on newly constructed JPCC pavements. This examination included determining how best to measure and locate roughness; if possible, identify its cause; determining which roughness measuring device is best suited for identifying areas to be corrected by grinding; and determining the expected benefits (improvements in quality of ride) to pavements which have been corrected (ground) according to selected roughness measuring devices.

SCOPE

Initially, this study was accomplished by testing seven newly constructed JPCC pavements. Only one of these projects was constructed under a profilograph specification. The remaining six projects were constructed under the LA DOTD 10-foot rolling straightedge specification. All projects were tested to the greatest degree possible with the following roughness measuring devices:

1. The May Ride Meter
2. The 10-foot Rolling Straightedge
3. The Rainhart Profilograph

Early in this study, the Rainhart profilograph was replaced with the Ames profilograph because the researchers felt that the Ames profilograph was easier to use and produced results of similar usefulness as those produced by the Rainhart profilograph. In like manner, the 10-foot Rolling Straightedge was soon abandoned after it became clear that the profilographs were superior to the straightedge in most respects.

The Mays Ride Meter was used as the benchmark to which the other devices' roughness measuring capabilities were compared. The straightedge and two types of profilographs were evaluated to determine the following:

1. Suitability of measuring and locating deviations from a planer surface.
2. Correlation with the Mays Ride Meter.
3. Suitability as a control and acceptance device.
4. Suitability as a grinding control device.

The data obtained during this study were evaluated in an effort to determine what causes roughness in JPCC pavement and how best to control, identify, and correct roughness when it occurs.

METHOD OF PROCEDURE

EQUIPMENT

The Mays Ride Meter

The LA DOTD uses the Mays Ride Meter to evaluate the roughness and serviceability of existing pavements. The Ride Meter measures roughness response by recording the mechanical displacement created by the relative motion between the rear axle and frame of a test vehicle. This mechanical movement is converted into an electrical impulse through a photoelectric cell. The electrical signal is transmitted back into a mechanical movement which is recorded on graph paper. The Mays Ride Meter supplies a permanent graphical log of roughness summation which is expressed in units of inches of roughness per mile. Additional information on the LA DOTD's calibration and use of the ride meter may be found in a report entitled, "The Mays Ride Meter" prepared by the Louisiana Department of Highways, Research and Development Section, Training Unit; 1975.

The 10 Foot Rolling Straightedge

At the initiation of this study the current LA DOTD specifications required the use of the 10-foot rolling straightedge as its project quality control tool for both rigid and flexible pavements. The straightedge is also used to asses pay penalties and/or designate areas requiring corrective action.

The straightedge consists of a metal beam (approximately 10-ft. long) that is supported at either end by two hard rubber wheels. At the center of the beam is the roughness indicator. The roughness indicator essentially consists of a scale wheel which is free to move vertically as the straightedge travels across the pavement and a pointer/scale and microswitches that are activated by the vertical movement of the scale wheel as the straightedge is pulled along the pavement. Vertical movement of the scale wheel in relation to the beam is indicated by the pointer. The scale and microswitches can be set to activate a dye release mechanism at a pre-set degree of vertical movement. The microswitches and dye release mechanism, when activated, spray a dye onto the pavement marking those areas outside the pre-set tolerance. These dye marks are measured and when divided by the total length of the pavement tested, give a roughness measurement that is expressed as the percent of the tested length that exceeds the pre-set tolerance. Additional information about the department calibration and use of the rolling straightedge and pictures of the device may be found in the current addition of LA DOTD Testing Procedures Manual, Volume 2, designations TR 603-84 and TR 618-84.

The Rainhart Profilograph

The Rainhart profilograph is a 26 ft. long device composed of a major truss which is supported at each end by two minor trusses. The minor trusses are supported at each end by a tripod, each supported by 3 small wheels. The instrument that records roughness is centered on the device and is located at the top center of the main truss. The minor trusses are pinned to the main truss and the tripods are connected to the minor trusses with a ball and socket arrangement allowing partially independent movement of each major component of the device. The 12 small wheels that support the device are called averaging wheels, and each traverses a different path as the profilograph is pushed longitudinally along the roadway. Due to the geometrics of the profilograph, 1/12th of the vertical movement of an individual averaging wheel is transmitted mechanically to the center of the main truss where the recording instrument is located.

The roughness recording instrument is actuated mechanically during vertical distance changes between the recorder and a 5 ft. circumference recording wheel which rides on the pavement surface below the recorder. The recorder is a strip chart recorder which is also equipped with a digital longitudinal distance counter and two vertical roughness counters. As the 5 ft. recording wheel moves longitudinally and vertically along the pavement surface, it mechanically drives the chart paper, pen carriage, and counters.

The profilograph truss and averaging wheels are designed to provide a relatively consistent vertical frame of reference to the recorder while the measuring wheel is free to move vertically as it is pushed over an undulating pavement surface. It is this independence between the "consistent" height of the recorder and the variable movement of the measuring wheel that allows the purported accurate recording of roughness and mapping of the surface profile.

The strip chart output has a 1 in. to 1 in. vertical movement scale and longitudinal scale which can be set to record a 1 in. to 10 ft. or 1 in. to 25 ft. scale. The digital roughness counters record each upward movement of the measuring wheel in relation to the recorder. One of the counters records the total upward movement while the other counter can be set to ignore (not count) the first 1/10th of an inch during each individual upward movement. The longitudinal distance counter records directly, in feet, the distance the profilograph moves during testing.

The profilograph is towed to a testing site on its own set of trailer wheels which retract during testing. The device is positioned on the beginning of the desired test path, and the recorder is then mounted on the main truss and connected to the measuring wheel. The profilograph is steered by a steering mechanism which controls the alignment of the front tripod. Testing is conducted by zeroing all counters and pushing the profilograph at a moderate walking speed along the desired path. Testing is usually conducted along each wheelpath of each lane for a representative length of the project. For most projects tested during this study, a length of 0.2 of mile was utilized. After each wheelpath run, the counter values and pertinent project data are recorded and the graphical output identified.

For this study the roughness or surface profile, recorded on the strip chart was evaluated by use of a 1/10 inch "blanking band" as specified by the Georgia Highway Department. Trace evaluation yields a summary statistic called the Profile Index (PI) of the surface tested. The blanking band is used to discount irregularities of the pavement surface, such as tining on concrete and the macrotexture of hot mix, which do not contribute to a rough ride. This discounting of small surface irregularities is also a feature on one of the digital counters; in that it discounts or "filters" the first 1/10 of an inch of movement of the measuring wheel, after it passes from a downstroke and starts an upstroke. The use of the Rainhart Profilograph was discontinued shortly after the beginning of this study when it became evident that the Ames Profilograph was, in our opinion, much easier to use and provided results which were considered equivalent to the Rainhart device.

The Ames Profilograph

The Ames Profilograph is an instrument designed to measure the road profile in a manner very similar to that of the Rainhart profilograph. The Ames profilograph is composed of a segmented 25-foot long hollow aluminum beam. The beam is supported at either end by a set of six averaging wheels, four of which are in-line, spaced on 30 inch centers and offset 15 inches and also parallel to the longitudinal centerline of the beam. The two remaining wheels are also parallel to the beam, located on the opposite side from the four wheel configuration. These two wheels have 20-inch centers and are offset 15 inches from the longitudinal centerline. The averaging wheels of the Ames profilogragh serve the same function as those of the averaging wheels of the Rainhart profilograph; that is, providing the recording device a relatively consistent frame of reference. The averaging wheels are pinned at either end of the beam in such a manner that only a portion of their vertical movement is transmitted to the recording device.

Vertical surface deviations are mechanically transmitted to the recorder through the action of a measuring wheel located at the center of the beam and a hinge/pivot arm assembly. The recorder, which is located at the rear of the profilograph, consists of a computer printer type paper drive which utilizes standard computer paper. The surface profile is traced upon the computer paper with an ink pen which is driven through the mechanically transmitted action of the measuring wheel, hinge/pivot arm assembly. The computer paper is driven by the printer drive through the mechanism of a bicycle tire and gear assembly which drives the paper at the scale of 1 inch equals 25 feet. The vertical scale of the trace is one to one; i.e., one inch of vertical movement of the measuring wheel is recorded as one inch of vertical movement on the trace.

The profile trace is evaluated in the same manner as the Rainhart trace with the exception that a 0.2 inch blanking band is commonly used.

Additional information about the Department's calibration and use of the Ames profilograph may be found in the current addition of LA DOTD Testing Procedures Manual, Designation TR-641.

DISCUSSION OF RESULTS

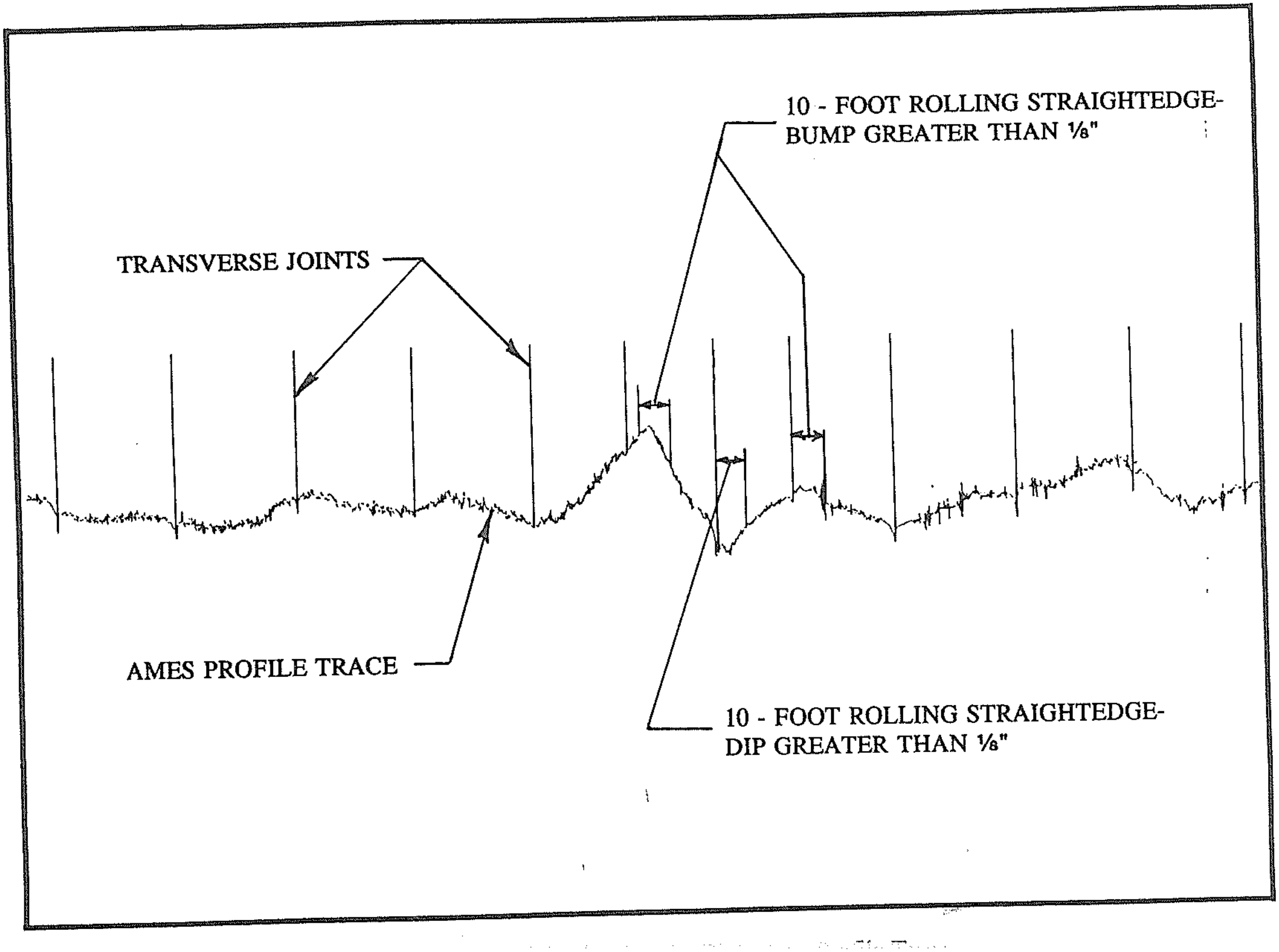
The following discussion is based upon the evaluation of equipment and test results, obtained from selected JPCC projects, utilizing the 10-foot rolling straightedge, the Rainhart and Ames profilographs and the Mays Ride Meter. This study was undertaken in response to major specification changes and the need to answer several questions that arose during formulation of these new specifications and as a result of their implementation.

Ability to accurately measure and locate roughness:

All of the pieces of test equipment are able to measure roughness in the manner to which they were designed. The rolling straightedge and the profilographs both indicate a vertical deviation from a planer surface and the horizontal length of these deviations. The accuracy to which these instruments measure and locate roughness is largely dependent on the relationship of the wave-shape of the occurring roughness to the wheelbase of the equipment, along with the profile filtering aspect of the moving reference frame.

When utilizing current technology, the wavelength to wheelbase length ratio is important to the measure and identification of the roughness because a long wavelength deviation cannot be accurately identified by a short (in relation to the wavelength) wheelbased instrument. A short wheelbased instrument will tend to "ride" the longer wavelength and not identify it in total, whereas a long wheelbased instrument will not "ride" a shorter wavelength and will be able to more accurately identify the deviation. An example of the difference in the identification and measure between the 10-foot rolling straightedge and the Ames profilograph is presented in Figure 1. In this figure the area indicated to be out of tolerance with the rolling straightedge (1/8 in. setting) is indicated on the trace obtained from the Ames profilograph. As indicated in this example, only a portion of the roughness identified by the profilograph is also identified by the straightedge.

The ability of the instrument to maintain a consistent reference frame is also important to its ability to accurately identify roughness. In this case, the reference frame can be defined as the vertical distance between the instrument's recording mechanism and the roadway surface


10 - FOOT ROLLING STRAIGHTEDGE-
BUMP GREATER THAN ⅛"
TRANSVERSE JOINTS
AMES PROFILE TRACE
10 - FOOT ROLLING STRAIGHTEDGE-
DIP GREATER THAN ⅛"

immediately below it. A consistent reference frame would be a line which is always the same distance and parallel to the theoretical planer surface of the roadway in the immediate area being tested. The relative distance of the recording mechanism to the roadway surface is affected by the vertical movements of the beam or truss supporting wheel. Therefore non-existent deviations can be indicated at a particular location through the actions of the supporting wheels as they pass over bumps or depressions. On relatively short wavelength deviations, the profilographs, through their supporting wheel spacing and their hinged arrangement, transmit only a portion of their vertical movement to the recording mechanism. Through the design of the straightedge, no mediation of vertical movement due to the actions of the support wheels is accomplished. The profilographs, in general, can be considered to maintain a more consistent frame of reference than the rolling straightedge.

As indicated above, due to a generally smaller wave length to wheelbase ratio and an increased ability to maintain a consistent reference frame the profilographs are better suited to measure and locate pavement roughness than the 10-foot rolling straightedge. Although the profilographs are better suited than the straightedge to measure and locate roughness, there remains the question of how accurate in relation to the actual road surface profile the profilographs are. This question was answered in a report entitled "Road Profile Study" (1), wherein the Rainhart profilograph was tested over a test track which contained various arrangements of induced roughness. This portion of the study indicated that the profilograph does not reproduce the actual road surface profile, but does properly identify the location and magnitude of bumps and depressions with wavelengths of less than the wheelbase length of the profilograph and/or with deviations of moderate or large amplitudes. It is reasonable to believe that deviations of this wave-shape occur frequently and are a major contributor to a reduced ride quality.

A visual comparison of the traces obtained from the Rainhart and Ames profilographs indicate that both instruments, when tested along the same path, equally identify locations of surface deviations. The major difference between the two traces is that the wave-shape amplitude indicated on the Rainhart trace is slightly less than that of the Ames. This is illustrated in Figure 2. It is not known which profilograph more closely approximates the actual road surface profile. Based upon the data analysis presented later, both Rainhart and Ames profilographs can be considered equal in their abilities to identify road surface deviations.

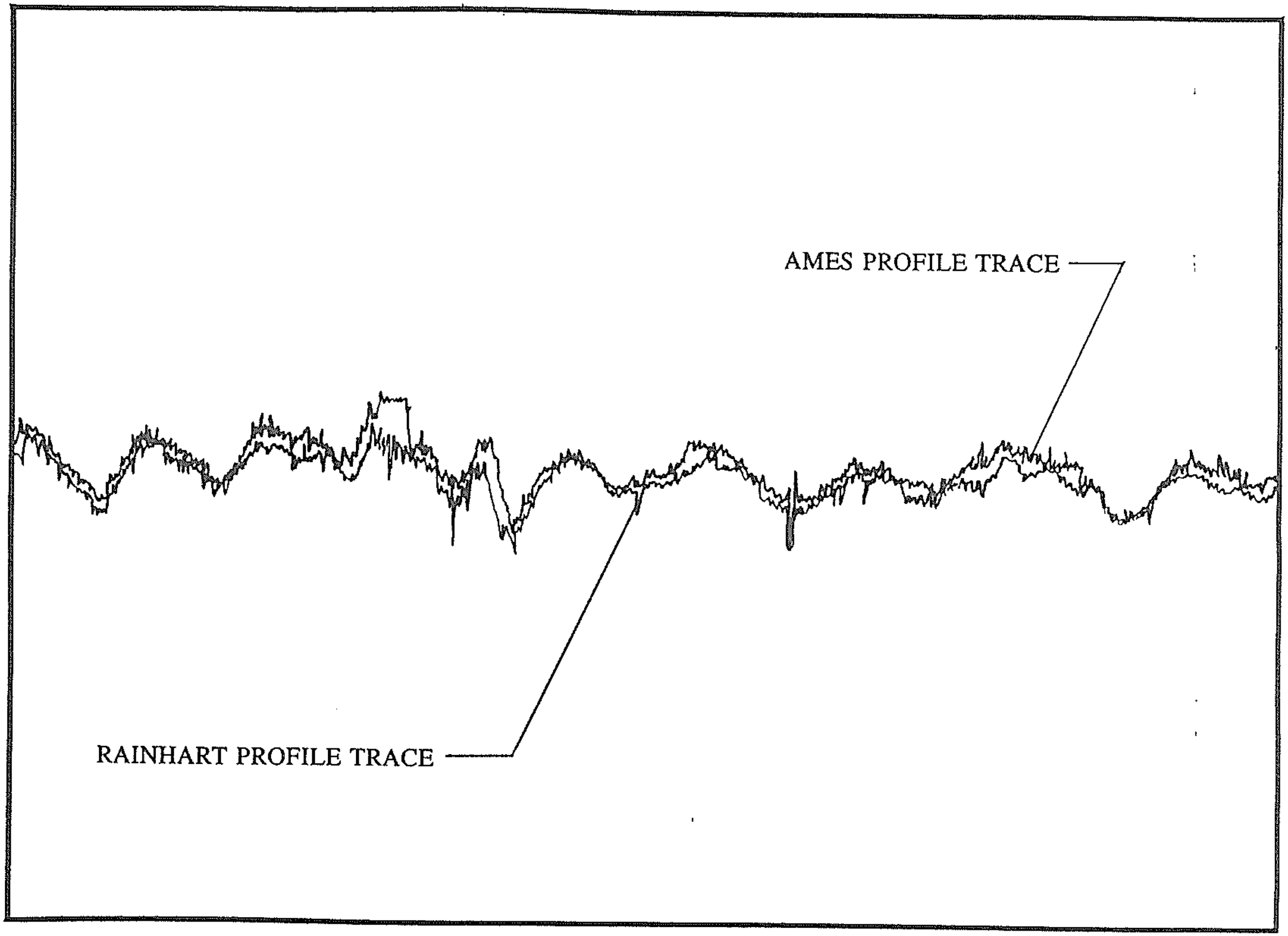


FIGURE 2. Overlay of Ames and Rainhart Profile Traces.

Suitability as a quality control and acceptance device:

Of the three devices evaluated, the straightedge is by far the least able to accurately measure and identify surface deviations due to its geometrics. In addition, the straightedge was found to be in actual usage non-repeatable to a large degree. The LA DOTD required that each project contractor supply a 10-foot rolling straightedge to be calibrated by the district laboratories and used by the project engineer. Specifications require that the calibration and use be in accordance with LA DOTD Testing and Procedures Manual; Method of Test, TR #'s 603-84 and 618-84, to provide statewide uniformity among equipment and test results. In actual practice this was found not to be the case. On many projects visited, very few of the straightedges in use on those projects were found to be in calibration. In fact, several of the straightedges being used were found to be in such disrepair that they could not be properly calibrated without overhaul.

Table 1 presents test results obtained from two straightedges both calibrated on the same day by the same experienced person, according to the applicable procedures. Both straightedges were in good working order and the same test path was used during testing.

TABLE 1
COMPARISON OF CALIBRATED STRAIGHTEDGES

Test #	Linear Percent Exceeding 1/8" Tolerance	
	Straightedge #1	Straightedge #2
1	1.4	0.5
2	0.9	0.5
3	4.8	0.3
4	4.5	0.7
5	1.7	0.1

The reason for the difference in the test results could not be determined, but it is believed to be due to the extreme sensitivity of the straightedges to calibration. It is believed that straightedges cannot be set to "read" the same by the same person much less by a number of different people scattered across the state. To this problem can be added changes in the calibration during use (vibration, mishandling etc.) and errors involved in identifying, measuring and recording the dye which has been "squirted" on the pavement surface. In theory the rolling straightedge can be considered a suitable quality control and acceptance tool, but it cannot be considered such in actual practice.

From limited test experience the profilographs appear to be very repeatable. The LA DOTD requires that all profilographs undergo a calibration process in which they are operated along a calibration test path. A comparison of profile traces from nine Ames profilographs operated along the same test path, indicates that the Ames profilograph is very repeatable device. During the previous study (1) the trace from one test section was compared between Louisiana's and Arkansas's Rainhart profilographs, also with favorable results. In the normal application profilographs do not require calibration, but do require maintenance of parts that become loose or worn. It appears that the repeatability of either profilograph is not equipment related but is trace evaluation related which is mostly affected by the evaluators ability to reduce the trace, the degree of roughness and the size of the blanking band.

