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16. Abstract

The Surface Dynamics Profilometer, which has been used for several years by the Texas State Department of Highways and Public Transportation for road profile and roughness measurements, was recently updated to include non-contact or laser probes in place of the road following wheels. The upgrade also included a more up-to-date on-board computing capability. Likewise, procedures and enhancements to the Walker Roughness Device (WRD, or SIometer) was also recently completed. This current project was initiated to monitor the usage of this equipment, making any necessary improvements, etc., as the equipment was being used in actual field use. The report provides results of various applications of this equipment during the past year. The data was taken primarily by D-10 personnel.

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FIELD IMPLEMENTATION OF NON-CONTACT PROFILING AND ROAD ROUGHNESS EQUIPMENT

by

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Report 394-1F

Field Implementation of Non-Contact
And Road Profiling Equipment

Project 8-10-87-394

conducted for

Texas State Department of Highways
and Public Transportation

in cooperation with the
U.S. Department of Transportation
Federal Highway Administration

August 1988

PREFACE

This project report presents results of Project 8-10-87-394, " Field Implementation Of Non-Contact Profiling and Road Roughness Equipment". This one year project was initiated to monitor the field implementation of the Surface Dynamics Profilometer (SDP) and the Walker Roughness Device (WRD). During a previous project the SDP had been upgraded to include non-contact measurement probes and an up-to-date computer system. The WRD had also been under study in an earlier project, where procedures and other enhancements had been developed for roughness measurements for PES.

This project was conducted in conjunction with D-10 personnel. Efforts of Department personnel, Robert Light, Curtis Goss, Joe Wise, and Jim Wyatt are gratefully acknowledged.

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August 1988

ABSTRACT

The Surface Dynamics Profilometer, which has been used for several years by the Texas State Department of Highways and Public Transportation for road profile and roughness measurements, was recently updated to include non-contact or laser probes in place of the road following wheels. The upgrade also included a more up-to-date on-board computing capability. Likewise, procedures and enhancements to the Walker Roughness Device (WRD, or SIometer) was also recently completed. This current project was initiated to monitor the usage of this equipment, making any necessary improvements, etc., as the equipment was being used in actual field operations. The report provides results of various applications of this equipment during the past year. The data was taken primarily by D-10 personnel.

KEY WORDS: Mays Ride Meter (MRM), Rainhart Profilograph, California Profilograph, Surface Dynamics Profilometer (SDP), SIometer, Walker Roughness Device (WRD), Present Serviceability Index (PSI).

SUMMARY

This project report presents results of Project 8-10-87-394, "Field Implementation Of Non-Contact Profiling and Road Roughness Equipment". This one year project was initiated to monitor the field implementation of the Surface Dynamics Profilometer (SDP) and the Walker Roughness Device (WRD). The computer and sensor or measuring components of the SDP had been updated during a previous project. Procedures and other enhancements had also been developed on another earlier project for usage of the WRD for roughness measurements into PES.

The Non-contact probes on the Surface Dynamics Profilometer have been successfully used during the past year for periodic measurements of the Austin Test sections and for other various profile and roughness measurements.

Two of the Self-calibrating roughness units were used in the last phases of the 1986 PES roughness data collection with good results. Minor modifications to the measurement procedures were made for implementation in the 1987 PES data collection. Six of these roughness units were used in the 1987 PES data collection. The report provides results of measurements with these devices and the SDP during the 1986-1987 period.

IMPLEMENTATION STATEMENT

The 690D Surface Dynamics Profilometer, owned by the State Department, has been up-graded so that measurements can be used with Selcom laser or non-contact probes in addition to the current road-following wheels. Additionally, the on-board computing capability was upgraded. The device can be used in its present condition improving previous procedures for road profile and roughness measurements.

The WRD provides the Department an economical, more up-to-date, and safer means of measuring pavement roughness and provides automated procedures for entering such measurements into the Pavement Evaluation System. The immediate effect of a low cost road roughness measuring device which does not require extensive calibration procedures will permit many districts within the state to easily obtain roughness measurements.