Correlation with the Mays Ride Meter:

In 1986 specification changes were introduced in an effort to construct JPCC pavements with an as-built SI of at least 4.5, the mean initial serviceability value of the JPCC pavements constructed at the AASHO Road Test. The serviceability concept was established at the Road Test in an effort to define and objectively measure pavement performance. This was /accomplished by a panel rating which ranked the pavement's ability to serve traffic and by comparing these ratings to the measurable values of slope variance, cracking and patching in addition to rutting (in the case of flexible pavements). From this comparison resulted the following predictive equation for rigid pavements:

$$p = 5.41 - 1.80 \log (1 + \overline{SV}) - 0.09 \sqrt{C+P}$$

in which

p = Present serviceability index.

$\overline{SV}$ = Mean of the slope variance in the two wheelpaths as measured with the AASHO profilometer.

C,P = Measures of cracking and patching in the pavement surface.

The AASHO profilometer was next correlated with the Chloe profilometer, yielding the following relationship which adjusts the SV obtained with the Chloe profilometer such that it may be used in the above serviceability equation.

$$\overline{SV} = 8.46 \ [\ Yi^2 \ / \ N - (Yi \ / \ N)^2 \ ] - 3.0$$

in which

$\overline{SV}$ = Value of slope variance to be used in the serviceability equation.

Yi = Chloe indicator of slope, obtained at 6" spacing.

N = Number of sample points.

The measure of SV was established at the AASHO Road Test as the primary indicator of SI for both rigid and flexible pavements. Regression analysis yielded two separate equations needed for the prediction of the serviceability; one for rigid (presented above) and one for flexible pavements. A comparison of the two equations indicates that for equal values of SV, (i.e. equal measured roughness qualities for a rigid and flexible pavement) different SI values would result. The rigid pavement would, in general, receive a higher serviceability rating than the flexible pavement with the same SV. This is especially true of newer pavements with little distress. As with the Road Test prediction of SI through the adjustment of SV, LA DOTD also modifies its SI prediction when testing with the Mays Ride meter on rigid and flexible sections. The Mays Ride Meter's roughness output is in in/mile and it does not "know" on which surface type it is riding. LA DOTD regularly calibrates the Louisiana Transportation Research Centers Mays Ride Meter (MRM) with the GM profilometer utilized by the Texas State Department of Highways and Public Transportation, which in turn yields the panel rated SI relationship. This SI vs. MRM in/mile is then adjusted to reflect the difference in ratings a rigid pavement would receive, even though it obtained the same measure of roughness as a flexible section when tested with the Ride Meter.

The rigid pavement SI vs. MRM in/mile adjustment was established through research by correlating the in/mile measurement of roughness obtained with the Mays Ride Meter vs. the SV obtained with the Chloe profilometer as presented graphically in Figure 3.

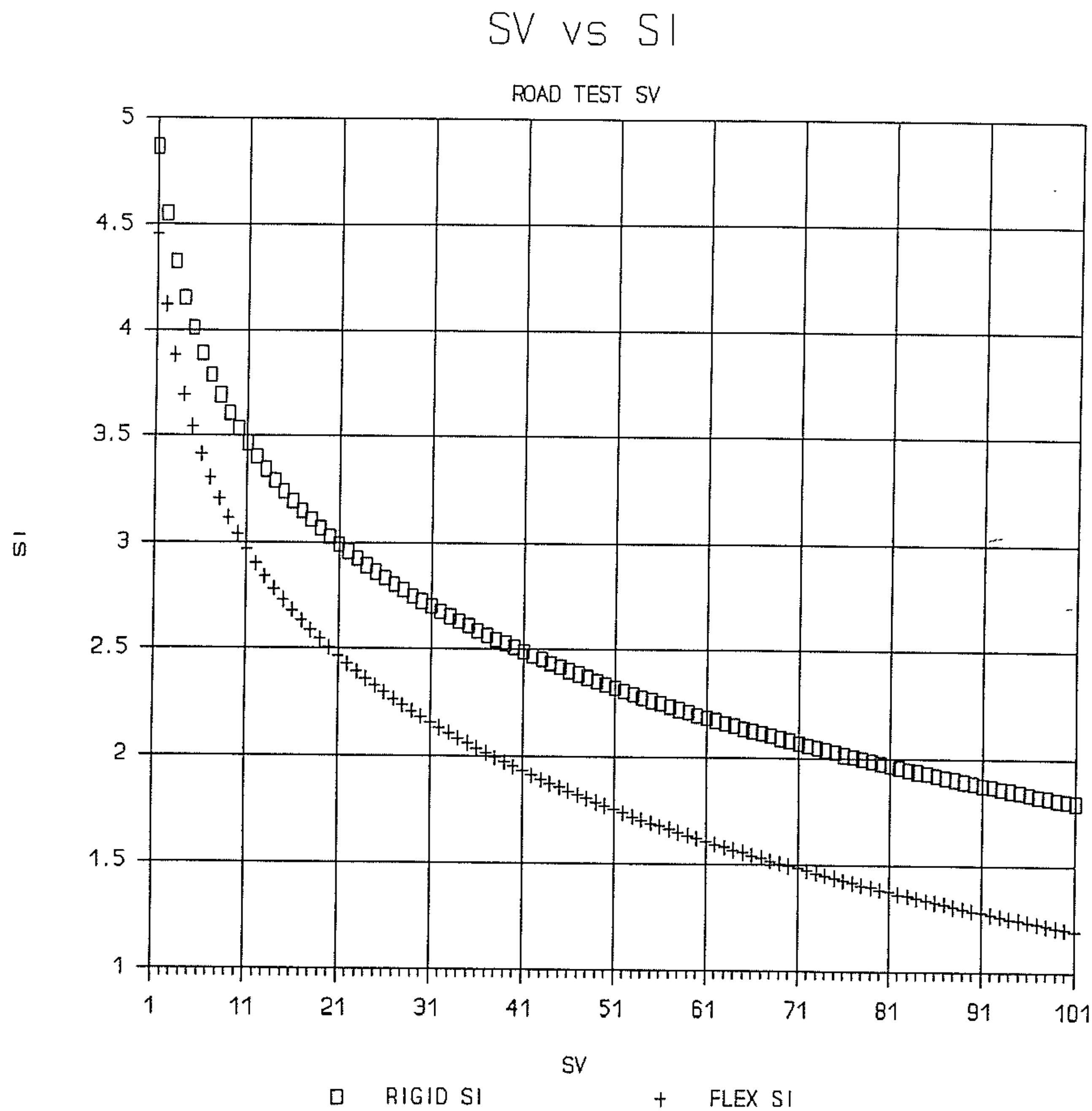

SV vs SI
ROAD TEST SV
5
4.5
4
3.5
3
2.5
2
1.5
1
SI
1
11
21
31
41
51
61
71
81
91
101
SV
RIGID SI
FLEX SI

FIGURE 3

Once the adjustment is applied to the in/mile output of a properly maintained and calibrated Mays Ride Meter, the SI' (Mays) is equivalent to the SI (AASHO panel) when the slight adjustments for cracking and patching are ignored. Affirmation of the rigid pavement adjustment was recently obtained in Louisiana, during participation in an NCHRP study (2) in which a panel rated 60 test sections. Test sections ratings obtained in Louisiana compare very favorably to the Mays predicted SI for both rigid and flexible pavements test sections.

Since the specification changes were instituted in an effort to construct rigid pavements to an initial SI level of 4.5, it was felt that the Chloe based MRM-SI measurements would be the preferred (available) instrument to which to compare the roughness measure obtained with the straightedge and the two profilographs.

Appendix A, (Project Data), Table 4-A contains the listing of the test results obtained during comparison testing between the 10-foot rolling straightedge and the Rainhart and Ames Profilograph with the Mays Ride Meter. As can be seen in Appendix A, (Project Data), Table 4-A, many gaps exist in the data due to both logistical problems associated with testing each project lot with four different devices and the decisions made to abandon two of the instruments after some initial data was obtained. A linear regression between data points was conducted utilizing a data analysis feature of LOTUS 1-2-3. The results of this analysis are presented in the following Table 2. The Rainhart trace was reduced by utilizing the 1/10 inch blanking band. The Ames traces were initially reduced with both the 1/10 inch and 2/10 inch blanking bands.

TABLE 2
RESULTS OF LINEAR REGRESSION

TESTED SURFACE	INDEPENDENT VARIABLE	DEPENDENT VARIABLE	R-SQUARED
AS-BUILT	MAYS SI	AMES (0.1)	0.71
AS-BUILT	MAYS SI	AMES (0.2)	0.61
AS-BUILT	MAYS SI	RAIN (0.1)	0.54
AS-BUILT	MAYS SI	ST. EDGE (1/8")	0.56
AS-BUILT	AMES (0.2)	AMES (0.1)	0.85
AS-BUILT	AMES (0.2)	RAIN (0.1)	0.94
GRIND/PROFILE	MAYS SI	AMES (0.2)	0.09
GRIND/ST. EDGE	MAYS SI	AMES (0.2)	0.54
GRIND/ST. EDGE	MAYS SI	AMES (0.1)	0.63
GRIND/ST. EDGE	AMES (0.2)	AMES (0.1)	0.86

A graphical depiction of data points utilized for the regressions listed in Table 2 is presented in Appendix A, Figures 1-A through 10-A

Both the Rainhart and Ames profilographs can be considered equally well suited for determining the location and extent of roughness occurring in JPCC pavements. The Ames profilograph was found to be the preferred instrument due to its durability, ease of operation and lack of problems associated with its trace recording mechanism.

Suitability as a grinding control device:

Although constructing JPCC pavements to an initial SI level of 4.5 is desirable, it is evident that this SI level will be seldomly obtained as paved and may not be obtainable even with grinding entire projects or portions of projects. It is not generally feasible to diamond grind the entire project, but only to address deviations from the planer surface on an individual deviation basis. Grinding bumps in JPCC pavements may not result in an SI level of 4.5, but in theory should increase the final SI from its as-built SI level when ground appropriately. Therefore, it is necessary to accurately locate these "bumps" to be ground and to be able to determine the success of grinding upon completion.

As previously indicated, the 10-foot rolling straightedge is the least able to accurately measure and locate roughness. Even though this is true it may still be suitable to use as a grinding control device. Its suitability was evaluated by measuring the before and after grinding on several projects controlled and ground to a specification of 0.0 linear percent, exceeding the 1/8" straightedge tolerance. This data is presented in Table 3. Again it should be noted that this is the new specification under which a SI of 4.5 was anticipated to be achieved.

The ability of the Ames profilograph to serve as a grinding control device was evaluated through data collected on the Interstate 12 construction project. This project was the only project where data were collected during the course of this study that was constructed under an experimental profilograph specification. This specification was structured such that a final profile index of 6 in/mile or less received 100% pay and all bumps exceeding 0.3 inches in 25 feet were to be ground to less than 0.3 inches in 25 feet. The averaged data collected during construction of this Interstate project can also be found in Table 3.

TABLE 3
RESULTS BEFORE AND AFTER GRINDING

PROJECT SPECIFICATION	AVERAGE PROFILE INDEX GRINDING		AVG. MAYS SI GRINDING	
	BEFORE	AFTER	BEFORE	AFTER
Profilograph	11.03	3.63	3.6	3.6
St. Edge	7.67	6.87	3.9	3.9

As indicated in the above table, little if any measurable difference in the average Mays SI or the Profile Index (Ames, 0.2 inch blanking band) was measured on the projects where the roughness was measured and ground according to the rolling straightedge. On the project where the profilograph (Ames, 0.2 inch BB with 0.3 inch bump grinding) was utilized to measure and correct roughness, a considerable decrease in the average PI was measured, yet with no associated increase in average Mays SI.

The reason for the inability to grind a pavement smooth with either device may be due to several of the following reasons:

1. Much of the roughness of a pavement (when characterized or measured by the Mays Ride Meter) may be contained or hidden within the 0.2 inch blanking band used to reduce the profilogram.
2. Grinding the tops off bumps will decrease the PI or Straightedge results but may actually increase the roughness as measured with the Mays Ride Meter.
3. The Mays Ride Meter travels and measures the roughness response of an axle supported in both wheel paths. Grinding control on projects is accomplished through an uncoordinated wheel path basis. Spot grinding a bump in one wheel path without grinding the same associated bump (if the bump extends across both wheel paths) in the adjoining wheel path may again reduce the PI or Straightedge results and may at the same time increase or do nothing to improve the roadway's roughness.

These results illustrate the apparent inability to achieve an SI of anywhere near 4.5 through grinding. They also illustrate that every effort should be made to construct a pavement as smooth as possible and not rely on grinding to correct mistakes.

Location of roughness in JPCC pavements:

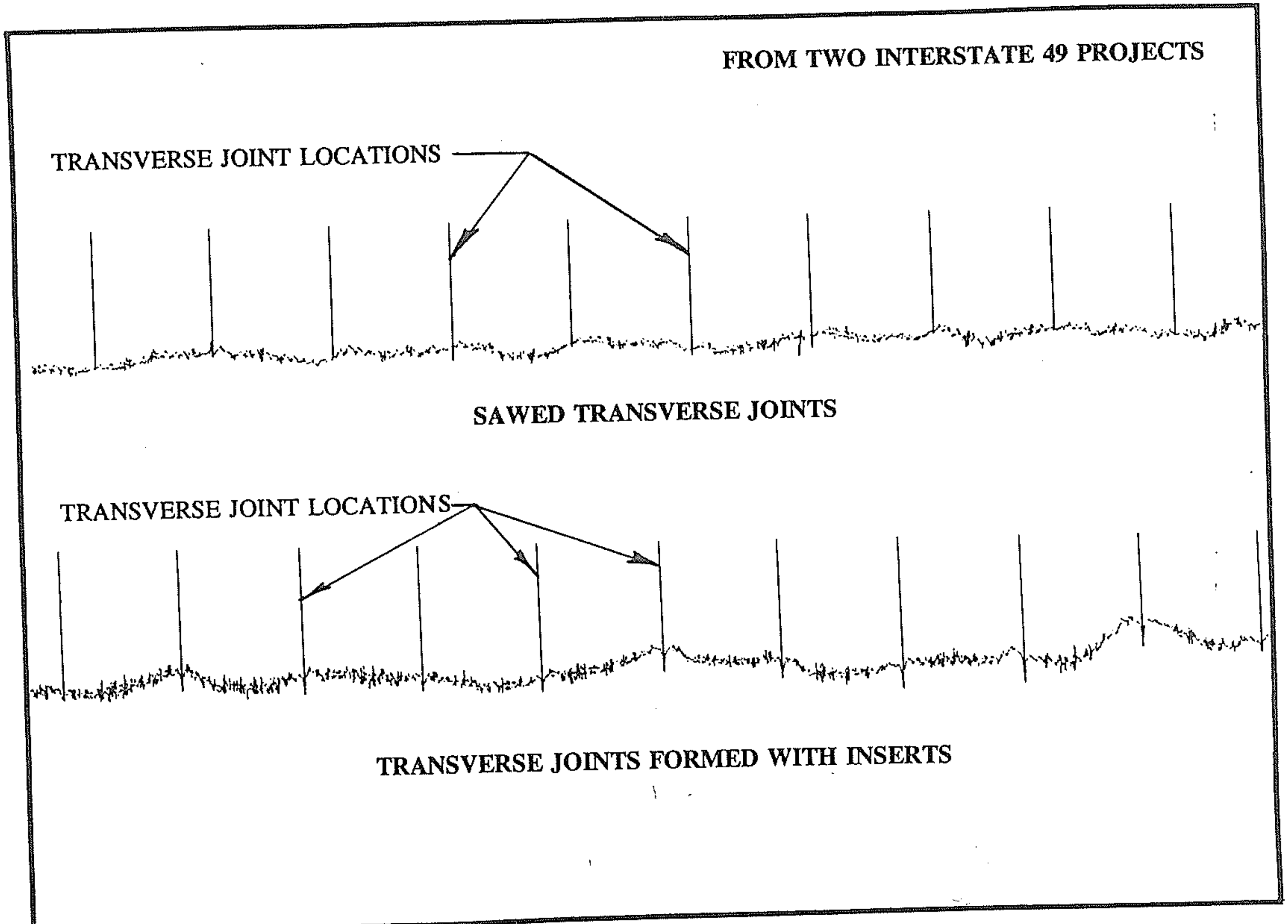
In addition to changing the specification concerning surface tolerance, the LA DOTD at the same time revised its specifications regarding the method of forming transverse joints. This revision was also instituted in an effort to help bring as-built SI levels to 4.5. Prior to this change it was almost a universal practice in the state to form the transverse joints by the insertion of a plastic forming device into the fresh concrete. Once formed, the plastic insert was removed and the joint sealed. This practice was commonplace throughout the state, because of the belief that our only native aggregate, (chert river gravel), was too hard and too difficult and expensive to saw.

It was felt by some that the practice of using plastic inserts created roughness at the joints regardless of the quality of hand finishing. This portion of the study is intended to address the question of whether roughness necessarily occurs at the joints due to the practice of using joint inserts. It is not intended to address every possible contributing factor that may occur, or this factors relationship to roughness.

Figure 4 is a reproduction of a representative portion of an Ames profilograph trace, obtained for two adjoining JPCC paving projects on Interstate 49. The projects were constructed by separate contractors, one of which formed the transverse joint cavity by using plastic inserts and the other by sawing with diamond tipped blades. The sections represented in Figure 4 were identified with the Ride Meter as being among the smoothest 0.2 of a mile section constructed on each project. The vertical lines extending upward from the profile trace are the transverse joint locations. Examination of the profile traces of which Figure 4 is representative indicated no discernable differences in the profile trace that could be attributed to the method of joint formation.

Figure 5 is a reproduction of a profile trace obtained from a newly constructed state highway. On this project the joint cavities were formed both by sawing and by utilizing plastic inserts. Again, no difference in the profile trace at the joint locations can be attributed to the method of formation. It is interesting to note in this Figure there appears to be a particular wavelength associated with this project. It is also interesting that the crest of the wave generally occurs at the transverse joint locations. It is believed that this wavelength is due to the grade string line supports used for the slip-form paver placed at the joint locations on 25 foot centers and that the paver followed a sag in the stringline between supports.

The above examination indicates that the practice of utilizing plastic inserts does not necessarily or automatically create roughness at the transverse joint locations.



FROM TWO INTERSTATE 49 PROJECTS
TRANSVERSE JOINT LOCATIONS
SAWED TRANSVERSE JOINTS
TRANSVERSE JOINT LOCATIONS
TRANSVERSE JOINTS FORMED WITH INSERTS

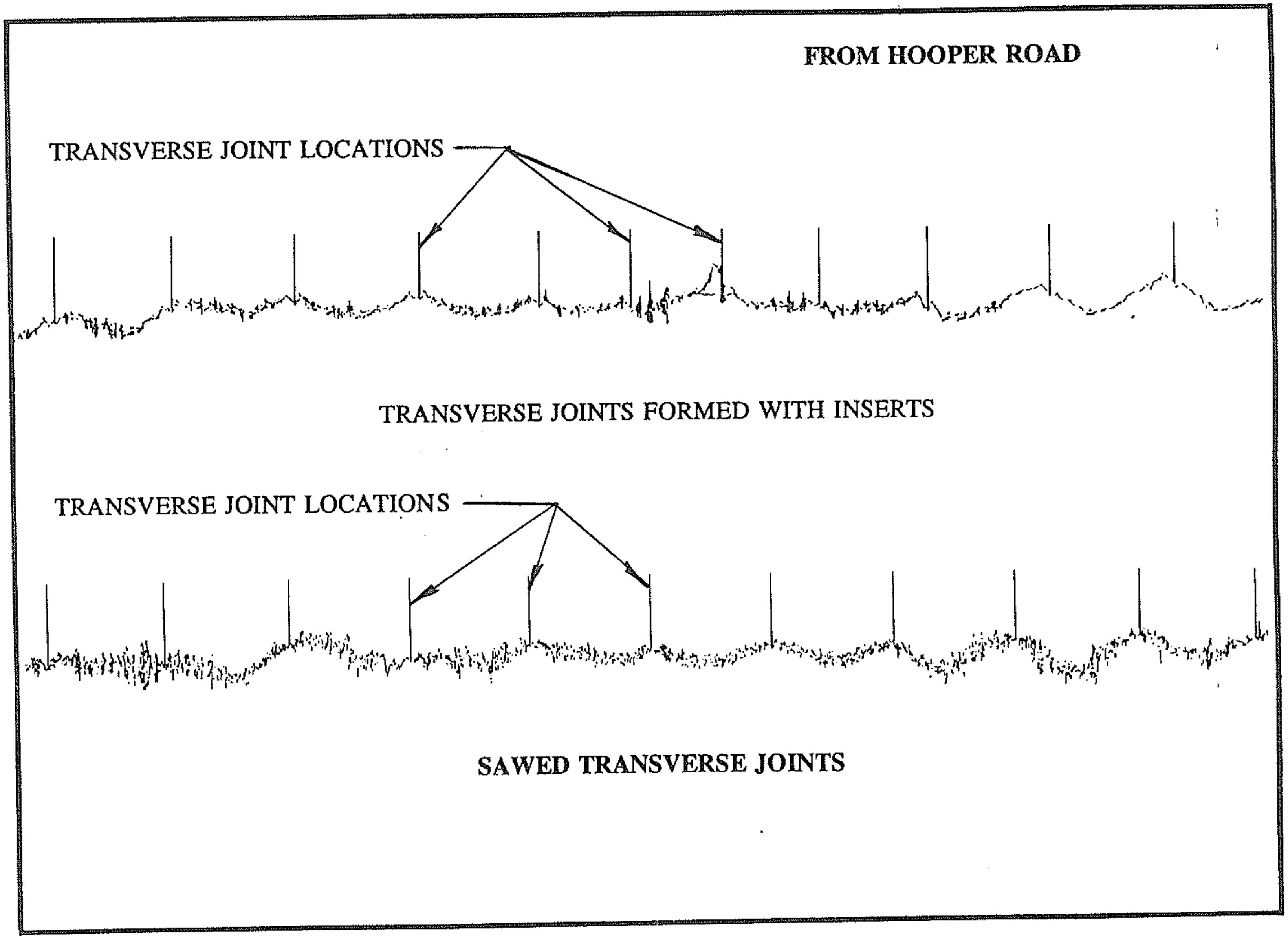


FIGURE 5. Comparison of Sawed and Formed Transverse Joints from One Project.

CONCLUSIONS

The following conclusions are based upon the data and experiences obtained during the course and within the scope of this study:

1. Profilographs due to their design, repeatability and relatively long wheelbase are the best current device available to measure and locate roughness as it occurs on JPCC pavements.

2. The 10-foot rolling straightedge and the Ames and Rainhart profilographs are generally correlatable with the Serviceability Index as determined with the Mays Ride Meter. The observed problems in calibration resulting in a lack of repeatability when using straightedge devices tend to make the profilographs the preferred instrument for construction smoothness monitoring and control.

3. Profilographs are suitable construction control and acceptance devices for surface roughness of newly constructed JPCC pavements. Although relatively mobile, the size and weight of profilographs lend themselves to use on rural interstate and arterial construction rather than urban.

4. The Ames profilograph was found to have greater overall utility than the Rainhart profilograph.

5. Profilographs may be well suited for grinding control due to their repeatability and hard-copy profile trace, yet requirements that allow for grinding a project into specification compliance should be reconsidered.

6. To obtain an initial Serviceability Index level of 4.5, Profile Indexes as determined utilizing a 0.2 inch blanking band must be considerably lower than generally recognized or assumed throughout the United States. Considering existing construction equipment and practices, the majority of recently built projects in Louisiana would require very extensive grinding to obtain or even approach an initial SI of 4.5.

7. Consideration should be given to development of a trace evaluation procedure that does not require the use of a blanking band. Blanking bands may obscure roughness that may greatly affect rideability.

8. The method of transverse joint formation does not necessarily affect roughness at the location of the transverse joint.

RECOMMENDATIONS

The following recommendations should be considered:

1. The LA DOTD should adopt the Ames profilograph as the surface roughness quality control and acceptance tool for JPCC pavements. It is recommended that state wide experience be gained with this device on rural interstate and arterials prior to initiating utilization on urban projects.

2. The LA DOTD should determine and adopt a reasonable target initial SI on JPCC pavements based upon route class, travel speed and location. Acceptance Profile Indexes specification resulting from correlation to the target SI can then be established.

3. Many states currently utilize Profile Indexes (0.2 inch blanking band) for quality control and acceptance of JPCC pavements. These state specifications range from the 20 inch per mile level to the 7 inch per mile level. This study indicates that even the most restrictive of these specifications allows for initial SI's well below 4.5. It is recommended that a national study be conducted to determine expected or generally obtainable as-constructed SI levels based upon route class and location and to recommend target SI and PI levels. A national study could also recommend standard equipment and procedures necessary to determine SI and relate PI and recommend a standard specification for the quality control and acceptance of JPCC pavements.

4. Methods to evaluate profilograms without utilizing blanking bands should be investigated.

5. Methods to increase initial pavement smoothness while severely limiting grinding should be explored.

LIST OF REFERENCES

1. Cumbaa, Steven L., Road Profile Study, Louisiana Transportation Research Center, Report No. 185, February 1986.

2. Janoff, M. S., Nick, J. B., and Davit, P.S., Pavement Roughness and Rideability, National Cooperative Highway Research Program, Report 275, September 1985.

APPENDIX A
PROJECT DATA

TABLE 4-A

PROJECT DATA												
				BEFORE GRINDING				AFTER GRINDING				
LOC	PROJ	LANE	LOT	AMES 0.1" BLANKED	AMES 0.2" BLANKED	MAYS SI	ST/EDGE 1/8" TOLERANCE	RAIN 0.1" BLANKED	AMES 0.1" BLANKED	AMES 0.2" BLANKED	MAYS SI	SPECIFICATION
EBR	I-12,WB	LANE 1	A1			3.4	3.6	25.47				PROFILOGRAPH
EBR	I-12,WB	LANE 1	A2	37.31	20.59	3.8	4	32.56		3.8		PROFILOGRAPH
EBR	I-12,WB	LANE 1	A3	22.53	7.74	3.9	1.7	17.48		5.3	4.1	PROFILOGRAPH
EBR	I-12,WB	LANE 1	A4	12.79	4.87	4.2	1.1	12.2		3.7	3.9	PROFILOGRAPH
EBR	I-12,WB	LANE 1	A5	13.02	2.64	4		9.68		2.3	4	PROFILOGRAPH
EBR	I-12,WB	LANE 1	A6	15.31	4.58	3.8	0.9	15.49		2.8	3.9	PROFILOGRAPH
EBR	I-12,WB	LANE 1	A7			3.9	1.3	16.78		3.8	4	PROFILOGRAPH
EBR	I-12,WB	LANE 1	A8	22.53	7.74	4.2	1.4	11.83		3.7	3.8	PROFILOGRAPH
EBR	I-12,WB	LANE 1	A9	19.36	6.86	3.4	1.4	14.96		4.8		PROFILOGRAPH
EBR	I-12,WB	LANE 1	A10	35.38	19.47	3.5	4.1	27.15		3.4		PROFILOGRAPH
EBR	I-12,WB	LANE 1	A11			3.4	3.7	32.95		3.4		PROFILOGRAPH
EBR	I-12,WB	LANE 1	A12			3.4	3.5	17.1		5.6		PROFILOGRAPH
EBR	I-12,WB	LANE 1	A13			3.6	2.1	32.03		5.4		PROFILOGRAPH
EBR	I-12,WB	LANE 1	A14			3.5	2.9	27.87		5.3		PROFILOGRAPH
EBR	I-12,WB	LANE 1	A15				4.5	20.77		3.5		PROFILOGRAPH
EBR	I-12,WB	LANE 1	A16	13.63	3.37		0	9		4.7		PROFILOGRAPH
EBR	I-12,WB	LANE 2	A1				3.7	28.58				PROFILOGRAPH
EBR	I-12,WB	LANE 2	A2	50.16	32.74	3.1	10.6	46.29		4.3		PROFILOGRAPH
EBR	I-12,WB	LANE 2	A3	31.5	15.84	3.6	2.4	22.53		2.8	4	PROFILOGRAPH
EBR	I-12,WB	LANE 2	A4	20.24	8.62	4	2.4	17.6		6.3	3.9	PROFILOGRAPH
EBR	I-12,WB	LANE 2	A5	18.66	7.92	4	2	16.16		7.2	3.9	PROFILOGRAPH
EBR	I-12,WB	LANE 2	A6	25.52	12.5	3.8	2.6	19.18		3.2	4	PROFILOGRAPH
EBR	I-12,WB	LANE 2	A7			3.6	2.8	22.13		2.9	3.9	PROFILOGRAPH
EBR	I-12,WB	LANE 2	A8	22	10.03	3.8	1.4	15.66		7.6	3.9	PROFILOGRAPH
EBR	I-12,WB	LANE 2	A9	28.51	13.55	4	0.9	19.18	5.2			PROFILOGRAPH

TABLE 4-A (Continued)

PROJECT DATA												
				BEFORE GRINDING				AFTER GRINDING				
LOC	PROJ	LANE	LOT	AMES 0.1" BLANKED	AMES 0.2" BLANKED	MAYS SI	ST/EDGE 1/8" TOLERANCE	RAIN 0.1" BLANKED	AMES 0.1" BLANKED	AMES 0.2" BLANKED	MAYS SI	SPECIFICATION
EBR	I-12,WB	LANE 2	A10	31.68	18.1	3.5	3.1	24.68		4.9		PROFILOGRAPH
EBR	I-12,WB	LANE 2	A11			3.3	3.8	32.1		5.1		PROFILOGRAPH
EBR	I-12,WB	LANE 2	A12			3.4	2.9	24		4.8		PROFILOGRAPH
EBR	I-12,WB	LANE 2	A13			3.3	3.6	28.69		4.2		PROFILOGRAPH
EBR	I-12,WB	LANE 2	A14			3.6	4.8	26.11		3		PROFILOGRAPH
EBR	I-12,WB	LANE 2	A15			3.2	2.9	28.69		6.5		PROFILOGRAPH
EBR	I-12,WB	LANE 2	A16	20.85	8.92		1.7	19.07		6.8		PROFILOGRAPH
EBR	I-12,WB	LANE 3	D2		14.9					4.1		PROFILOGRAPH
EBR	I-12,WB	LANE 3	D3		14.8					4	4.1	PROFILOGRAPH
EBR	I-12,WB	LANE 3	D4		15.1					4.2	4.1	PROFILOGRAPH
EBR	I-12,WB	LANE 3	D5		12.1					3.3	3.9	PROFILOGRAPH
EBR	I-12,WB	LANE 3	D6		6					4.4	3.9	PROFILOGRAPH
EBR	I-12,WB	LANE 3	D7		13.4					4.2	4	PROFILOGRAPH
EBR	I-12,WB	LANE 3	D8							2.1	4	PROFILOGRAPH
EBR	I-12,WB	LANE 3	D9							2.6		PROFILOGRAPH
EBR	I-12,WB	LANE 3	D10							2.1		PROFILOGRAPH
EBR	I-12,WB	LANE 3	D11							5.1		PROFILOGRAPH
EBR	I-12,WB	LANE 3	D12							4.8		PROFILOGRAPH
EBR	I-12,WB	LANE 3	D13							3.2		PROFILOGRAPH
EBR	I-12,WB	LANE 3	D14							5.9		PROFILOGRAPH
EBR	I-12,WB	LANE 4	D2		12.4					4.1		PROFILOGRAPH
EBR	I-12,WB	LANE 4	D3		15.8					4.6	4.1	PROFILOGRAPH
EBR	I-12,WB	LANE 4	D4		15.3					6.5	3.8	PROFILOGRAPH
EBR	I-12,WB	LANE 4	D5		14.1					3	3.8	PROFILOGRAPH

TABLE 4-A (Continued)

PROJECT DATA												
				BEFORE GRINDING				AFTER GRINDING				
LOC	PROJ	LANE	LOT	AMES 0.1" BLANKED	AMES 0.2" BLANKED	MAYS SI	ST/EDGE 1/8" TOLERANCE	RAIN 0.1" BLANKED	AMES 0.1" BLANKED	AMES 0.2" BLANKED	MAYS SI	SPECIFICATION
EBR	I-12,WB	LANE 4	D7		8.5					6.8	4	PROFILOGRAPH
EBR	I-12,WB	LANE 4	D8							2.8	4	PROFILOGRAPH
EBR	I-12,WB	LANE 4	D9							5.1		PROFILOGRAPH
EBR	I-12,WB	LANE 4	D10							3.6		PROFILOGRAPH
EBR	I-12,WB	LANE 4	D11							3		PROFILOGRAPH
EBR	I-12,WB	LANE 4	D12							3.9		PROFILOGRAPH
EBR	I-12,WB	LANE 4	D13							4.6		PROFILOGRAPH
EBR	I-12,WB	LANE 4	D14							5.4		PROFILOGRAPH
EBR	I-12,EB	LANE 1&2	B2		9.27					4.25	3.8	PROFILOGRAPH
EBR	I-12,EB	LANE 1&2	B3		5.98					5.98	3.8	PROFILOGRAPH
EBR	I-12,EB	LANE 1&2	B4		11.62					5.67	3.9	PROFILOGRAPH
EBR	I-12,EB	LANE 1&2	B5		8.31					4.49	3.9	PROFILOGRAPH
EBR	I-12,EB	LANE 1&2	B6		12.23					5.86	3.8	PROFILOGRAPH
EBR	I-12,EB	LANE 1&2	B7		12.44					5.1	3.7	PROFILOGRAPH
EBR	I-12,EB	LANE 1&2	B8		6.48					2.62	4	PROFILOGRAPH
EBR	I-12,EB	LANE 1&2	B9		9.83					3.47	3.8	PROFILOGRAPH
EBR	I-12,EB	LANE 1&2	B10		10.67					5.96	3.6	PROFILOGRAPH
EBR	I-12,EB	LANE 1&2	B11		11.1					5.62	3.4	PROFILOGRAPH
EBR	I-12,EB	LANE 1&2	B12		8.1					4.65	3.6	PROFILOGRAPH
EBR	I-12,EB	LANE 1&2	B13		7.44					5.02	3.7	PROFILOGRAPH
EBR	I-12,EB	LANE 1&2	B14		12.04					5.13	3.7	PROFILOGRAPH
EBR	I-12,EB	LANE 1&2	B15		7.73					4.62	3.7	PROFILOGRAPH
EBR	I-12,EB	LANE 1&2	B16		3.24					3.24		PROFILOGRAPH
EBR	I-12,EB	LANE 3&4	C2		8.78					4.75		PROFILOGRAPH
EBR	I-12,EB	LANE 3&4	C3		6.86					3.22		PROFILOGRAPH

TABLE 4-A (Continued)

PROJECT DATA												
				BEFORE GRINDING				AFTER GRINDING				
LOC	PROJ	LANE	LOT	AMES 0.1" BLANKED	AMES 0.2" BLANKED	MAYS SI	ST/EDGE 1/8" TOLERANCE	RAIN 0.1" BLANKED	AMES 0.1" BLANKED	AMES 0.2" BLANKED	MAYS SI	SPECIFICATION
EBR	I-12,EB	LANE 3&4	C4		5.75					5.75		PROFILOGRAPH
EBR	I-12,EB	LANE 3&4	C5		12.21					3.82		PROFILOGRAPH
EBR	I-12,EB	LANE 3&4	C6		9.24					5.54		PROFILOGRAPH
EBR	I-12,EB	LANE 3&4	C7		16.02					5.57		PROFILOGRAPH
EBR	I-12,EB	LANE 3&4	C8		14.33					3.9		PROFILOGRAPH
EBR	I-12,EB	LANE 3&4	C9		11.48					3.06		PROFILOGRAPH
EBR	I-12,EB	LANE 3&4	C10		10.81					4.5		PROFILOGRAPH
EBR	I-12,EB	LANE 3&4	C11		6.47					5.21		PROFILOGRAPH
EBR	I-12,EB	LANE 3&4	C12		15.39					5.75		PROFILOGRAPH
EBR	I-12,EB	LANE 3&4	C13		13.64					5.92		PROFILOGRAPH
EBR	I-12,EB	LANE 3&4	C14		17.44					5.87		PROFILOGRAPH
EBR	HOOPER	OUTSIDE	1	13.04	5.7							STRAIGHTEDGE
EBR	HOOPER	INSIDE	1	10.27	4.07							STRAIGHTEDGE
EBR	HOOPER	INSIDE	2	15.08	10.89							STRAIGHTEDGE
EBR	HOOPER	OUTSIDE	2	16.97	12.36							STRAIGHTEDGE
EBR	HOOPER	OUTSIDE	3	18.26	12.98							STRAIGHTEDGE
EBR	HOOPER	INSIDE	3	12.76	7.26							STRAIGHTEDGE
CALHOUN	I-20,EB	OUTSIDE	8	15.4	3.8	4			18	6	4	STRAIGHTEDGE
CALHOUN	I-20,EB	INSIDE	8	19	5.7	3.8			19.2	6.8	3.9	STRAIGHTEDGE
CALHOUN	I-20,EB	OUTSIDE	9	9.9	3.33	4.2			13.1	2.7	4.2	STRAIGHTEDGE
CALHOUN	I-20,EB	INSIDE	9	15.6	3.1	4			15.2	4.1	4	STRAIGHTEDGE
CALHOUN	I-20,EB	OUTSIDE	17	26.8	12.1	3.6	1.9		25.5	11.5	3.8	STRAIGHTEDGE
CALHOUN	I-20,EB	INSIDE	17	18.4	7	3.7			17.8	8.4	4	STRAIGHTEDGE
CALHOUN	I-20,EB	OUTSIDE	18	23	7.8	3.8	2.5		17.2	6.8	3.9	STRAIGHTEDGE
CALHOUN	I-20,EB	INSIDE	18	18.8	5.7	3.8			17.6	6.6	3.9	STRAIGHTEDGE

TABLE 4-A (Continued)

PROJECT DATA												
				BEFORE GRINDING				AFTER GRINDING				
LOC	PROJ	LANE	LOT	AMES 0.1" BLANKED	AMES 0.2" BLANKED	MAYS SI	ST/EDGE 1/8" TOLERANCE	RAIN 0.1" BLANKED	AMES 0.1" BLANKED	AMES 0.2" BLANKED	MAYS SI	SPECIFICATION
CALHOUN	I-20,EB	OUTSIDE	19	28.3	13.3	3.6	2.7		27.9	11.9	3.8	STRAIGHTEDGE
CALHOUN	I-20,EB	INSIDE	19	39.4	24.8	3.6			34.8	16	3.7	STRAIGHTEDGE
CALHOUN	I-20,EB	OUTSIDE	20	24	8	4	2.5		24	7	3.9	STRAIGHTEDGE
CALHOUN	I-20,EB	INSIDE	20			3.7			22.8	7.8	3.8	STRAIGHTEDGE
CALHOUN	I-20,EB	OUTSIDE	21	18.8	6.4	4	1.1		22.7	7.8	3.9	STRAIGHTEDGE
CALHOUN	I-20,EB	INSIDE	21	24	10.5	4.1			25.9	9.2	3.9	STRAIGHTEDGE
CALHOUN	I-20,EB	OUTSIDE	12	19.2	6.2		1.4		14.2	3.1		STRAIGHTEDGE
CALHOUN	I-20,EB	INSIDE	12	17.2	2.7				12.9	2.3		STRAIGHTEDGE
CALHOUN	I-20,EB	OUTSIDE	13	19.6	4.1		0.7		16.4	2.7	3.9	STRAIGHTEDGE
CALHOUN	I-20,EB	INSIDE	13	21.2	5.7				16	3.9	3.9	STRAIGHTEDGE
DELHI	I-20,WB	OUTSIDE	26	19.2	5.7	3.7						STRAIGHTEDGE
DELHI	I-20,WB	INSIDE	26	28.7	13.7	3.8						STRAIGHTEDGE
DELHI	I-20,WB	OUTSIDE	27	11.7	1.4	4.1						STRAIGHTEDGE
DELHI	I-20,WB	INSIDE	27	25.5	12.9	3.8						STRAIGHTEDGE
DELHI	I-20,WB	OUTSIDE	28	9.3	1.4	4.2						STRAIGHTEDGE
DELHI	I-20,WB	INSIDE	28	30.9	13.5	3.6						STRAIGHTEDGE
DELHI	I-20,WB	OUTSIDE	29			4						STRAIGHTEDGE
DELHI	I-20,WB	INSIDE	29			3.8						STRAIGHTEDGE
DELHI	I-20,WB	OUTSIDE	30			4.1						STRAIGHTEDGE
DELHI	I-20,WB	INSIDE	30			4.1						STRAIGHTEDGE
DERRY	I-49	IN	1	4.5	0.75	4.56	0					STRAIGHTEDGE
DERRY	I-49	OUT	1	4.5	0.5	4.64	0					STRAIGHTEDGE
DERRY	I-49	IN	2	4.25	0.25	4.55	0					STRAIGHTEDGE
DERRY	I-49	OUT	2	4.75	1	4.45	0					STRAIGHTEDGE
DERRY	I-49	IN	3	8.5	2.75	4.3	1.2					STRAIGHTEDGE

TABLE 4-A (Continued)

PROJECT DATA												
				BEFORE GRINDING				AFTER GRINDING				
LOC	PROJ	LANE	LOT	AMES 0.1" BLANKED	AMES 0.2" BLANKED	MAYS SI	ST/EDGE 1/8" TOLERANCE	RAIN 0.1" BLANKED	AMES 0.1" BLANKED	AMES 0.2" BLANKED	MAYS SI	SPECIFICATION
DERRY	I-49	OUT	3	11	5	4.4	1.4					STRAIGHTEDGE
DERRY	I-49	IN	4	17.75	10.5	4.1	2.1					STRAIGHTEDGE
DERRY	I-49	OUT	4	15.5	5.25	4.3	1.8					STRAIGHTEDGE
S.DERRY	I-49	OUT	5	9.24	3.3	4.25	0.9					STRAIGHTEDGE
S.DERRY	I-49	IN	1	9	2.75	4.5	0					STRAIGHTEDGE
S.DERRY	I-49	OUT	1	10	3.5	4.3	0.4					STRAIGHTEDGE
S.DERRY	I-49	IN	2	11.75	5.5	4.5	0.7					STRAIGHTEDGE
S.DERRY	I-49	OUT	2	14.5	6.75	4.3	0.9					STRAIGHTEDGE
RAPIDES	I-49		100		6.6							STRAIGHTEDGE
RAPIDES	I-49		101		2.4							STRAIGHTEDGE
RAPDES	I-49		102		1.8	4.3						STRAIGHTEDGE
RAPIDES	I-49		103		2	4.25						STRAIGHTEDGE
RAPIDES	I-49		104		2.9	4.2						STRAIGHTEDGE
RAPIDES	I-49		105		1.2	4.25						STRAIGHTEDGE
RAPIDES	I-49		106		5.2	4.05						STRAIGHTEDGE
RAPIDES	I-49		107		1.8	4.25						STRAIGHTEDGE
RAPIDES	I-49		108		2	4.3						STRAIGHTEDGE
RAPIDES	I-49		109		1.5	4.25						STRAIGHTEDGE
RAPIDES	I-49		110		3.4	4.2						STRAIGHTEDGE
RAPIDES	I-49		111		4.5	4.1						STRAIGHTEDGE
RAPIDES	I-49		112		4.6	4.1						STRAIGHTEDGE
RAPIDES	I-49		113		4.7	4.15						STRAIGHTEDGE
RAPIDES	I-49		114		5.4							STRAIGHTEDGE
RAPIDES	I-49		115		13.7							STRAIGHTEDGE
[illegible]	[illegible]		[illegible]		[illegible]							STRAIGHTEDGE

TABLE 4-A (Continued)

PROJECT DATA												
				BEFORE GRINDING				AFTER GRINDING				
LOC	PROJ	LANE	LOT	AMES 0.1" BLANKED	AMES 0.2" BLANKED	MAYS SI	ST/EDGE 1/8" TOLERANCE	RAIN 0.1" BLANKED	AMES 0.1" BLANKED	AMES 0.2" BLANKED	MAYS SI	SPECIFICATION
RAPIDES	I-49		117		3.7	4.2						STRAIGHTEDGE
RAPIDES	I-49		118		2.2	4.2						STRAIGHTEDGE
RAPIDES	I-49		119		2.4							STRAIGHTEDGE
RAPIDES	I-49		120		0.7	4.15						STRAIGHTEDGE
RAPIDES	I-49		121		2.9	4.1						STRAIGHTEDGE
RAPIDES	I-49		122		3.6	4.1						STRAIGHTEDGE
RAPIDES	I-49		123		3.6	4.1						STRAIGHTEDGE
RAPIDES	I-49		124		4.1	4.3						STRAIGHTEDGE
RAPIDES	I-49		125		0.5	4.4						STRAIGHTEDGE
RAPIDES	I-49		126		0.7	4.45						STRAIGHTEDGE
RAPDES	I-49		127		1.4	4.3						STRAIGHTEDGE
RAPIDES	I-49		128		2.9	4.2						STRAIGHTEDGE
RAPIDES	I-49		129		5.7							STRAIGHTEDGE
RAPIDES	I-49		130		10.3							STRAIGHTEDGE
RAPIDES	I-49		131		6.4							STRAIGHTEDGE
RAPIDES	I-49		132		4.8							STRAIGHTEDGE
RAPIDES	I-49		133		1.2							STRAIGHTEDGE
RAPIDES	I-49		134		8							STRAIGHTEDGE
RAPIDES	I-49		135		3.8							STRAIGHTEDGE
RAPIDES	I-49		136		7							STRAIGHTEDGE
RAPIDES	I-49		137		4.8							STRAIGHTEDGE
RAPIDES	I-49		138		3.5							STRAIGHTEDGE
RAPIDES	I-49		139		5.6							STRAIGHTEDGE
RAPIDES	I-49		140		5.8							STRAIGHTEDGE
RAPIDES	I-49		141		6.6							STRAIGHTEDGE