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CHAPTER 1

INTRODUCTION

Background and Study Objective

The Surface Dynamics Profilometer (SDP) has been used for several years by the Texas State Department of Highways and Public Transportation (TSDHPT) for road profile measurements. It is considered as the standard for roughness measurements in the State. PSI roughness measurements, for instance, are used for calibrating the Mays Ride Meter and for correlation of the Walker self-calibrating roughness device (WRD or SIometer). In project 8-10-85-494 the road following wheels used by the SDP were replaced with non-contact or Selcom laser probes [Ref 1]. Additionally, the on-board computing was upgraded.

In Project 8-10-85-479, the WRD was upgraded for correlations with the profilometer. Other enhancements were included so that it could be used for PES roughness measurements [Ref 2].

This current one year project was initiated primarily to monitor the field implementation of the SDP and WRD equipment and make any necessary corrections discovered during the field usage. Continued usage of the SDP for various profile and roughness measurements were to be monitored. The measuring capability of the WRD or SIometers were evaluated to determine the feasibility of replacing the aging Mays Meters for P.E.S. measurements.

Report Scope

The following chapter will briefly describe the operating principles of the SDP and WRD units. More detailed description of these two devices were included in the previous project reports and the references and thus are not discussed.

Chapter 3 provides a description of the various field usage activities and their results. This data was collected primarily by D-10 personnel during the course of the project.

A project Summary is presented in Chapter 4.

CHAPTER 2

MEASURING EQUIPMENT

Surface Dynamics Profilometer

The Surface Dynamics Profilometer was originally designed by General Motors and built by K. J. Law Engineers in 1967. The device has, as primary sensors, two accelerometers and two linear potentiometers. The potentiometers are connected to road-following wheels. The accelerometers determine the amount and direction of vertical acceleration undergone by the vehicle while the potentiometers and wheels measure the distance from the vehicle body to the road surface. A profile measurement is calculated by summing the double integral of the accelerometer signal and the displacement signal from the potentiometer [Ref 3]. The Department purchased one of the first units built by Law Engineers in 1968. A second unit was purchased in the mid 1970's. This unit was initially operated by the University of Texas Center for Transportation Research and later transferred to the Department for data collection. Recently, two non-contact, or Selcom laser probes, were installed on the SDP, replacing the potentiometer/road-following wheel combination [Ref 1].

The SDP measures profile data with considerable accuracy and consistency and is independent of the vehicle suspension. It has been used as a standard reference device for performance evaluation of less accurate and expensive road roughness measurement devices [Ref 4].

The principal statistic currently used by the TSDHPT in analyzing profile data from the SDP is root-mean-square vertical acceleration (RMSVA). This statistic is discussed in Reference 4. RMSVA is the basis for the mathematical model to compute present serviceability index for a section of a road. The implementation of this model is a program called VERTAC (VERTical ACceleration). The two RMSVA statistics used in the PSI model are for four and 16 foot base lengths. Initially this program could only be run on a large mainframe computer system. The current version is run on the portable Compaq, located in the SDP [Ref 1].

WALKER ROUGHNESS DEVICE

Even though the profilometer produces accurate measurements, it is rather expensive to obtain and operate. Because of this the Mays Ride Meter and, more recently, the WRD are currently being used in Texas for roughness measurements. The WRD was initially called the SIometer as it directly provides serviceability index. The TSDHPT has six of these units for PES.

The WRD provides an estimate of the road profile. From these measurements a slope variance of the estimated profile for a four inch base length is then calculated. The WRD uses this value, which has been correlated to PSI, to determine the serviceability index (SI) of the road [Refs 2,7,8].

The WRD consists of three components: a sensor unit, main control module and, optionally, a computer for storing the results. The device uses an accelerometer as its primary sensor. Before using the device for measurements it is driven over a short road section which is used by the WRD to perform a statistical model of the vehicle's response. The model parameters determined in this dynamic calibration procedure is then later used during the measuring process for removing the vehicle's or correlated characteristics. The process of identifying and modeling the current or dynamic vehicle characteristics is referred to as the self-calibrating process.