TABLE 4-A (Continued)

PROJECT DATA												
				BEFORE GRINDING				AFTER GRINDING				
LOC	PROJ	LANE	LOT	AMES 0.1" BLANKED	AMES 0.2" BLANKED	MAYS SI	ST/EDGE 1/8" TOLERANCE	RAIN 0.1" BLANKED	AMES 0.1" BLANKED	AMES 0.2" BLANKED	MAYS SI	SPECIFICATION
RAPIDES	I-49		142		6.7							STRAIGHTEDGE
RAPIDES	I-49		143		8							STRAIGHTEDGE
RAPIDES	I-49		144		8.4							STRAIGHTEDGE
RAPIDES	I-49		145		1.8							STRAIGHTEDGE
RAPIDES	I-49		146		4.3							STRAIGHTEDGE
RAPIDES	I-49		147		4.3							STRAIGHTEDGE
RAPIDES	I-49		148		4.9							STRAIGHTEDGE
RAPIDES	I-49		149		2.8							STRAIGHTEDGE
RAPIDES	I-49		150		6.4							STRAIGHTEDGE
RAPIDES	I-49		151		0.6							STRAIGHTEDGE
RAPDES	I-49		152		4.1							STRAIGHTEDGE
RAPIDES	I-49		153		4							STRAIGHTEDGE
RAPIDES	I-49		154		8.1							STRAIGHTEDGE

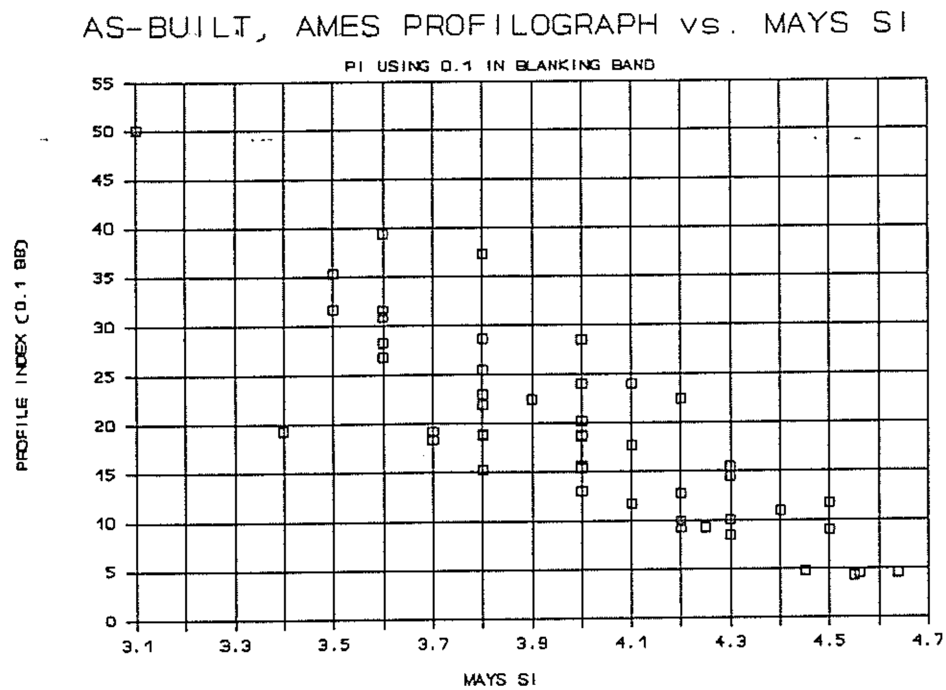


FIGURE 1-A

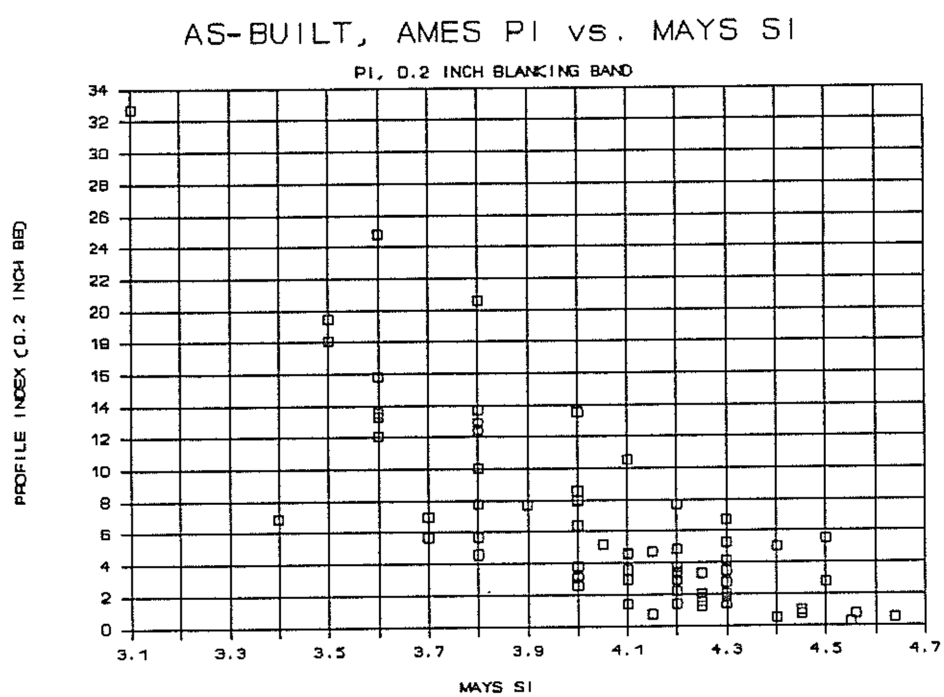


FIGURE 2-A

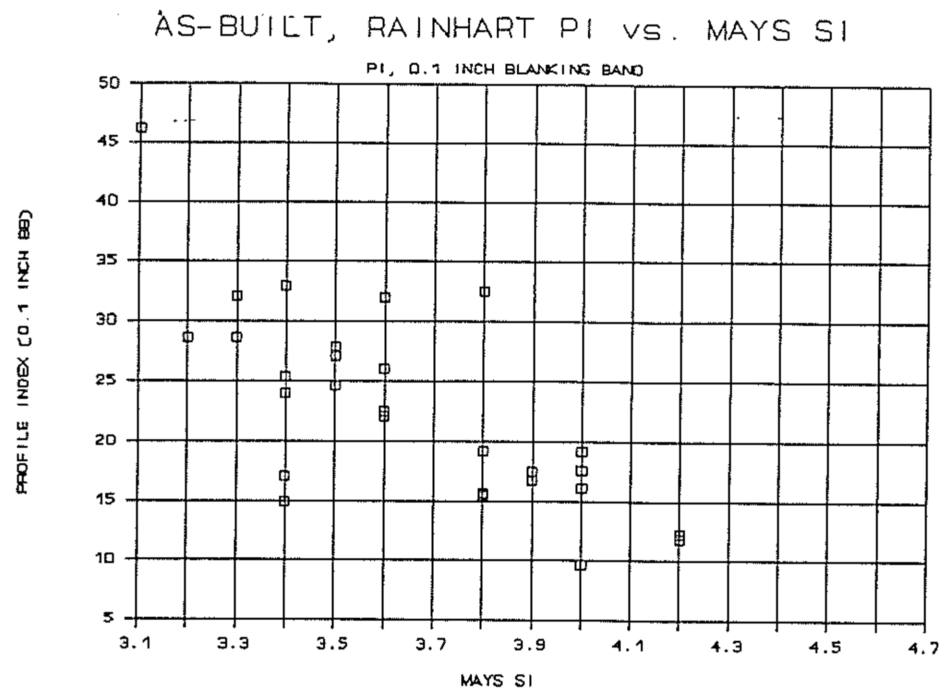


FIGURE 3-A

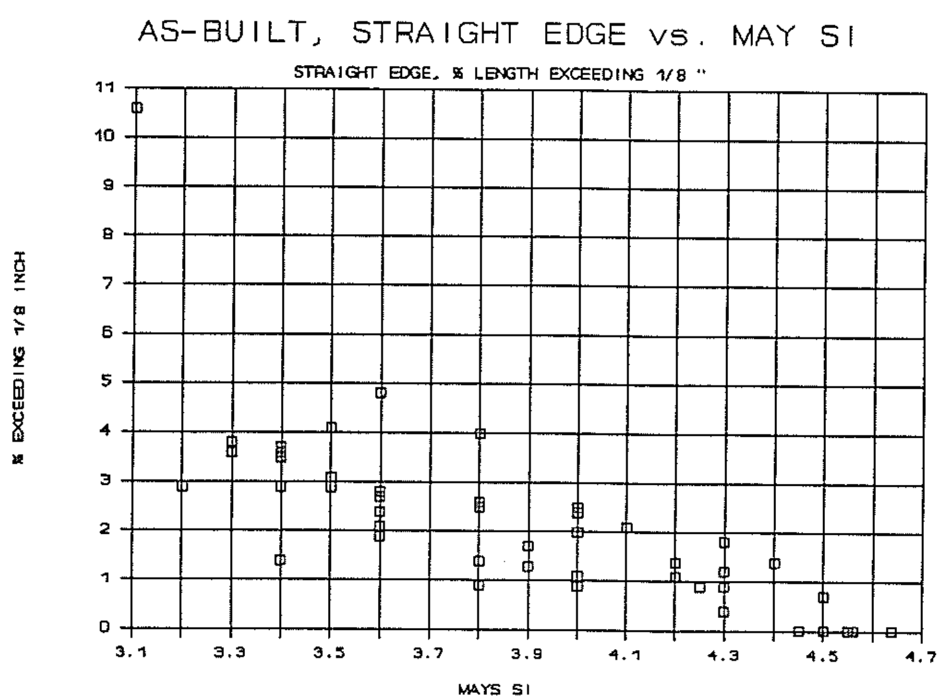


FIGURE 4-A

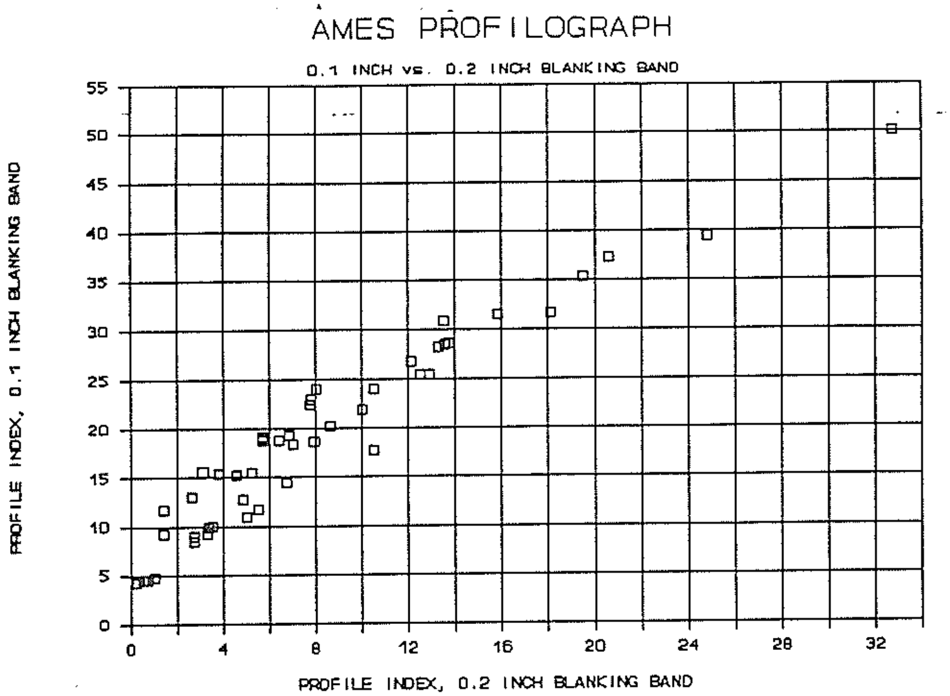


FIGURE 5-A

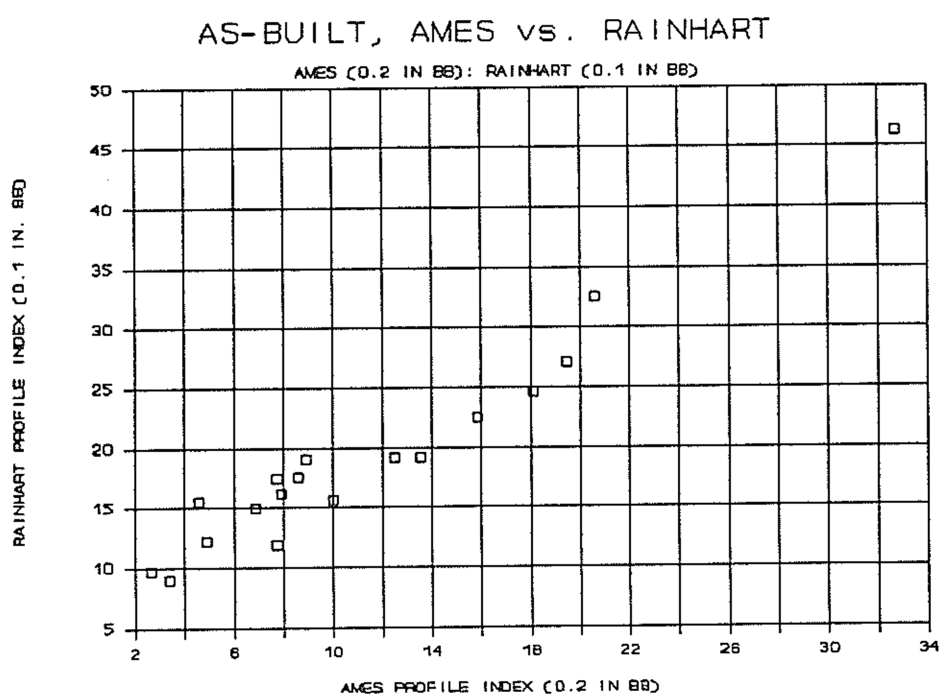


FIGURE 6-A

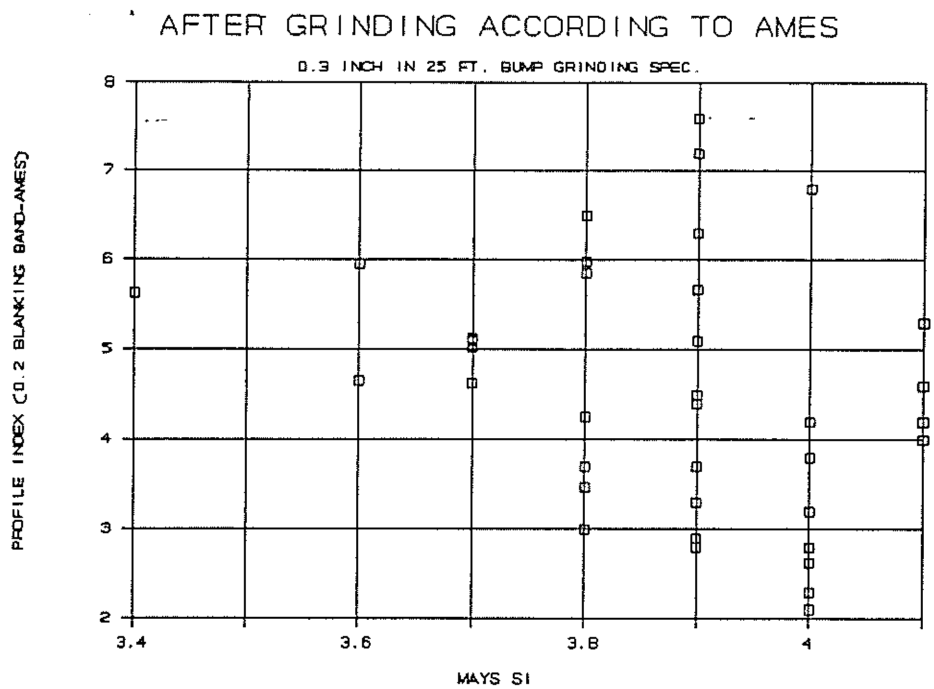


FIGURE 7-A

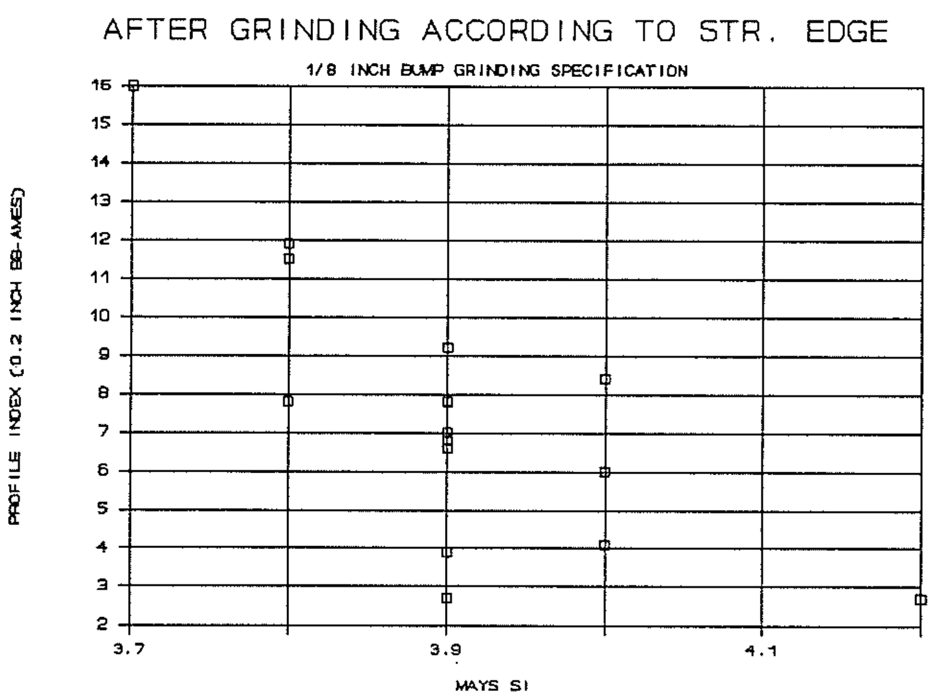


FIGURE 8-A

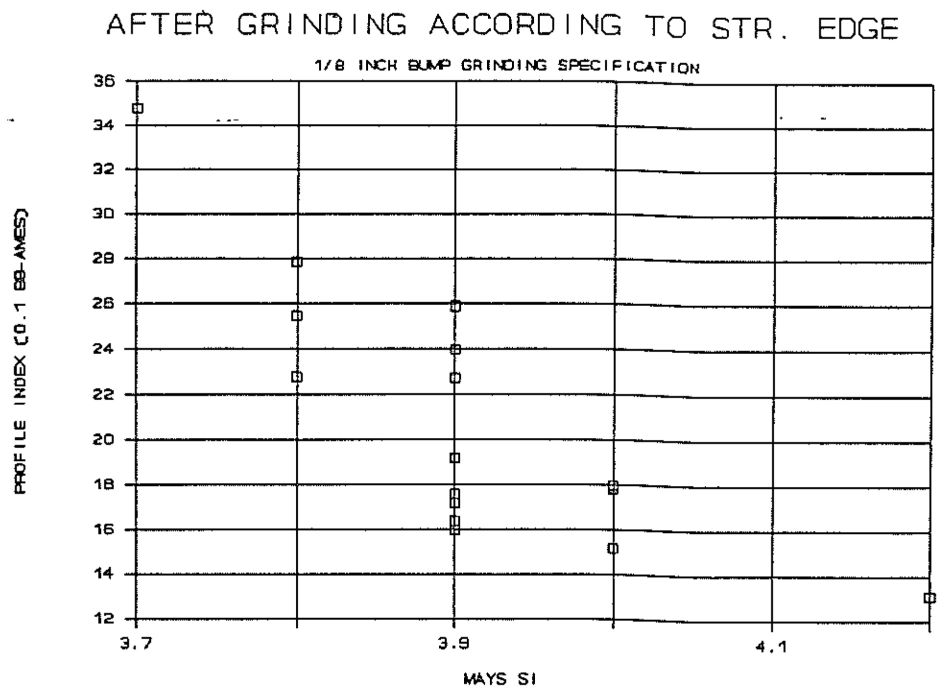


FIGURE 9-A

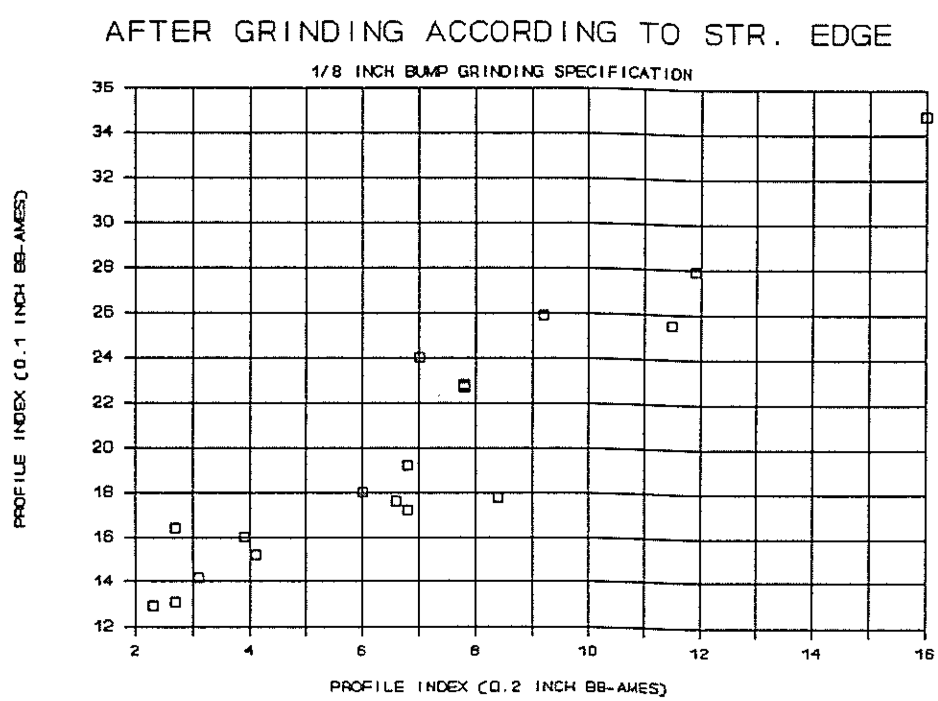


FIGURE 10-A

APPENDIX B

PAVEMENT ROUGHNESS AND PROFILOGRAPH SPECIFICATIONS REPORT

PAVEMENT ROUGHNESS AND PROFILOGRAPH SPECIFICATIONS

REPORT

By

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For

LOUISIANA DEPARTMENT OF TRANSPORTATION
AND DEVELOPMENT

JUNE, 1991

OBJECTIVE:

This report was written in an effort to concisely summarize and document the current status or body of knowledge as related to pavement roughness and pavement roughness construction specifications.

SCOPE:

The scope of this work is limited to the examination of existing research results by LTRC which are based on Louisiana pavements. Data from the TSD Hwys and the AASHO Road Test has been included for comparison.

INTRODUCTION:

Highway pavement roughness has been measured and evaluated for many years. The AASHO Road Test introduced the concept of measured roughness as related to the public perception of quality of ride or serviceability. Since the Road Test, serviceability has become a pavement design variable and has been routinely estimated or measured to determine as-built smoothness of projects and network condition.

Typically the roughness that the public "feels" is different for HMAC and JPCC pavements, with newly constructed HMAC pavement roughness composed of roughness with a longer wavelength than that of JPCC.

DISCUSSION/PANEL ESTIMATION AND MEASUREMENT OF SERVICEABILITY

Correlations between the perception of a panel of raters of pavement serviceability and the AASHO profilometer measured summary roughness statistic slope variance (SV) was developed at the AASHO Road Test. For new construction the relationships are as follows:

For HMAC Pavements,

Serviceability Index (SI) = 5.03 - 1.91 log(1+SV)

For JPCC Pavements,

Serviceability Index (SI) = 5.41 - 1.80 log(1+SV)

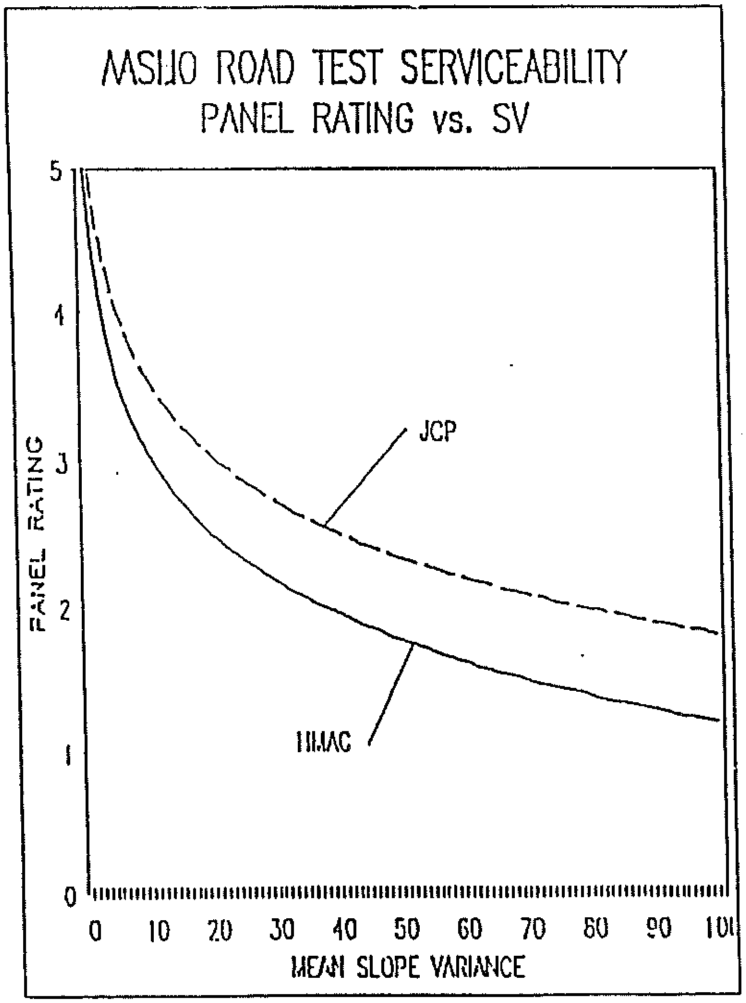
These two Road Test equations are presented graphically in Figure 1. The relationships developed indicate that at the same measured level of roughness a panel will rate a JPCC Pavement better than HMAC; or conversely for pavements with the same panel rating a HMAC Pavement will contain less measured roughness than the JPCC Pavement.

In 1986 through LDOTD's participation in a national study (NCHRP I-23) LTRC was able to verify that a panel will rate the serviceability of a HMAC Pavement differently than that of a JPCC Pavement even though they contain the same degree of measured roughness.

The AASHO Profilometer has been superseded by various roughness measuring equipment such as the Chloe Profilometer, the BPR Roughometer, the Mays Ride Meter and the Inertial Profilometer. Historically LDOTD utilized the calibrated Mays Ride Meter to characterize pavement roughness. Relationships between the Mays Ride Meter roughness statistic in/mile and SI have been developed and verified for both HMAC and JPCC Pavements. These relationships are presented graphically in Figure 2.

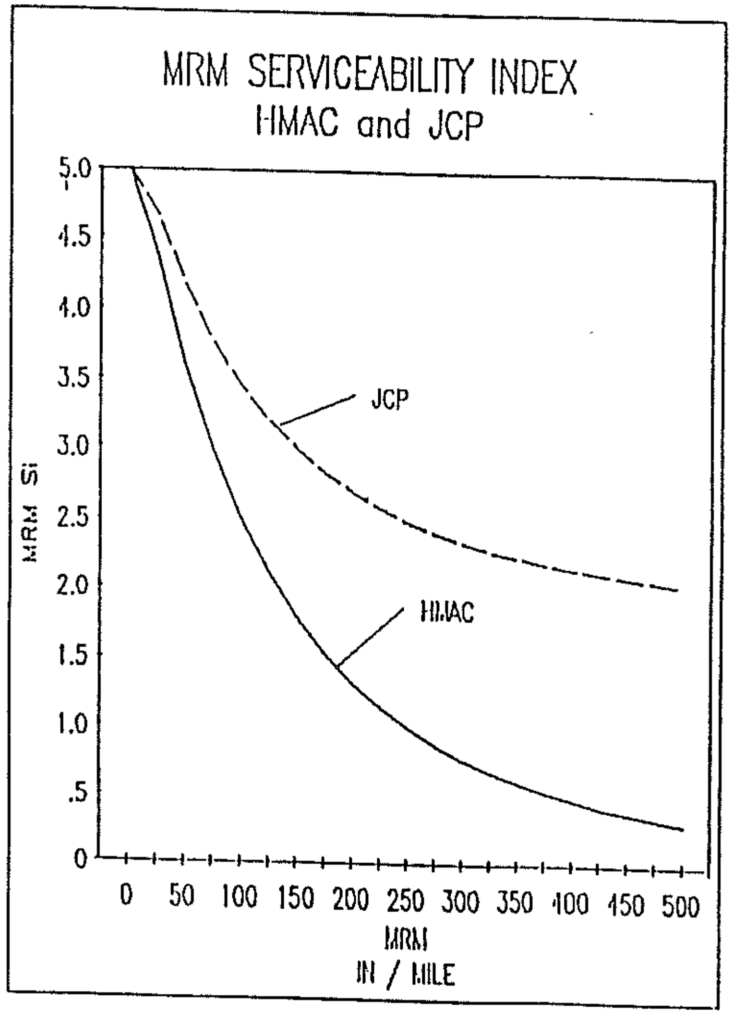
Texas has recently completed studies comparing the SI obtained with the Surface Dynamics Profilometer and the Profile Index (PI) obtained with the California Style Profilograph. Figure 3 graphically presents the results of this evaluation. It is again evident that measured roughness and its relationship to the estimate of a pavements serviceability varies with pavement type.

LTRC has historically utilized the Mays Ride Meter to develop relationships between SI and other measures of roughness such as that obtained from the 10-foot rolling straightedge and the Rainhart and California style profilographs. The California style Ames Profilograph has recently been selected by LDOTD as the instrument to be utilized for new construction quality control and acceptance for both HMAC and JCPP Pavements. LTRC data between the Mays Ride



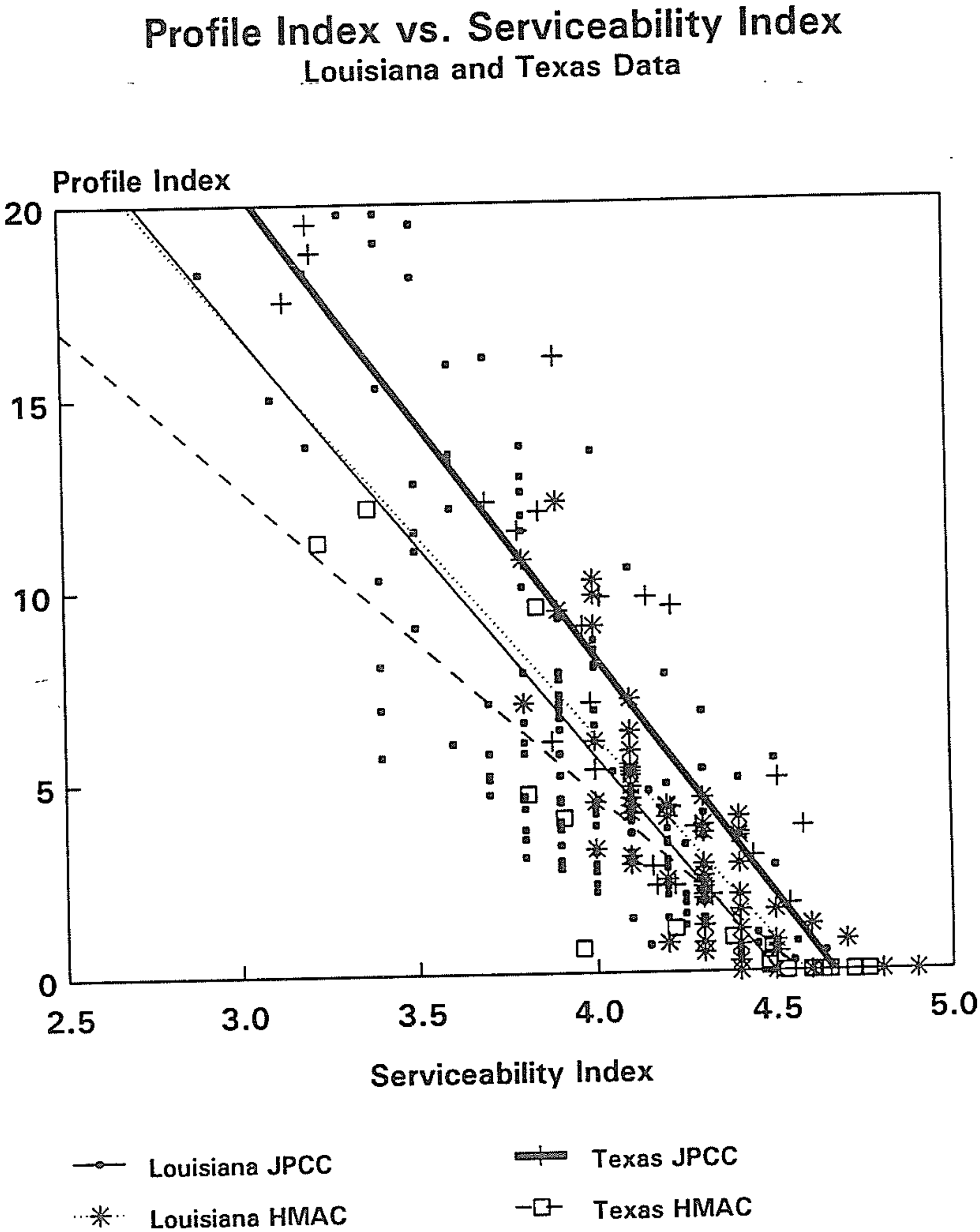
Panel Rating Versus Slope Variance for Rigid and Flexible Pavements -- AASHO Road Test

FIGURE 1



Mays Ride Meter (In/Mile) Versus SI for Rigid and Flexible Pavements -- Louisiana

FIGURE 2



Profile Index vs. Serviceability Index
Louisiana and Texas Data
Profile Index
20
15
10
5
0
2.5
3.0
3.5
4.0
4.5
5.0
Serviceability Index
Louisiana JPCC
Louisiana HMAC
Texas JPCC
Texas HMAC

FIGURE 3

Meter and the Ames Profilograph are also presented in Figure 3. General data trends agree with the trends developed in Texas. It is believed that the Texas data is the more precise of the two data sets because of the greater repeatability and sensitivity of the Texas Inertial Profilometers as compared to that of the Mays Ride Meter.

DISCUSSION/PAVEMENT DESIGN BASED UPON SERVICEABILITY CONCEPT

LDOTD utilizes the AASHTO design for highway pavements. This design methodology is based upon the concept that highways are initially constructed at a high level of serviceability and through time and loading lose serviceability to the point that they require corrective actions. The current LDOTD pavement design is based upon pavements being constructed to at least an SI level of 4.3. The design methodology indicates that pavements constructed to levels higher than 4.3 will last longer and carry more loading than expected. The other side of the coin is that pavements constructed at levels less than 4.3 will not last as long since they will reach a terminal serviceability level sooner, prior to carrying design loading.

DISCUSSION/DATA ANALYSIS

LTRC and LDOTD have been collecting Ames Profilograph data on test sections from construction projects for several years. Appendix A and B presents data and project listings, summary statistics and graphical data presentation obtained from 107 HMAC and 242 JPCC test sections.

The statistics for both JCPP and HMAC construction indicate that wide variations in the as constructed profile index are common and these variations exist across all types of construction and even within individual projects. Figure 4 presents the frequency distribution for randomly tested sections of multi-lift HMAC and JPCC pavements. The data presented in this figure indicates that the occurrence of lower Profile Indices is more prevalent for HMAC than for JPCC pavements. Other trends that are evident are as follows:

1. Lower PI values and lower mean PI values were obtained on Interstate type JPCC construction than on urban type JPCC construction. Maximum PI values were found to be near the same level regardless of construction type.

2. Lower PI values and lower mean PI values were obtained on multi-lift HMAC construction than on single lift HMAC construction. Maximum PI values were found to be less on multi-lift construction (new or overlay) than on single lift construction.

3. The mean PI value (3.93) for multi-lift HMAC construction is less than the mean PI value (6.51) for Interstate type JPCC construction.

4. The mean PI value (9.08) for single lift HMAC construction is less than the mean PI value (17.51) for urban type JPCC construction.

5. For JPCC pavements the maximum PI value (32.74) was found to occur on an Interstate type JPCC pavement. For HMAC construction the maximum PI value (23.6) was recorded for a binder course of a multi-lift HMAC overlay project.

6. From the data collected it is evident that under current Louisiana specification HMAC pavements are typically paved smoother than JPCC pavements.

DISCUSSION/CONSTRUCTION ACCEPTANCE SPECIFICATIONS

There are three primary reasons that LDOTD requires smooth pavements to be constructed. The first reason is that in the traveling public's point of view a successful paving construction project is one that among other factors is smooth, providing a comfortable ride. A second reason, as mentioned earlier, is the fact that current design procedures require a newly constructed facility to have an initially high SI such that the pavements can carry their design loading over their design life. The third primary reason for requiring a smooth pavement is an indirect one in that a smooth paving project is one that generally necessitates high quality, consistent and effective paving practices.

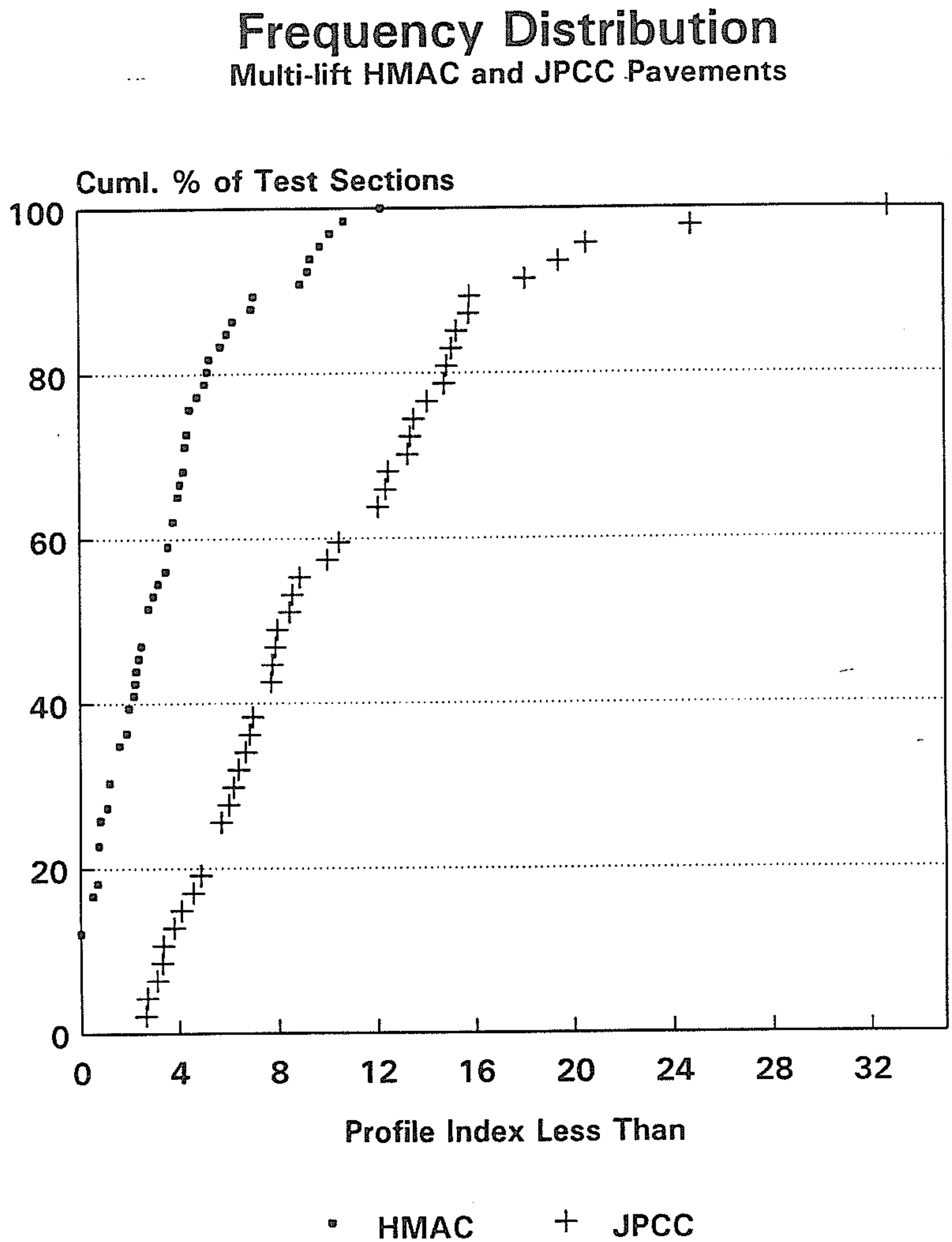

Frequency Distribution
Multi-lift HMAC and JPCC Pavements
Cuml. % of Test Sections
100
80
60
40
20
0
0
4
8
12
16
20
24
28
32
Profile Index Less Than
HMAC
JPCC

FIGURE 4

As can be seen in Figure 3, Louisiana data indicates that to achieve the target SI value of 4.3, JPCC and HMAC Pavement should be constructed to a Profile Index (PI) of approximately 3.0 inches/mile. According to the more precise Texas data, HMAC and JPCC pavements would have to be constructed to PI levels of approximately 3.0 and 5.0 inches/mile respectively to achieve the target SI value of 4.3. Based upon the more precise Texas data set, the general agreement between Texas and Louisiana data and the prevalence of and trend towards lower PI values on HMAC pavements in relation to JPCC pavements, it is our opinion that realistic target PI values of 3.0 in/mile for HMAC and 5.0 in/mile for JPCC are appropriate on construction projects. These (PI) values should be specified on all paving projects except where other considerations make achieving these values virtually impossible. Examples of other considerations are such things as urban, discontinuous paving and single lift construction.

Many states are applying both positive and negative payment adjustments for pavements constructed outside the specified target PI range. These payment adjustments are instituted to provide incentives for contractors to take the required care and efforts to construct a smooth pavement with little if any corrective actions. If the LDOTD chooses not to apply positive payment adjustments (incentives) then the target PI values would still be applicable.

<u>RECOMMENDED PROFILOGRAPH SPECIFICATION INDICES/JPCC PAVEMENT</u>:

MAIN TRAVELED (TRAFFIC) LANES;

For purposes of this discussion the following designations shall apply:

1. Type A Paving - Paving projects or portions of paving projects consisting of construction of traffic lanes(s) typified by larger (in length) projects amendable to relatively continuous paving by slip-form paving methods.

2. Type B Paving - Paving projects or portions of paving projects consisting of construction of traffic lane(s) typified by urban projects, not amendable to continuous paving operations, generally requiring split-slab construction techniques.

NOTE: The primary factors believed to influence the profile index is the roughness inherent to various degrees in the normal paving process and the roughness at construction joints. No correlation has yet been found between the number of catchbasins contained within a lot and the profile index.