The accelerometer, or sensor, is housed in a small case which is weighted down or clamped firmly in a vertical position inside the trunk of the vehicle. Similar to the SDP, the accelerometer measures the vertical acceleration of the vehicle. The signal from the accelerometer is transmitted to the main control module where it is digitized and processed.

The WRD, in general, is a compact device which can be installed and operated in most any vehicle. It is simple to use and can be operated by only one person. Its cost is inexpensive compared to the SDP's and is not much more than the cost of the MRM with trailer.

CHAPTER 3

FIELD IMPLEMENTATION ACTIVITIES

Introduction

As indicated, extensive data runs using the SDP and SIometer were performed by D-10 personnel during the year. As these measurements were taken, various corrections, modifications and or operational changes were made by project personnel to provide more accurate measurements. Descriptions and results of many of these activities are provided in the following sections. Few statistical methods were employed on the data as this was not a planned objective.

PSI Measurements On Austin Test Sections

When the first Profilometer was obtained in the late 1970's a number of sections were selected in the Austin area to monitor the operation of the equipment. These sections, which were approximately 0.2 miles in length, were selected to represent a cross section of typical roughness types. The sections have been monitored over the years. Sections have been replaced or added as needed. In addition to playing a major role in checking the proper operations of the SDP, they have also been used for correlating the MRM and more recently, the WRD. Table 3.1 provides a history of the various PSI measurements obtained from the SDP over the past several years. This history has been used in this and the previous project for comparing measurements obtained from the old system with those from the upgraded one. As explained in the project report [Ref 1], the PDP1134 system sustained major damage and the new system was implemented without being able to directly compare profile measurements from the old and new systems. Thus, the PSI measurements and root mean square values for the various wavelengths from these previous measurements, were used as the primary method to determine if the old and new systems were giving similar results. Table 3.1 illustrates the PSI measurements for sections the last time the data was run with the PDP1134 system and with the runs made with the upgraded Compaq computer system. It also illustrates the runs made with the laser probes.

Table 3.2 provides two different runs using the road following wheels and the laser probes made in February 1987. Figure 3.1 illustrates the history of SDP runs using the

Table 3.1
PSI History Austin Test Sections

SEC.NO	LASER JUN '87	LASER FEB '87	<NEW SDP WHEELS AUG '86	OLD SDP> WHEELS APR '86	WHEELS JAN '86	WHEELS OCT '85
1	2.29	2.29	2.20	2.11	2.08	1.98
2	1.65	1.69	1.20	1.74	1.74	1.86
3	3.73	3.41	3.10	3.16	2.92	3.12
4	1.70	1.76	1.50	1.37	1.47	1.31
6	1.97	1.92	2.30	2.15	2.09	2.28
7	4.52	4.15	4.20	4.60	4.57	4.56
8	3.44	3.31	3.00	3.52	3.47	3.18
9	3.65	3.55	3.40	3.98	3.24	3.19
10	----	4.22	4.30	4.40	4.32	4.28
11	3.04	3.00	2.60	2.67	----	1.57
14	4.04	4.12	3.80	4.03	3.98	3.87
15	4.15	3.92	4.10	4.14	3.99	3.96
19	3.95	3.95	4.00	4.15	4.10	4.08
23	4.08	3.83	4.20	4.01	3.82	3.79
28	3.34	3.45	3.30	3.13	3.08	3.05
30	2.13	2.35	2.10	2.12	2.13	2.30
31	3.42	3.27	3.00	3.36	3.16	3.07
32	4.58	4.24	4.40	4.41	4.33	4.26
33	4.59	4.39	4.30	4.30	4.31	4.12
34	4.46	4.21	3.50	3.76	3.79	3.61
35	2.79	2.48	2.40	2.73	2.64	2.69
36	4.56	4.18	3.80	4.45	4.40	4.26
37	4.45	4.24	4.40	4.44	4.32	4.30
38	2.76	2.58	2.80	2.88	----	1.18
40	3.83	3.40	3.70	3.76	3.61	3.66
41	4.05	3.46	3.50	3.41	3.35	3.25
44	1.22	1.30	1.70	1.15	1.18	1.16
55	3.12	2.91	3.00	2.96	3.01	2.86