JOINTED PORTLAND CEMENT CONCRETE

PAVING TYPE	TARGET PI (in/mile/lot)	BUMP LIMIT (inches/25 ft.)
Type A	4.1 to 6.0	0.3
Type B	8.1 to 12.0	0.4

PAY ADJUSTMENT (PER LOT)	PROFILE INDEX Type A	Type B
102 %	0.0 to 4.0	0.0 to 8.0
100 %	4.1 to 6.0	8.1 to 12.0
95 %	6.1 to 10.5	12.1 to 18.0
90 %	10.6 to 14.0	18.1 to 26.0
CORRECT OR REMOVE	> 14.0	> 26.0

COMMENTS:

1. Incentive pay adjustments apply only to as-built PI. No grinding allowed to increase pay adjustment greater than 100%.

2. The 0.4" bump limit for Type B paving, as defined above, applies to all wheelpath bumps encountered during profilograph testing including manholes, catchbasin deviations and intersection blockouts. If 0.4" bump limit is exceeded and cannot be satisfactorily corrected the pavement in that area shall be removed and replaced with pavement meeting the 0.4" bump specification.

3. The 0.3" bump limit for Type A paving as defined above applies to all wheelpath bumps encountered during profilograph testing including manholes, catchbasins and intersection blockouts. If the 0.3" bump limit is exceeded and cannot be satisfactorily corrected the pavement in that area shall be removed and replaced with pavement meeting the 0.3" bump specification.

4. Each project may contain paving lots subject to different profilograph specifications depending upon the primary type of paving within that lot. Lot limits and designated paving type should be identified during the plan-in-hand review or other appropriate planning stage.

RECOMMENDED PROFILOGRAPH SPECIFICATION INDEXES/HMAC PAVEMENTS

MAIN TRAVELED (TRAFFIC) LANES;

For purposes of this discussion the following designation shall apply:

Type A Paving - Projects or portions of projects consisting of multi-lift structural HMAC construction.

Type B Paving - Projects or portions of projects consisting of single-lift structural HMAC construction.

STRUCTURAL HOT MIX ASPHALTIC CONCRETE

PAVING TYPE	TARGET PI in/mile/lot)	BUMP LIMIT (inches/25 ft.)
Type A	2.1 to 4.0	0.3
Type B	4.1 to 10.0	0.4

PAY ADJUSTMENT (PER LOT)	PROFILE INDEX Type A	Type B
102 %	0.0 to 2.0	0.0 to 4.0
100 %	2.1 to 4.0	4.1 to 10.0
95 %	4.1 to 8.0	10.1 to 15.0
90 %	8.1 to 12.0	15.1 to 20.0
CORRECT OR REMOVE	> 12.0	> 20.0

COMMENTS:

1. Incentive pay adjustments apply only to as-built PI. No corrections allowed to increase pay adjustment greater than 100%.

2. The 0.4" bump limit for Type B paving as defined above, applies to all wheel path bumps encountered during profilograph testing including manholes, catchbasin deviations etc. If 0.4" bump limit is exceeded and cannot be satisfactorily corrected the pavement in that area shall be removed and replaced with pavement meeting the 0.4" bump specification.

3. The 0.3" bump limit for Type A paving as defined above applies to all wheelpath bumps encountered during profilograph testing including manholes, catchbasins etc. If the 0.3" bump limit is exceeded and cannot be satisfactorily corrected the pavement in that area shall be removed and replaced within pavement meeting the 0.4" bump specification.

4. Each project may contain lots subject to different profilograph specifications depending upon the primary type of paving within that lot. Lot limits and designated paving type must be identified in plans.

5. Profilograph specifications only apply to structural HMAC pavement applications.

It is understood that the California Style Profilograph is the best available instrument for construction control and acceptance at this time. Although it is the best instrument available, it has its shortcomings. Research will continue on problems associated with data reduction from the profile trace and the subsequent analysis of this data. It is anticipated that the above recommended specification limits will change with time. The above specification limits are considered to be somewhat more stringent than those of any other state agencies at this time; however it has been demonstrated that the indicated smoothness levels can be readily obtainable by the construction community when care and good construction practices are exercised.

APPENDIX A

DATA PRESENTATION / HOT MIX ASPHALTIC CONCRETE

ASPHALT CONSTRUCTION - District 02

PROJECT	CONSTRUCTION TYPE	SECTION	TEST SECTION NUMBER	ORIGINAL SURFACE PI	MILLED PI	LIFT 1ST PI	LIFT 2ND PI	LIFT 3RD PI	LIFT 4TH PI	LIFT 5TH PI
La. 3127	new construction	8" limestone	1						0.7	
428-03-10		2" Type 5A base	2						1.1	
		4" binder	3						1.6	
		1.5" wearing								
U.S. 90	mill/2 lift overlay	2" binder	1				2.4			
05-07-39		1.5" wearing	2				1.2			
			3				2.0			

ASPHALT CONSTRUCTION District 03

PROJECT	CONSTRUCTION TYPE	SECTION	TEST SECTION NUMBER	ORIGINAL SURFACE PI	MILLED PI	LIFT 1ST PI	2ND PI	3RD PI	4TH PI	5TH PI
La. 330	in-place cement stab.	1.5" binder	1				2.8			
397-01-09	base course/2 lift	1.5" wearing	2				6.0			
			3				4.5			
La. 668	existing HMAC/2 lifts	2" binder	1	32.5		17.2	9.7**			
399-01-03		1.5" wearing	2	12.6		8.6	1.6			
			3	17.8		6.8	4.1			
La. 85	existing HMAC patched	2.5" binder	1	25.9		17.5	4.8			
236-02-10	& widened/2 lifts	1.5" wearing	2*	20.3		23.6	6.5			
			3	29.4		23.6	9.0			

* Railroad X (400' excluded)
** In Curve

ASPHALT CONSTRUCTION - District 04

PROJECT	CONSTRUCTION TYPE	SECTION	TEST SECTION NUMBER	ORIGINAL SURFACE PI	MILLED PI	LIFT 1ST PI	LIFT 2ND PI	LIFT 3RD PI	LIFT 4TH PI	LIFT 5TH PI
La. 787	in-place cement stab.	2" binder	1			7.1	6.1			
841-03-06	base course/2 lift	1.5" wearing	2			6.6	4.6			
			3			9.9	7.7			
U.S. 79	existing HMAC/1 lift	2" wearing	1	9.2		3.5				
27-06-12	overlay		2	9.4		4.5				
			3	9.3		2.5				
U.S. 171	mill/2 lift overlay	2" binder	1	10.1			2.6			
25-07-14		1.5" wearing	2	29.6			2.9			
			3	41.2			4.2			
La. 175	existing HMAC/2 lift	2" binder	1	15.1		10.5	4.2			
35-03-17		1.5" wearing	2	17.7		10.7	3.5			
			3	6.4		5.0	3.8			

ASPHALT CONSTRUCTION District 05

PROJECT	CONSTRUCTION TYPE	SECTION	TEST SECTION NUMBER	ORIGINAL SURFACE PI	MILLED PI	1ST PI	2ND PI	3RD PI	4TH PI	5TH PI
La. 499	in-place cement stab.	2" binder	1				3.9			
126-03-10	base course/2 lifts	1.5" wearing	2				5.4			
			3				5.0			

ASPHALT CONSTRUCTION - District 07

PROJECT	CONSTRUCTION TYPE	SECTION	TEST SECTION NUMBER	ORIGINAL SURFACE PI	MILLED PI	LIFT 1ST PI	LIFT 2ND PI	LIFT 3RD PI	LIFT 4TH PI	LIFT 5TH PI
La. 27	in-place cement	1.5" binder	1				7.1			
31-09-27	stabilized base course/	1.5" wearing	2				10.2			
	2 lift		3				9.4			
La. 108	existing pavement	2" binder	1	43.7		11.5	4.4			
192-02-05	patched 2 lift overlay	1.5 wearing	2	30.9		9.1	5.2			
			3	28.0		7.4	4.1			
La. 3059	existing pavement	2" binder	1	21.0		3.6	0.8			
383-01-09	2 lift overlay	1.5 wearing	2	14.2		3.2	1.6			
			3	21.0		3.0	0.8			

ASPHALT CONSTRUCTION - District 08

PROJECT	CONSTRUCTION TYPE	SECTION	TEST SECTION NUMBER	ORIGINAL SURFACE PI	MILLED PI	1ST PI	2ND PI	3RD PI	4TH PI	5TH PI
La. 6	existing pavement	2" binder	1	13.4			1.2			
34-05-24	patched 2 lift overlay	1.5" wearing	2	22.8			4.0			
			3	63.8			3.6			
La. 113	in-placement stabilized	1.5" binder	1				5.1			
140-02-11	base course/2 lift	1.5" wearing	2				3.6			
			3				9.8			
La. 117	existing pavement	2" binder	1	40.6		12.0	10.2			
114-03-18	patched 2 lift overlay	1.5" wearing	2	29.4		14.4	11.4			
			3	45.2		12.3	5.1			
La. 117	existing pavement	2" binder	1	47.8		11.6	5.1			
114-02-21	patched 2 lift overlay	1.5 wearing	2	26.1			10.5			
			3	22.1		7.0	4.4			

ASPHALT CONSTRUCTION District 58

PROJECT	CONSTRUCTION TYPE	SECTION	TEST SECTION NUMBER	ORIGINAL SURFACE PI	MILLED PI	LIFT 1ST PI	2ND PI	3RD PI	4TH PI	5TH PI
La. 4	existing HMAC/2 lift	2" binder	1	11.5		4.7	1.4			
36-02-19	overlay	1.5" wearing	2	13.8		2.9	1.8			
			3	32.5		6.0	3.0			
La. 565	existing HMAC/2 lifts	2" binder	1	4.4		4.4	2.3			
815-17-04		1.5" wearing	2	13.6		4.5	4.7*			
			3	43.6		13.9	4.4			
La. 127	in-place cement stab.	2" binder	1				3.4			
127-01-13	base course/2 lifts	2" wearing	2				1.8			
			3				4.1			

ASPHALT CONS

PROJECT	CONSTRUCTION TYPE	SECTION	SECTION NUMBER	SURFACE PI	MILLED PI	1ST PI	2ND PI	3RD PI	PI	PI
La. 70	existing pavement	1.5" wearing	1			18.2				
232-01-09	patched 1 lift overlay		2			8.2				
			3			12.6				
La. 414	in-place cement	2" binder	1			16.2	9.3			
839-13-05	stabilized base course/	1.5" wearing	2			6.2	2.8			
	2 lift overlay		3			14.0	4.8			
La. 22	new construction	12" florolite	1							3.8
266-01-09		4.5" HM basecourse	2							1.9
		4" binder	3							3.2
		1.5" wearing								

ASPHALT CONSTRUCTION - District 62

PROJECT	CONSTRUCTION TYPE	SECTION	TEST SECTION NUMBER	ORIGINAL SURFACE PI	MILLED PI	LIFT 1ST PI	2ND PI	3RD PI	4TH PI	5TH PI
La. 441 & 442	in-place cement	2" binder	1				2.8			
	stabilized base course/	1.5" wearing	2				5.3			
	2 lift		3				4.3			
La. 445	in-place cement	2" binder	1			1.6	1.6			
278-02-05	stabilized base course/	1.5" wearing	2			2.6	4.3			
	2 lift		3			3.5	2.2			
La. 442	existing HMAC/2 lift	2" binder	1				2.3			
	overlay	1.5" wearing	2				3.8			
			3				4.0			

LTRC HMAC TEST SECTIONS
MULTI-LIFT CONSTRUCTION

Highway	Profile Index
I-49	0.00
I-49	0.50
I-49	0.00
I-49	2.25
I-49	0.50
I-49	0.00
I-49	0.75
I-49	7.00
I-49	0.75
I-49	3.00
I-49	0.00
I-49	0.50
I-49	2.00
I-49	2.50
I-49	0.75
I-49	9.00
LA. 19	10.75
LA. 19	6.25
LA. 19	4.25
LA. 19	4.50
LA. 19	5.75
LA. 19	12.25
I-10	3.50
I-10	0.00
I-10	0.00
I-10	0.00
I-10	0.00

DISTRICT DATA
OVERLAY PROJECTS
PROFILE INDEX STATISTICS

Number of Lifts	Profile Index Minimum	Maximum	Mean
1	2.5	18.2	8.25
2	0.8	11.4	4.16

DISTRICT DATA
NEW CONSTRUCTION PROJECTS
PROFILE INDEX STATISTICS

Number Of Lifts	Profile Index Minimum	Maximum	Mean
2	1.6	10.2	5.1
4	0.7	1.6	1.1
5	1.9	3.8	3.0

DISTRICT DATA
COMBINED PROFILE INDEX STATISTICS

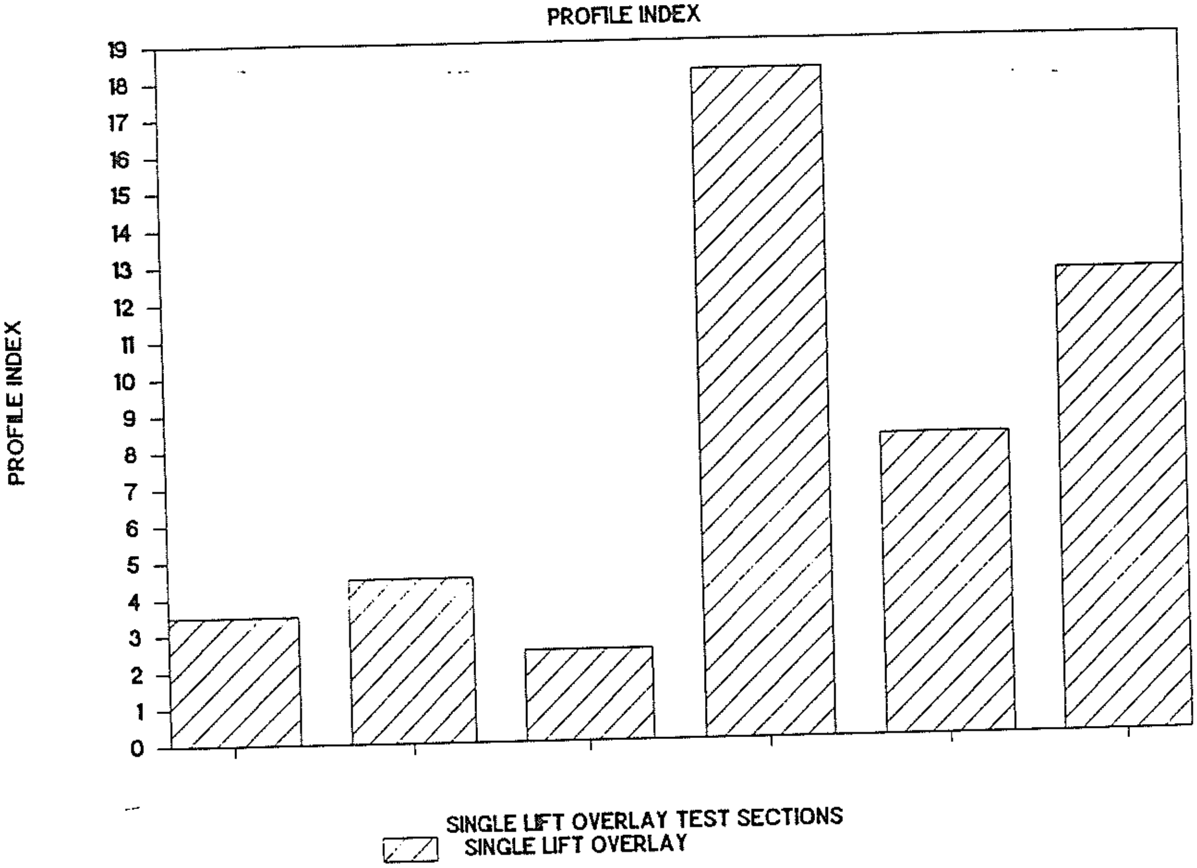
Number of Lifts	Profile Index Minimum	Maximum	Mean
1	2.5	18.2	8.25
1*	1.6	23.6	9.08
>1	0.7	11.4	4.34

* Assuming binder course is one lift.