Table 3.2
Lasers Vs. Wheels February 1987

SEC.NO	WHEELS FEB'87	LASER FEB '87
1	2.60	2.29
2	1.90	1.69
3	3.40	3.41
4	2.00	1.76
6	2.30	1.92
7	3.80	4.15
8	3.40	3.31
9	3.60	3.55
10	4.40	4.22
11	2.90	3.00
14	3.90	4.12
15	4.10	3.92
19	3.90	3.95
23	4.00	3.83
28	3.20	3.45
30	2.20	2.35
31	3.20	3.27
32	4.50	4.24
33	4.60	4.39
34	4.40	4.21
35	2.60	2.48
36	4.30	4.18
37	4.20	4.24
38	2.70	2.58
40	3.60	3.40
41	3.40	3.46
44	1.30	1.30
55	3.10	2.91

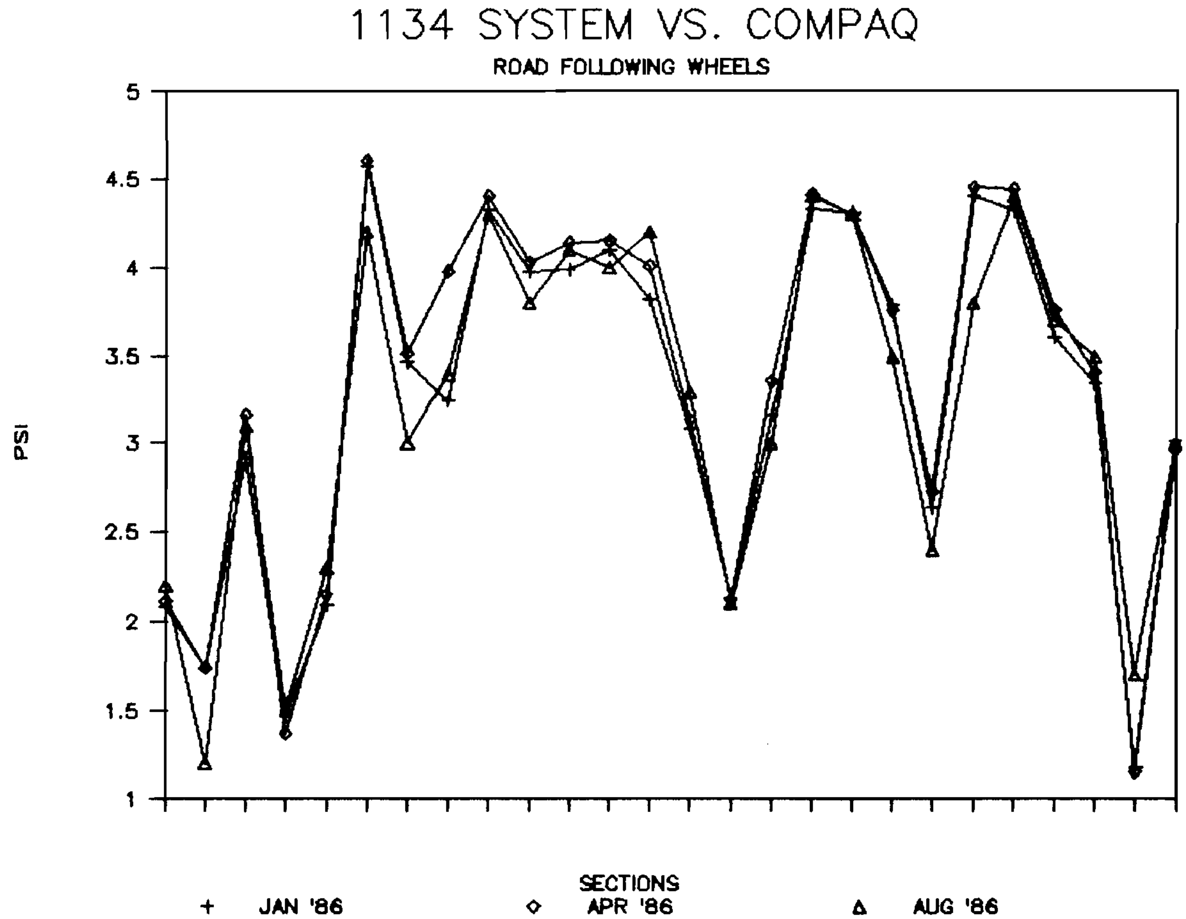

Figure 3.1

1134 System Vs. Compaq

original PDP1134, the road following wheels with the Compaq computer system, and the Laser probes with the Compaq system. Figure 3.2 illustrate graphically the data in Table 3.2.

More recently, the Austin sections have been run at 50 MPH and PSI values compared with the 20 MPH values. These results are indicated in Table 3.3.

At the latter part of the project, rod and level measurements were made on three sections. These sections were then run with the SDP. Initial examinations indicated a close relationship in the measurements.

<u>Old Vs. New PSI Equation</u>

In 1984, a new rating session was conducted by the Center for Transportation Research at the University of Texas at Austin (See TSDHPT Project 394 Project Report). A new PSI model was developed from this research. The PC Vertac program (described in Ref 1), was modified to provide both the old PSI measurement and the new. Figure 3.3 illustrates the results of comparing the new and old PSI equations with the upgraded system. It was noted, and which is also indicated from this figure, that the two did not provide very similar results. In fact, the new model appeared to provide less sensitivity to roughness measurements. To insure that the upgrade wasn't incorrectly reporting these differences, old profile measurements available from previous PDP1134 measurements on the Austin test sections were obtained and the old and new equation compared from this data. Figure 3.4 illustrates these results for a number of these old profile runs on the Austin sections. As can be observed from these two figures, similar results were obtained. The slope coefficient of the runs in Figure 3.3, was found to be 0.37 with a standard error of estimate of 0.05. The data from the 1134 system illustrated in Figure 3.4 provided an estimated slope of 0.46. Assuming this system provided the correct estimate of the true population or model slope, this estimate is found to be within the 95% confidence interval of the model of Figure 3.3. That is, for 24 degrees of freedom, and 95% confidence, the upper limit of the estimate of the true model slope of Figure 3.3 is 0.47. Of course, the 0.46 estimate would also include confidence limits which makes any differences even more statistically insignificant.

At present all PSI runs made by TSDHPT are with the old PSI model. The comparison was investigated as an additional test on the measurements provided by the old and upgraded systems.

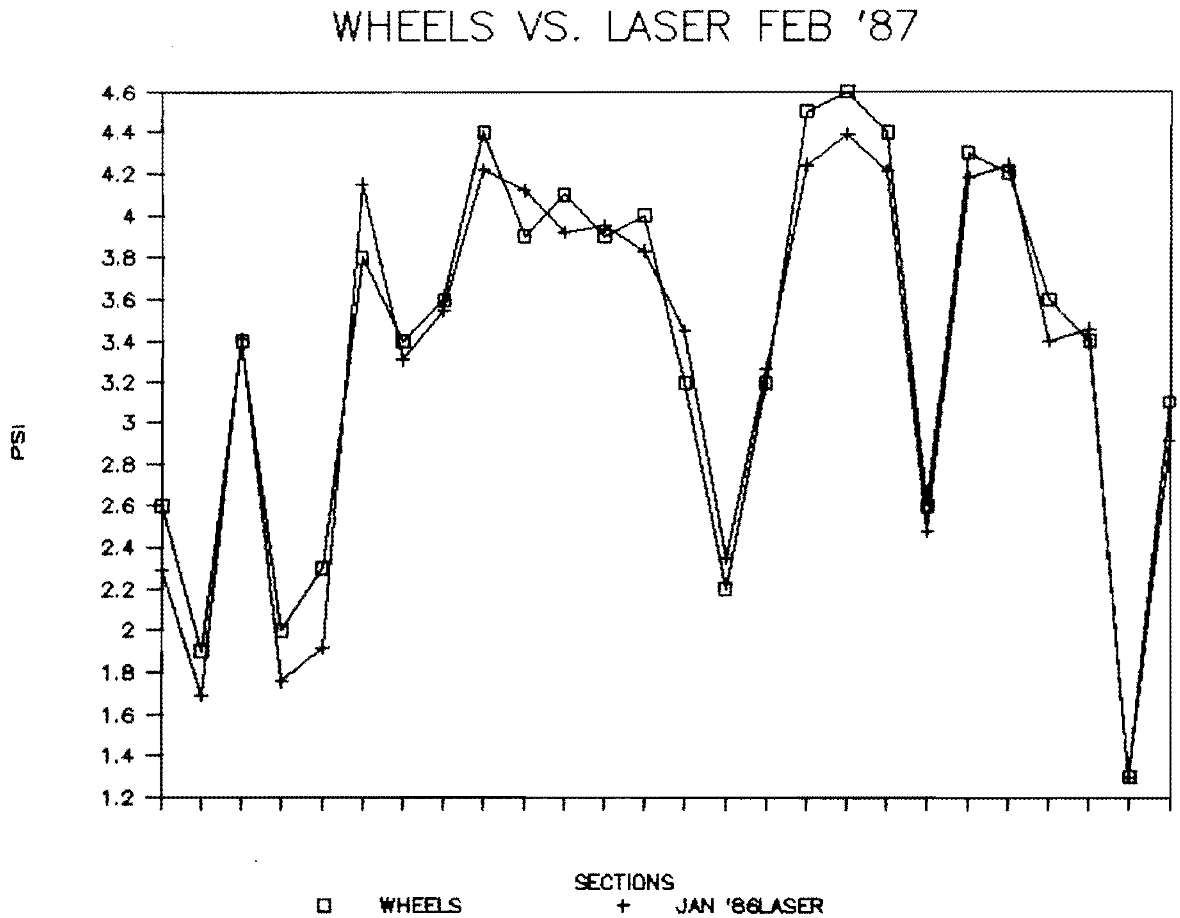

Figure 3.2

Wheels Vs. Laser Feb'87

Table 3.3
Comparison of PSI at
20 and 50 MPH

SECTION	20 MPH AVG	50 MPH AVG
1	1.90	2.09
2	1.72	1.80
3	3.85	3.79
4	1.81	1.60
6	1.80	1.89
7	4.41	4.30
8	4.05	3.90
9	3.71	3.52
11	2.97	3.12
14	4.14	3.96
15	4.09	4.09
19	3.96	3.89
23	4.10	3.95
28	3.35	2.84
30	2.33	2.36
31	3.56	3.60
32	4.07	4.10
33	4.57	4.51
34	4.55	4.36
35	2.84	2.84
36	4.60	4.56
38	2.61	2.66
40	3.75	3.81
41	3.93	4.13
44	1.34	1.33
55	3.35	3.23