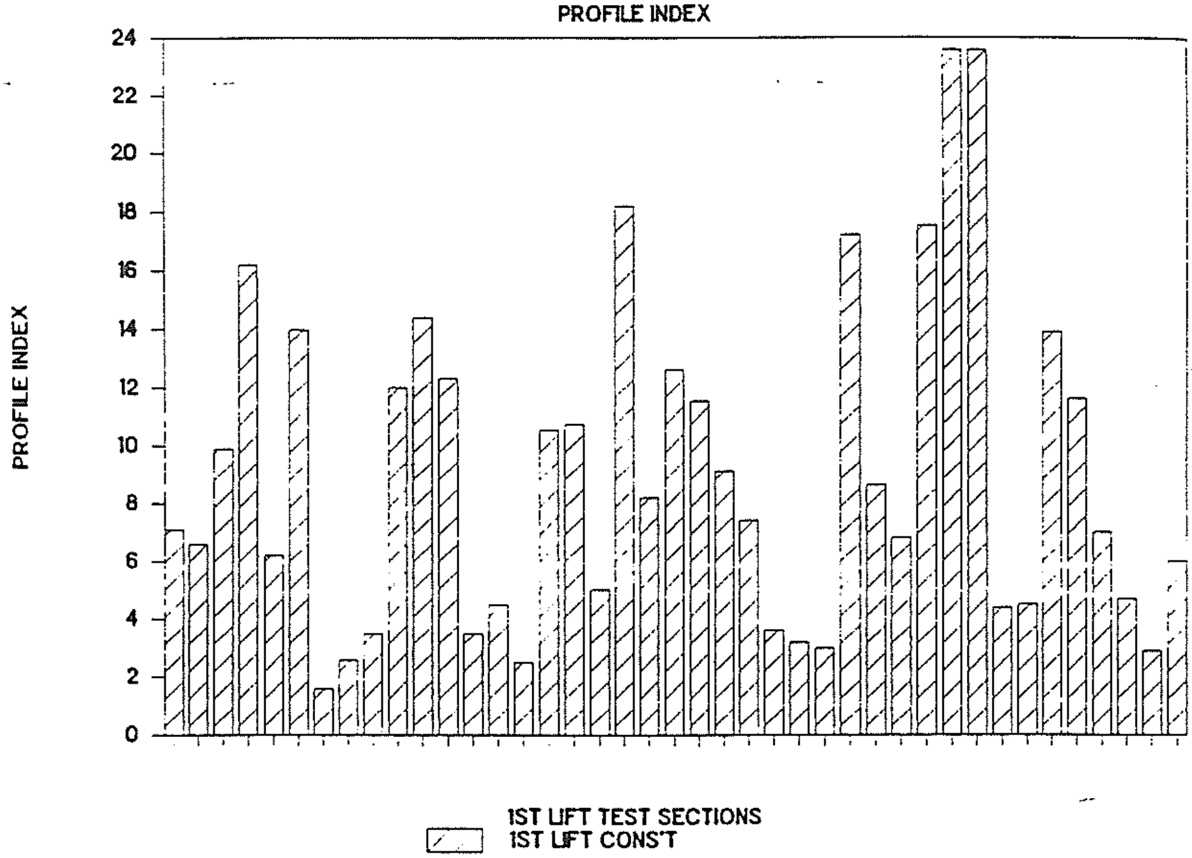
DISTRICT AND LTRC DATA COMBINED
PROFILE STATISTICS
MULTI-LIFT CONSTRUCTION

Profile Index Minimum	Maximum	Mean
0.00	12.25	3.93

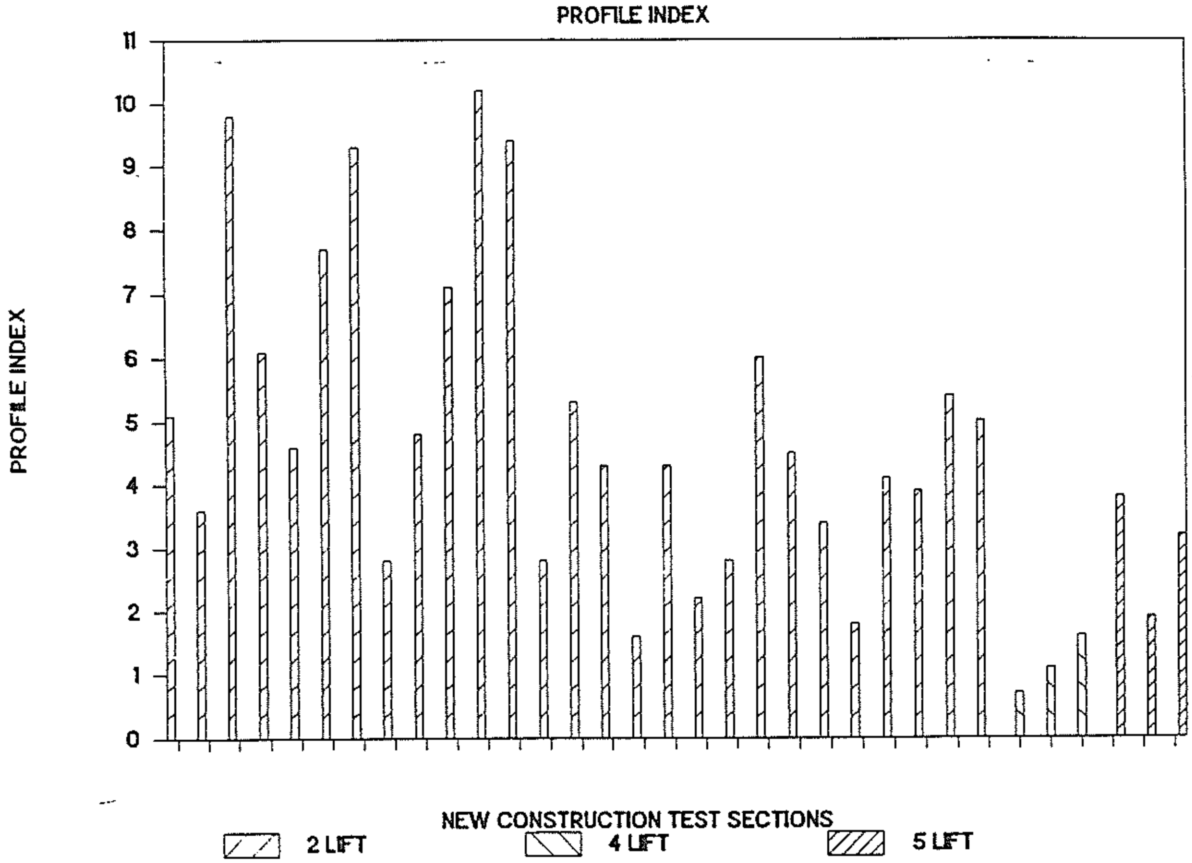
SINGLE LIFT OVERLAYS/DISTRICT DATA

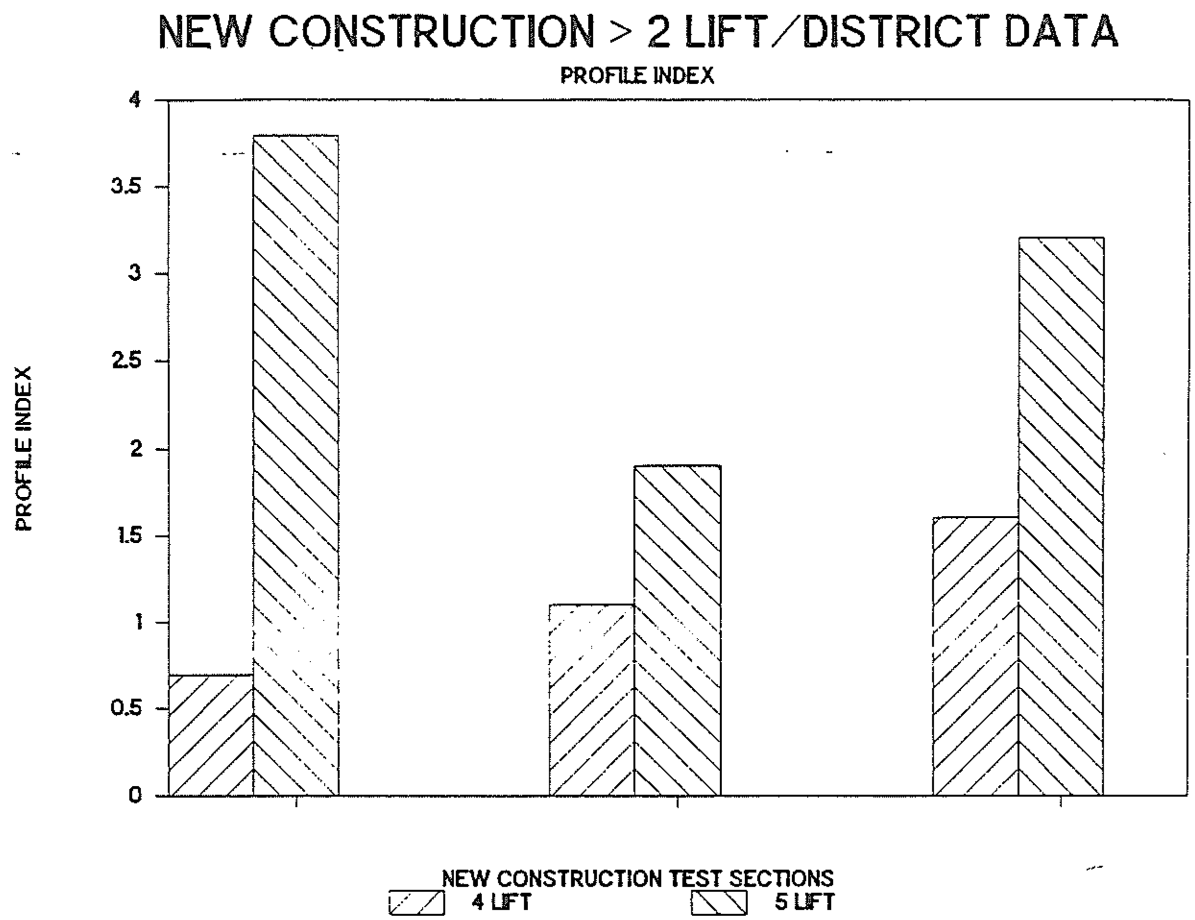


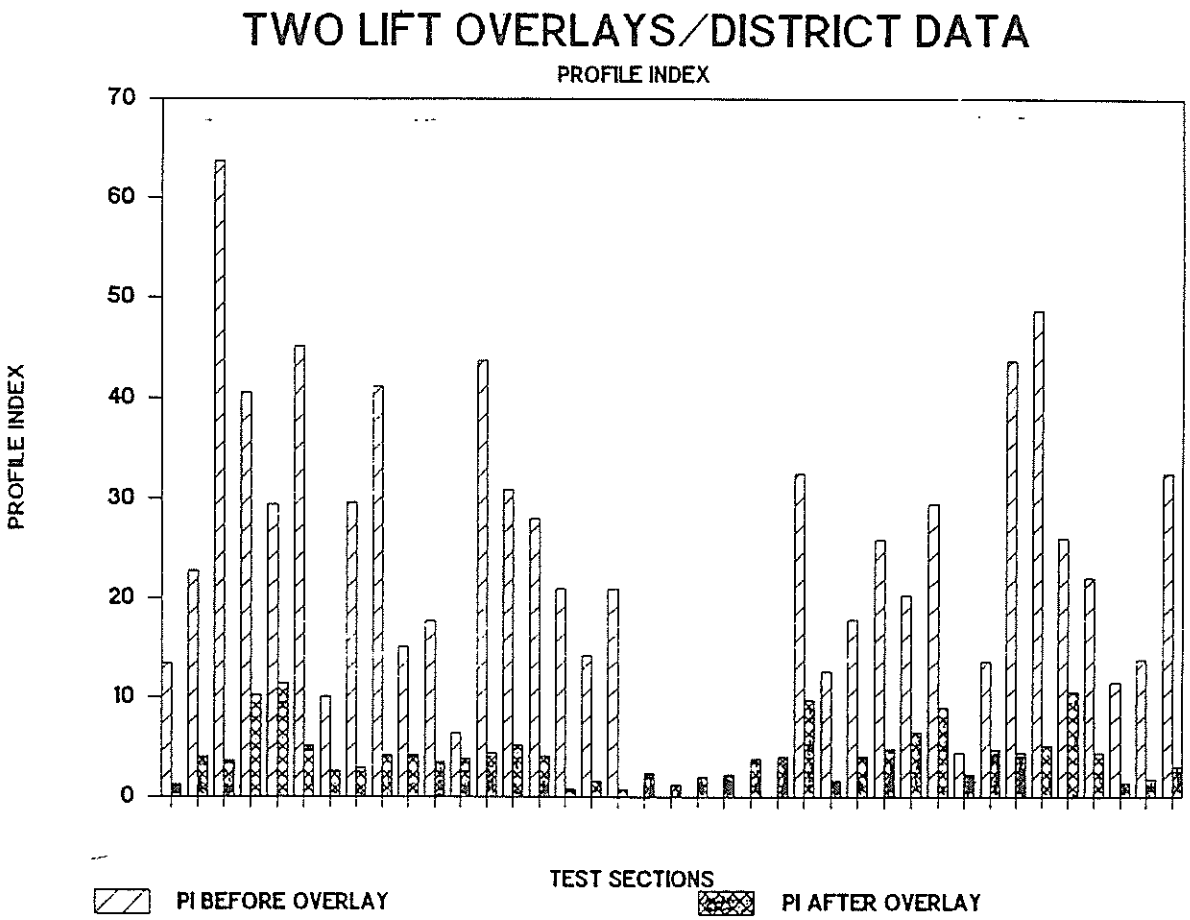
FIRST LIFT CONSTRUCTION/DISTRICT DATA



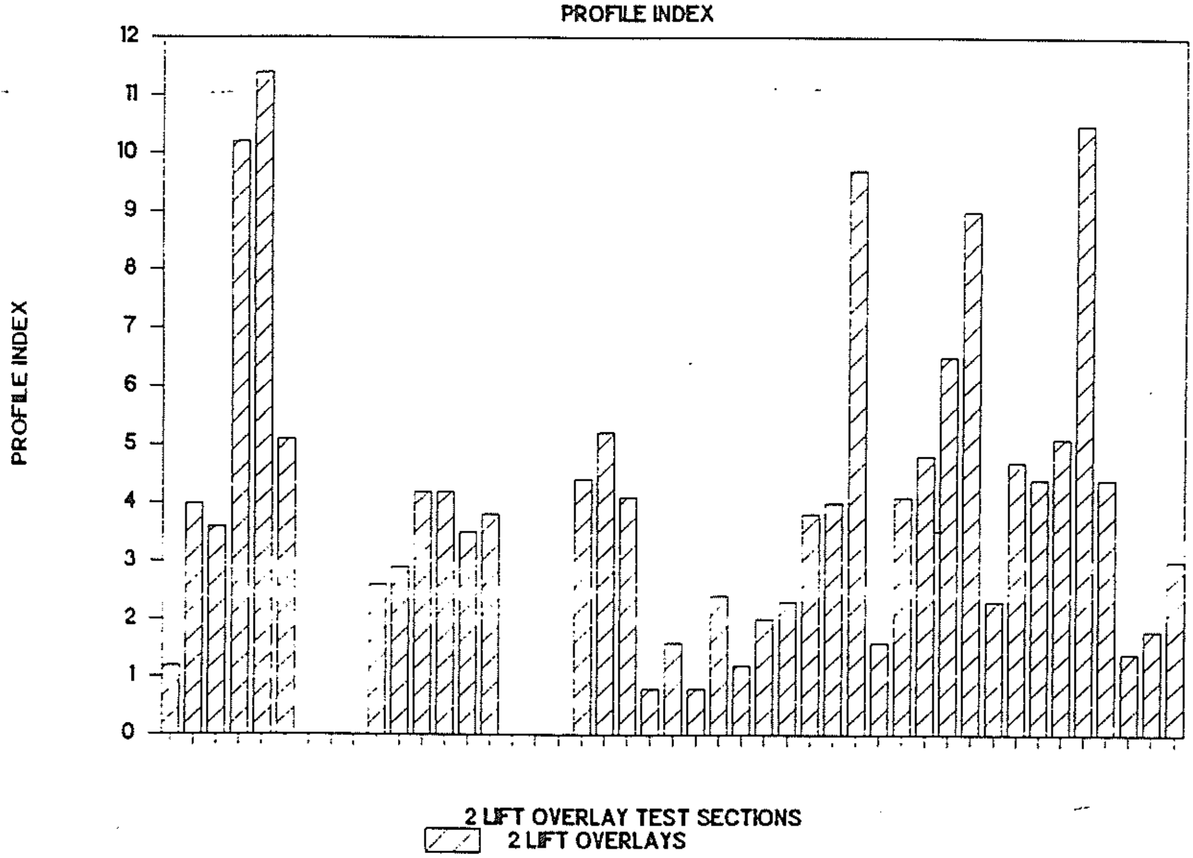
NEW CONSTRUCTION / DISTRICT DATA

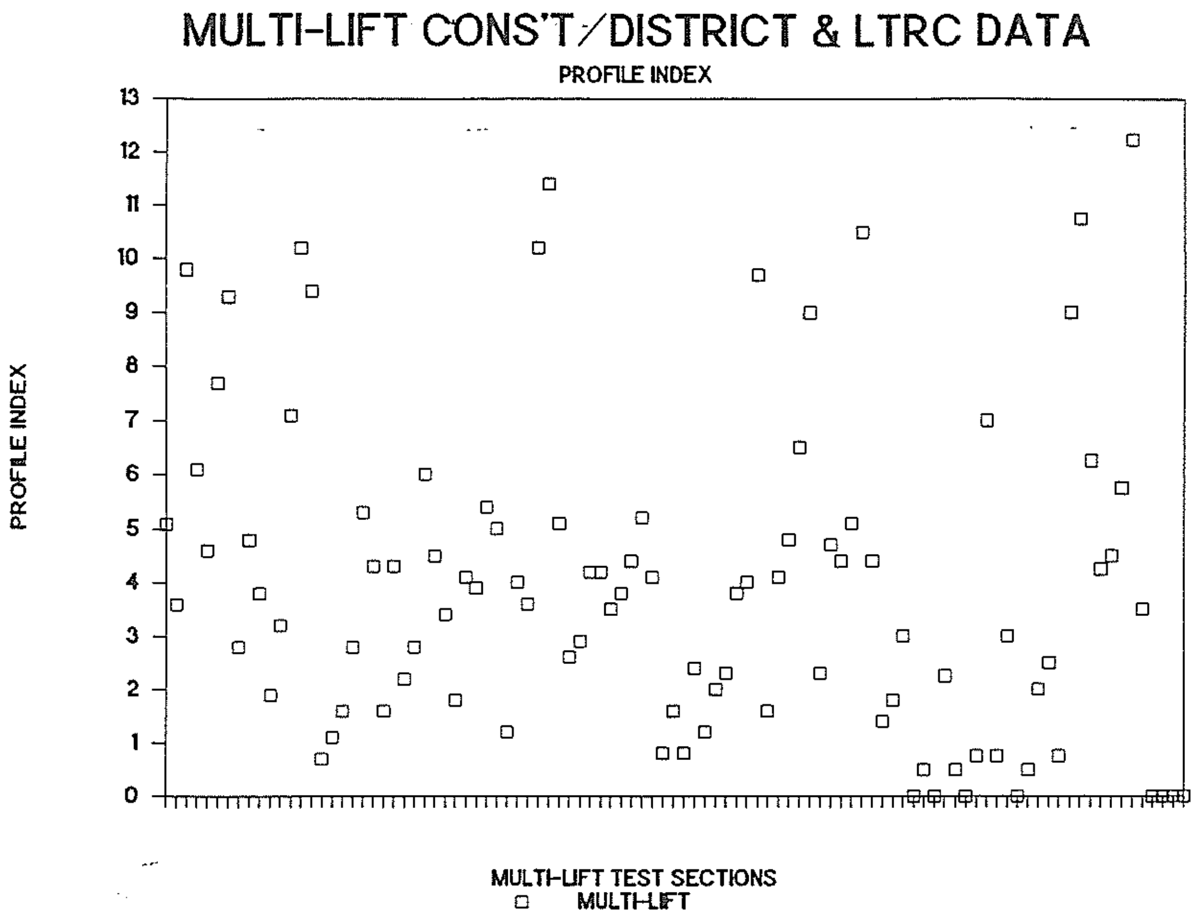



NEW CONSTRUCTION > 2 LIFT/DISTRICT DATA
PROFILE INDEX
PROFILE INDEX
4
3.5
3
2.5
2
1.5
1
0.5
0
NEW CONSTRUCTION TEST SECTIONS
4 LIFT
5 LIFT


TWO LIFT OVERLAYS/DISTRICT DATA
PROFILE INDEX
70
60
50
40
30
20
10
0
PROFILE INDEX
TEST SECTIONS
PI BEFORE OVERLAY
PI AFTER OVERLAY

2 LIFT OVERLAYS/DISTRICT DATA




MULTI-LIFT CONS'T/DISTRICT & LTRC DATA
PROFILE INDEX
PROFILE INDEX
0
1
2
3
4
5
6
7
8
9
10
11
12
13
MULTI-LIFT TEST SECTIONS
MULTI-LIFT

APPENDIX B

DATA PRESENTATION / JOINTED PORTLAND CEMENT CONCRETE

JPCC TEST SECTIONS
45 MPH OR GREATER

Highway	Profile Index
I-12	20.59
I-12	7.74
I-12	4.87
I-12	2.64
I-12	4.58
I-12	7.74
I-12	6.86
I-12	19.47
I-12	3.37
I-12	32.74
I-12	15.84
I-12	8.62
I-12	7.92
I-12	12.50
I-12	10.03
I-12	13.55
I-12	18.10
I-12	8.92
I-20	3.80
I-20	5.70
I-20	3.33
I-20	3.10
I-20	12.10
I-20	7.00
I-20	7.80
I-20	5.70
I-20	13.30
I-20	24.80
I-20	8.00
I-20	6.40
I-20	10.50
I-20	6.20
I-20	2.70
I-20	4.10
I-20	5.70
I-20	6.00 AGS
I-20	6.80 AGS
I-20	2.70 AGS
I-20	4.10 AGS
I-20	11.50 AGS
I-20	8.40 AGS
I-20	6.80 AGS

* AGS = After grinding according to 10-ft. straightedge.
AGP = After grinding according to California Profilograph.

JPCC TEST SECTIONS
45 MPH OR GREATER (Continued)

Highway	Profile Index
I-20	6.60 AGS
I-20	11.90 AGS
I-20	16.00 AGS
I-20	7.00 AGS
I-20	7.80 AGS
I-20	7.80 AGS
I-20	9.20 AGS
I-20	3.10 AGS
I-20	2.30 AGS
I-20	2.70 AGS
I-20	3.90 AGS
I-20	5.70
I-20	13.70
I-20	1.40
I-20	12.90
I-20	1.40
I-20	13.50
I-49	0.75
I-49	0.50
I-49	0.25
I-49	1.00
I-49	2.75
I-49	5.00
I-49	10.50
I-49	5.25
I-49	3.30
I-49	2.75
I-49	3.50
I-49	5.50
I-49	6.75
I-12	4.25 AGP
I-12	5.98 AGP
I-12	5.67 AGP
I-12	4.49 AGP
I-12	5.86 AGP
I-12	5.10 AGP
I-12	2.62 AGP
I-12	3.47 AGP
I-12	5.96 AGP
I-12	5.62 AGP
I-12	4.65 AGP
I-12	5.02 AGP
I-12	5.13 AGP
I-12	4.62 AGP
I-12	3.24 AGP
I-12	4.75 AGP

JPCC TEST SECTIONS
45 MPH OR GREATER (Continued)

Highway	Profile Index
I-12	3.22 AGP
I-12	5.75 AGP
I-12	3.82 AGP
I-12	5.54 AGP
I-12	5.57 AGP
I-12	3.90 AGP
I-12	3.06 AGP
I-12	4.50 AGP
I-12	5.21 AGP
I-12	5.75 AGP
I-12	5.92 AGP
I-12	5.87 AGP
I-49	1.20
I-49	2.00
I-49	4.30
I-49	3.20
I-49	3.90
I-49	4.40
I-49	3.10
I-49	0.40
I-49	0.60
I-12	14.90
I-12	14.80
I-12	15.10
I-12	12.10
I-12	6.00
I-12	13.40
I-12	12.40
I-12	15.80
I-12	15.30
I-12	14.10
I-12	6.70
I-12	8.50
I-12	4.10 AGP
I-12	4.00 AGP
I-12	4.20 AGP
I-12	3.30 AGP
I-12	4.40 AGP
I-12	4.20 AGP
I-12	2.10 AGP
I-12	2.60 AGP
I-12	2.10 AGP
I-12	5.10 AGP
I-12	4.80 AGP
I-12	3.20 AGP
I-12	5.90 AGP

JPCC TEST SECTIONS
45 MPH OR GREATER (Continued)

Highway	Profile Index
I-12	4.10 AGP
I-12	4.60 AGP
I-12	6.50 AGP
I-12	3.00 AGP
I-12	5.10 AGP
I-12	6.80 AGP
I-12	2.80 AGP
I-12	5.10 AGP
I-12	3.60 AGP
I-12	3.00 AGP
I-12	3.90 AGP
I-12	4.60 AGP
I-12	5.40 AGP
I-12	3.80 AGP
I-12	5.30 AGP
I-12	3.70 AGP
I-12	2.30 AGP
I-12	2.80 AGP
I-12	3.80 AGP
I-12	3.70 AGP
I-12	4.80 AGP
I-12	3.40 AGP
I-12	3.40 AGP
I-12	5.60 AGP
I-12	5.40 AGP
I-12	5.30 AGP
I-12	3.50 AGP
I-12	4.70 AGP
I-12	4.30 AGP
I-12	2.80 AGP
I-12	6.30 AGP
I-12	7.20 AGP
I-12	3.20 AGP
I-12	2.90 AGP
I-12	7.60 AGP
I-12	5.20 AGP
I-12	4.90 AGP
I-12	5.10 AGP
I-12	4.80 AGP
I-12	4.20 AGP
I-12	3.00 AGP
I-12	6.50 AGP
I-12	6.80 AGP
I-49	6.60
I-49	2.40
I-49	1.80

JPCC TEST SECTIONS
45 MPH OR GREATER (Continued)

Highway	Profile Index
I-49	2.00
I-49	2.90
I-49	1.20
I-49	5.20
I-49	1.80
I-49	2.00
I-49	1.50
I-49	3.40
I-49	4.50
I-49	4.60
I-49	4.70
I-49	5.40
I-49	13.70
I-49	11.60
I-49	3.70
I-49	2.20
I-49	2.40
I-49	0.70
I-49	2.90
I-49	3.60
I-49	3.60
I-49	4.10
I-49	0.50
I-49	0.70
I-49	1.40
I-49	2.90
I-49	5.70
I-49	10.30
I-49	6.40
I-49	4.80
I-49	1.20
I-49	8.00
I-49	3.80
I-49	7.00
I-49	4.80
I-49	3.50
I-49	5.60
I-49	5.80
I-49	6.60
I-49	6.70
I-49	8.00
I-49	8.40
I-49	1.80
I-49	4.30
I-49	4.30
I-49	4.90

JPCC TEST SECTIONS
45 MPH OR GREATER (Continued)

Highway	Profile Index
I-49	2.80
I-49	6.40
I-49	0.60
I-49	4.10
I-49	4.00
I-49	8.10

JPCC TEST SECTIONS
URBAN CONSTRUCTION

Highway	Profile Index
HOOPER	5.70
HOOPER	4.07
HOOPER	10.89
HOOPER	12.36
HOOPER	12.98
HOOPER	7.26
PERKINS	19.00
PERKINS	18.25
PERKINS	28.75
PERKINS	19.75
PERKINS	28.75
PERKINS	31.75
PERKINS	20.25
PERKINS	10.25
PERKINS	11.50
PERKINS	8.00
PERKINS	11.00
PERKINS	9.00
PERKINS	15.25
PERKINS	11.50
PERKINS	27.75
PERKINS	19.75
PERKINS	18.25
PERKINS	12.75
PERKINS	15.00
PERKINS	13.75

JPCC TEST SECTIONS
45 MPH OR GREATER
(ALL SECTIONS)

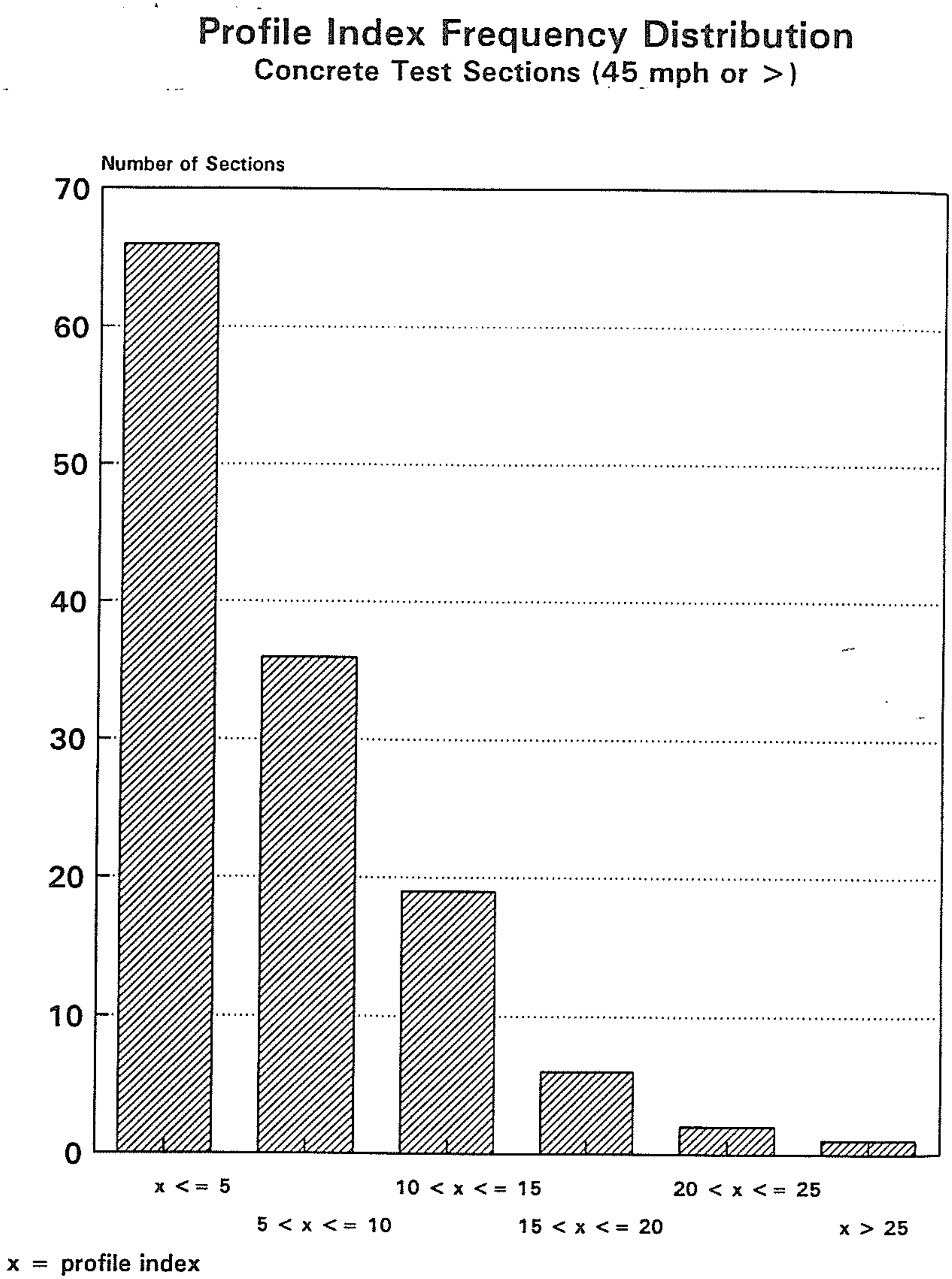
Profile Index		
Low	High	Mean
0.25	32.74	6.51

JPCC TEST SECTIONS
45 MPH OR GREATER

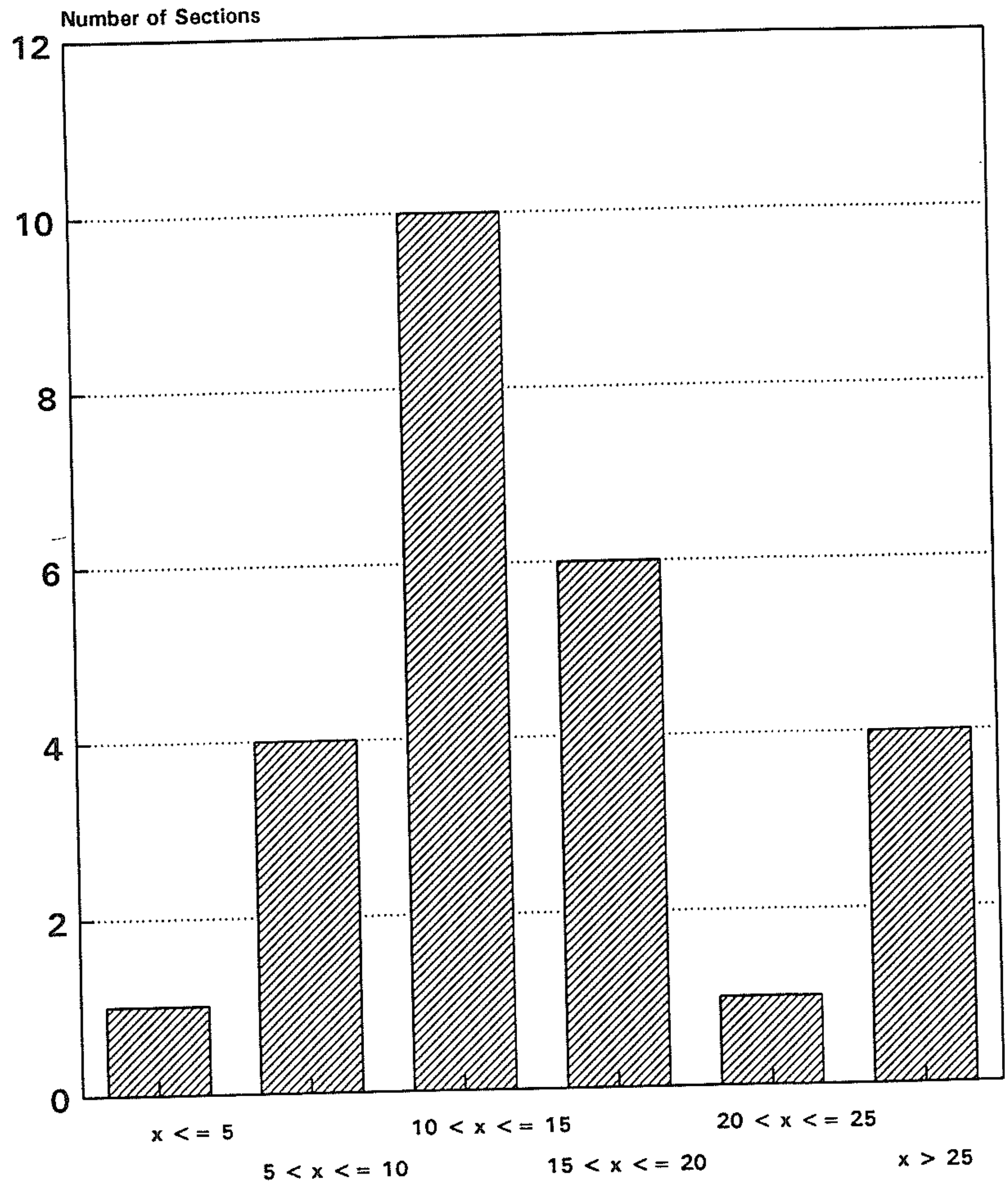
Profile Index (Ride Corrected Using Profilograph)			
	Low	High	Mean
Before Correction	3.37	32.74	11.84
After Correction	2.17	6.80	4.15

JPCC TEST SECTIONS
URBAN CONSTRUCTION

Profile Index		
Low	High	Mean
8.00	31.75	17.51


Profile Index Frequency Distribution
Concrete Test Sections (45 mph or >)
Number of Sections
70
60
50
40
30
20
10
0
x <= 5
5 < x <= 10
10 < x <= 15
15 < x <= 20
20 < x <= 25
x > 25
x = profile index

Profile Index Frequency Distribution
Urban Concrete Test Sections



x = profile index

APPENDIX C
CURRENT SPECIFICATIONS

601.11 SURFACE TOLERANCE REQUIREMENTS (LONGITUDINAL).

(a) **General:** The pavement travel lanes will be tested using an approved Ames California Type 25-Foot Profilograph over each wheel path of each lane except that the outside wheel path will not be tested on projects which are classified in Table 1 as Category III projects and which have catch basins and curb along the outside edge of the pavement. The resulting profile trace will be evaluated to determine the location of high points (bumps) in excess of specification limits and to determine the pavement's Average Profile Index. The Average Profile Index is defined as the arithmetical average of the profile Indexes of the Wheel paths for each test section or lot of the travel lanes.

Associated pavements (acceleration lanes, deceleration lanes, continuous turn lanes and ramps) will be tested using the profilograph over the centerline of each lane or ramp. The resulting profile trace will be evaluated to determine the location of high points (bumps) in excess of specification limits.

Shoulders, turnouts, crossovers and the 25-foot areas of new travel lanes in tie-in areas shall be tested with an approved 10-foot metal static straightedge.

The operation of the profilograph, including evaluation of the profile trace, determination of the profile Index for each wheel path in each travel lane, calculation of the Average Profile Index for each roadway and determination of high points (bumps) in excess of specification limits shall be in accordance with DOTD TR 641. The operation of the profilograph and evaluation of the profile trace shall be by trained, qualified personnel who have successfully completed the Department's training and evaluation program.

The Blanking Band Template for determining the Profile Index shall be 0.2 inch. The Bump Template for determining high points (bumps) in excess of specification limits shall be 0.3 inch in 25 feet or less for Category I or II in Table I or 0.4-inch in 25 feet or less for Category III in Table 1. The pavement profile determination will terminate approximately 25 feet from each bridge approach slab or existing pavement that is joined by new pavement constructed under these specifications. Obviously deficient areas, as determined by the engineer, shall be corrected before any profilograph testing is performed.

(b) **Requirements:** Surface finish testing will be conducted in the longitudinal direction. Deficiencies shall be isolated in both the longitudinal and transverse direction. All pavement travel lanes and associated pavements, regardless of design speeds or paving operations, with surface deviations represented by high points (bumps) in excess of 0.3 inch in

25-feet or less for Category I or II or 0.4 inch in 25 feet or less for Category II shall be corrected.

A report as required in DOTD TR 641 of each profile trace performed by the contractor shall be supplied to the engineer for review.

(1) **Design Speed Greater than 45 MPH:** For pavements with design speeds of 45 mph or greater, the contractor shall furnish paving equipment and employ methods that produce a riding surface having an Average Profile Index of not more than 6.0 inches per mile per lot.

(2) **Urban Areas Using Continuous Paving Operations:** For urban areas using continuous paving operations with design speeds 45 mph or less, the contractor shall furnish paving equipment and employ methods that produce a riding surface having an Average Profile Index of not more than 12.0 inches per mile per lot.

(3) **Urban Areas Not Using Continuous Paving Operations:** For urban areas not using continuous operations (such as: areas with catch basins, manholes, crossovers, driveways, curb and gutter sections, and split-slab construction) with design speeds 45 mph or less, the contractor shall furnish paving equipment and employ methods that produce a riding surface having an Average Profile Index or not more than 20.0 inches per mile per lot.

(4) **Tie-in Areas, Shoulders, Turnouts and Crossovers:** For pavement tie-in areas, shoulders, turnouts and crossovers, the contractor shall furnish equipment and employ methods that produce an acceptable riding surface. Pavement tie-in areas with surface deviations in excess of 1/4-inch in 10 feet shall be corrected. Pavement shoulders, turnouts and crossovers with surface deviations in excess of 1/2-inch in 10 feet shall be corrected.

(c) **Equipment:** The profilograph used for daily paving quality control and to identify surface areas requiring corrective actions shall consist of an approved Ames California Type 25-Foot Profilograph furnished, calibrated and operated in accordance with DOTD TR 641 by the contractor.

The profilograph used for surface tolerance acceptance and to determine surface finish payment adjustments shall consist of an approved Ames California Type 25-Foot Profilograph furnished, calibrated and operated in accordance with DOTD TR 641 by the Department.

The pavement profile is recorded by the profilograph at a scale of 1:1 vertically and 1 inch equals 25 feet longitudinally.

An approved 10-foot metal static straightedge shall be furnished by the contractor for both quality control and acceptance surface tolerance testing of tie-in areas, shoulders, and turnouts and crossovers.

(d) **Initial Surface Testing:**

(1) **Pavement Travel Lanes:** During initial paving operations, for pavement travel lanes either when starting up or after a shut-down period, the pavement surface shall be tested with the profilograph and the Average Profile Index calculated by the contractor as soon as the concrete has cured sufficiently to allow testing. The purpose of this initial testing is to aid the contractor and the Department in evaluating the paving operations and equipment. If this initial testing and evaluation indicates that the Average Profile Index exceeds the minimum requirements given in Table 1 for payment, the contractor shall alter paving operations to produce pavement within these limits. If the contractor's operations continue to produce pavement outside these limits, the contractor shall stop and make all necessary corrections to produce pavements within these minimum limits.

(2) **Associated Pavement:** During initial paving operations for associated pavements, either when starting up or after a shut-down period, the pavement surface shall be tested with the profilograph and the high points (bumps) in excess of specification limits evaluated by the contractor as soon as the concrete has cured sufficiently to allow testing. The purpose of this initial testing is to aid the contractor and the Department in evaluating the paving operations and equipment. If this initial testing and evaluation indicates that there are excessive high points (bumps) in excess of the requirements given in Heading (b), the contractor shall stop and alter paving operations to reduce and limit the number of high points (bumps) in excess of specification limits. Once the initial pavement smoothness and paving operations are acceptable, the contractor shall proceed with the paving operations.

(3) **Shoulders, Turnouts and Crossovers:** During initial paving operations, either when starting up or after a shut-down period, the surface shall be tested and evaluated by the contractor with an approved 10-foot metal static straightedge as soon as the concrete has cured sufficiently to allow testing. The purpose of this initial testing is to aid the contractor and the Department in evaluating the paving operations and equipment. If this initial testing indicates surface deviations in excess of 1/2-inch in 10 feet, the contractor shall stop and alter paving operations to produce pavement with surface deviations of 1/2-inch or less in 10 feet.

Once the initial surface smoothness and paving operations are acceptable, the contractor shall proceed with paving operations.

(4) Curing membrane damaged during the testing operation shall be repaired by the contractor as directed at no direct pay.

(e) **Quality Control Surface Testing:** The contractor shall test each day's paving with the profilograph no later than during the first work day following placement of the pavement.

(1) **Pavement Travel Lanes:** If the contractor fails to meet the minimum requirements given in Table 1, the paving operation will be suspended and will not be allowed to resume until the paving and finishing operation is corrected by the contractor to meet the requirements of Table 1. After the paving and finishing operation has been corrected by the contractor and the engineer allows the paving operation to continue, the paving operation will be tested in accordance with Heading (d) above.

Areas with high points (bumps) in excess of the requirements given in Heading (b), shall be isolated both longitudinally and transversely and corrected by the contractor for the full longitudinal and transverse extent of their occurrence in accordance with Heading (e)(5). Additional profiles as necessary shall be taken by the contractor to define the limits of all out-of-tolerance pavement requiring correction.

After correcting all individual deviations in excess of the requirements in heading (b), additional corrective action shall be made by the contractor as necessary to reduce the Average Profile Index to the minimum requirements given in Table 1. Corrections shall be made in accordance with Heading (e)(5).

On those areas where corrective action is taken, the pavement shall be reprofiled as many times as necessary by the contractor to verify that corrections have produced an Average Profile Index conforming to the minimum requirements given in Table 1 and that the surface deviations in excess of the requirement given in heading (b), have been corrected.

(2) **Associated Pavement:** Acceleration lanes, deceleration lanes, continuous turn lanes and ramps constructed under these specifications shall be tested after completion with the profilograph. High points (bumps) having deviations in excess of the requirements given in Heading (b), shall be isolated and corrected by the contractor for the full longitudinal and transverse extent of their occurrence in accordance with Heading (e)(5). Verification of the required correction by reprofiling shall be conducted by the contractor.

(3) **Shoulders, Turnouts and Crossovers:** The surface of shoulders, turnouts and crossovers shall be tested after completion with an approved 10-foot metal static straightedge. Surface deviations in excess of 1/2-inch in 10 feet will be isolated by the engineer and shall be corrected by the contractor at no direct pay to within 1/2 inch deviation in accordance with heading (e)(5).

(4) **Tie-in Areas:** After corrective work has been completed, the surface of the 25-foot area of new pavement adjacent to tie-ins with existing pavements or approach slabs which is not tested with the profilograph will be tested in each wheel path for its entire length with an approved 10-foot metal static straightedge. The joint between the new and existing pavement or approach slab will also be tested with the straightedge placed longitudinally across the joint in each wheel path. Surface deviations in excess of 1/4-inch in 10 feet will be isolated by the engineer and shall be corrected by the contractor in accordance with heading (e)(5).

(5) If the Department determines the Average Profile Index for pavement travel lanes does not conform to the specification requirements for 100 percent payment, given in Table 1, the contractor will be allowed to make corrections in accordance with heading (e)(5) and the Department will reprofile for acceptance one additional time.

601.18 ACCEPTANCE REQUIREMENTS.

(a) **General:** Sampling and testing for acceptance will be conducted on each lot of pavement for thickness, compressive strength and surface tolerance. Any pavement that is obviously deficient shall be satisfactorily corrected or removed and replaced.

A lot of portland cement concrete pavement or shoulders is an identifiable area of approximately 4,000 square yards paid under the same item. The final area of pavement placed will be considered as a lot if it is at least 2,000 square yards; otherwise, it will be included in the previous lot.

(b) **Thickness and Compressive Strength:** Strength and thickness of pavements will be determined from hardened concrete cores in accordance with DOTD TR 225. Each lot will be divided into five equal segments and one core will be obtained from each segment after the pavement has met surface tolerance requirements.

All core holes in the pavement from acceptance coring shall be patched by the contractor using an approved pavement or structural concrete mixture meeting the requirements of Section 901. The surface of the patch shall be finished to match the surrounding pavement.

(1) Thickness: The average thickness of the pavement lot shall not be less than the specified thickness by more than 0.10 inch. Underthickness deficiencies in excess of 0.10 inch will be subject to the payment adjustments shown in Table 1. Overthickness will be waived at no direct pay.

In calculating average pavement thickness, individual measurements in excess of specified thickness by more than 0.25 inch will be considered as specified thickness plus 0.25 inch.

Individual areas found deficient in thickness by more than 1.00 inch will be evaluated by the engineer, and if in the engineer's judgment the deficient areas warrant removal, they shall be removed and replaced with concrete of specified thickness. If the deficient area is allowed to remain in place, payment will be made at 50 percent of the contract unit price for that fraction of the lot with greater than 1.00 inch underthickness. Payment for the remainder of the lot will be made in accordance with Table 1 based on the average thickness of the entire lot.

(2) Compressive Strength: Average compressive strength for the lot shall not be less than 4,000 psi (3,600 psi when air entrainment is used).

When the average strength for the lot is less than 4,000 psi (3,600 psi when air entrainment is used), the contract unit price will be adjusted in accordance with Table 1. When an individual core indicates compressive strength less than 3,000 psi, and if in the judgment of the engineer the concrete may be left in place, payment for the quantity of concrete represented by the deficient core will be made at 50 percent of the contract unit price. If removal is warranted, the entire deficient section shall be replaced with concrete of the specified quality.

The compressive strength of cores will be determined after a minimum of 28 days.

(3) Projects with less than 2,000 square yards: Projects with less than 2,000 square yards of pavement may be cored as required in Headings (1) and (2) above, or may be accepted on the basis of compressive strength cylinders and thickness measurements taken by the engineer.

(c) Surface Tolerance: The surface of each pavement lot will be tested longitudinally with an approved profilograph as described in Subsection 601.11. If sections of pavement do not meet the requirements for surface tolerance, an adjustment in unit price for the lot will be made in accordance with Table 1. There is no payment adjustment for associated pavements, tie-in areas, shoulders, and turnouts and cross-overs.

601.19 QUALITY CONTROL: The contractor shall be responsible for the production, transporting, placement, joint construction, surface finishing, maintenance and curing of all concrete pavement and shoulders constructed in accordance with these specifications. The contractor shall control the work to produce concrete pavement and shoulders which are uniform and conform to the plan dimensions and test requirements. The contractor shall perform whatever tests necessary to ensure the concrete pavement and shoulders conform to these specifications. Construction methods shall be such that random cracking does not occur.

601.20 MEASUREMENT. The quantities of portland cement concrete pavement for payment will be the design quantities specified in the plans and adjustments thereto. Design quantities will be adjusted if the engineer makes changes to adjust to field conditions, if plan errors are proven, or if design changes are necessary. Design areas of pavement are based on the horizontal dimensions shown on the plans, the length being along the centerline of the pavement.

601.21 PAYMENT. Payment for portland cement concrete pavement will be on a lot basis at the contract unit price per square yard, which includes furnishing and placing all materials including tie bars, dowel bars and joint material. If the pavement does not conform to acceptance requirements, payment will be made at an adjusted unit price in accordance with Table 1. When payment adjustments are made for more than one deficiency, they shall be cumulative.

Payment will be made under:

Item No.		
601(01)	Portland Cement Concrete Pavement (___" Thick)	Square Yard
601(02)	Portland Cement Concrete Pavement (___" Thick) (Crossovers and Turnouts)	Square Yard
601(03)	Portland Cement Concrete Shoulder (___" Thick)	Square Yard

TABLE 1
PAYMENT ADJUSTMENT SCHEDULE

	Payment (Percent of Contract Unit Price/Lot)[1]					
	100	98	95	80	50 or remove and replace[2]	Correct or remove and replace[2]
Deficiency in Average Thickness of 5 cores per lot, inches	0 to 0.10	- - - -	0.11 to 0.25	0.26 to 0.50	Over 0.50	- - - -
Average Compressive Strength, psi Without Air Entrainment With Air Entrainment	4000 & over 3600 & over	- - - -	3000 to 3999 3150 to 3599	3000 to 3499 3000 to 3149	Below 3000 Below 3000	- - - -
Category I Average Profile Index (inches/mile/lot) for pavement travel lanes with design speed greater then 45 mph[3]	6.0 or less	6.1 to 7.0	7.1 to 8.0	- - - -	- - - -	over 8.0
Category II Average Profile Index (inches/mile/lot) Urban Areas using continuous paving operations with design speeds 45 mph or less	12.0 or less	12.1 to 13	13.1 to 14.0	- - - -	- - - -	over 14.0
Category III Average Profile Index (inches/mile/lot) Urban areas not using continuous paving opeations with design speeds 45 mph or less[3]	20.0 or less	20.1 to 22.0	22.1 to 24.0	24.1 to 26.0	- - - -	over 26.0