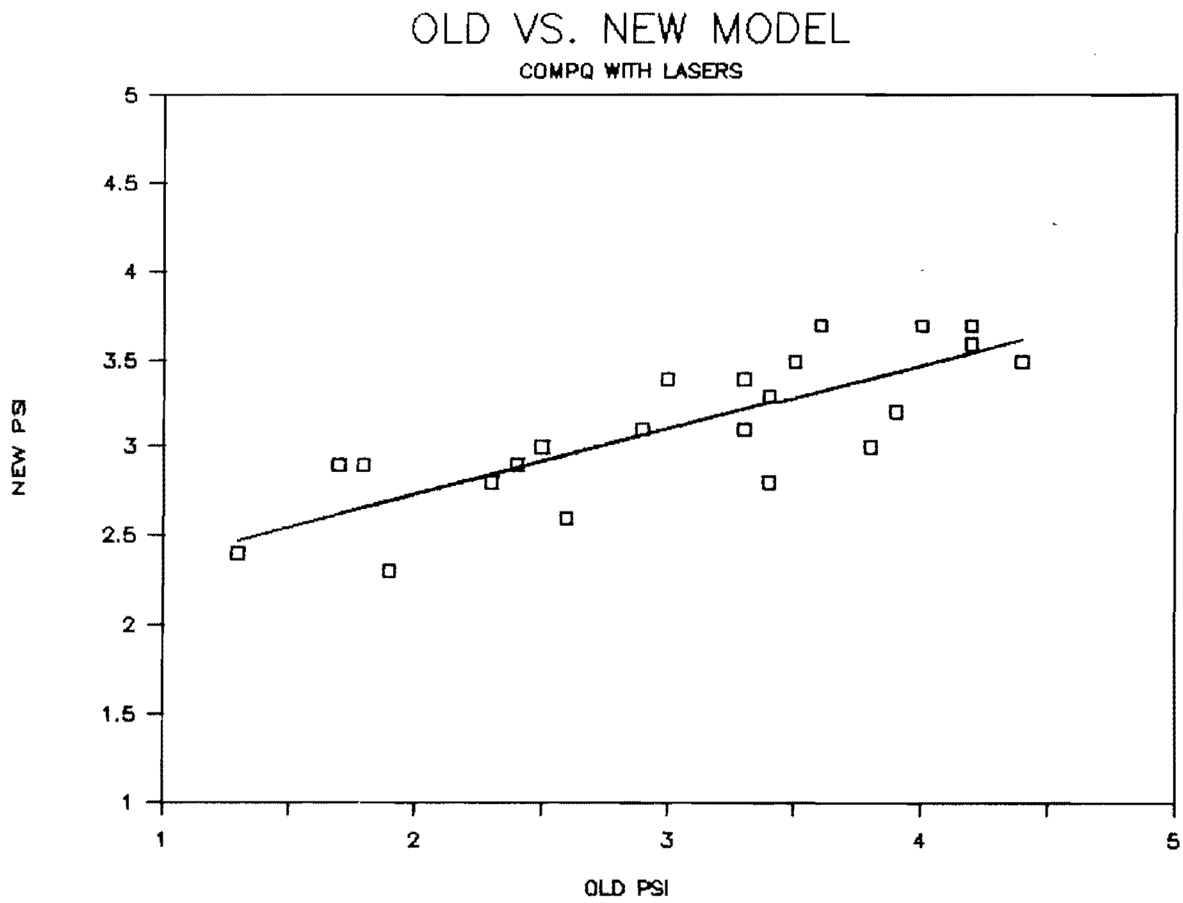

Figure 3.3

Old Vs. New Model

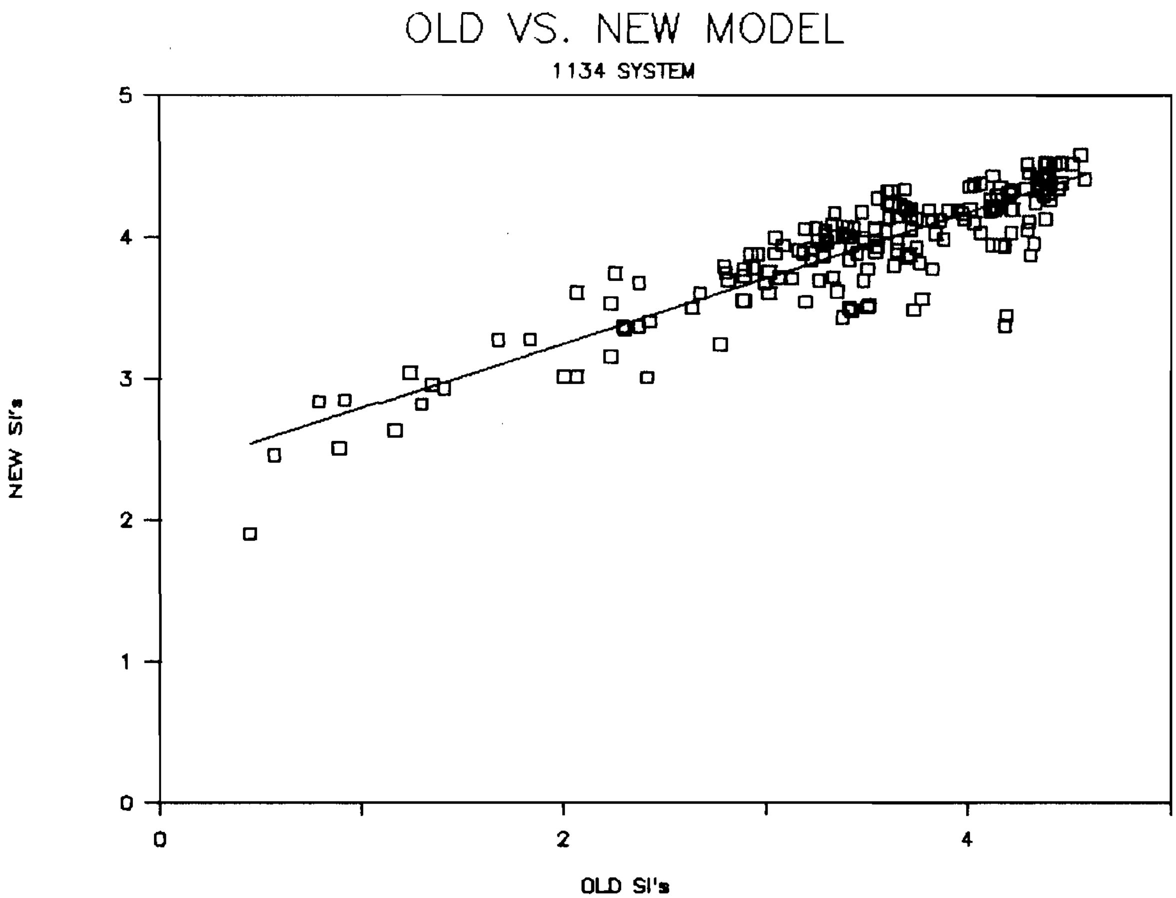

Figure 3.4

Old Vs. New Model (1134 System)

Correlations of PSI with California and Rainhart Profilograph

A correlation study between profile index from the California and Rainhart profilographs, and PSI from the SDP was performed during the past year. The results of the study is presented in reference 10. The measurements made with the SDP were with the upgraded laser based system.

Forty-one rigid pavements sections of 0.2 mile length were selected for the research. These sections were selected from roads in the Angleton, Beaumont, and Dallas areas of Texas. Each section was run by all four roughness measuring devices. The general geographical section location and name given to each section can be found in the above referenced report.

Table 3.4 provides the processed measurement values. The table provides the profile index of each profilograph for the 0.1 and 0.2 inch blanking bands. The profilographs were run only once on each section. The PSI readings from the SDP are the average of two and three readings. The average of three runs were used for the WRD except for the Beaumont sections. For these sections, only one run was made. The slope variance readings from the WRD are unscaled (The WRD provides these values along with SI). Measurements from the WRD were made at 50 MPH. Since three of the sections could not be used at this speed only 38 sections were used for the WRD data.

The study included the development of mathematical models of the two profilographs and a comparison of the actual profilograph output and the output predicted by the model. The model used the profile from the SDP to compute the predicted profilograph output and corresponding profile index. The actual profilograph traces taken from the same sections are compared to the model's predicted traces. Several recordings were made using both profilographs. Since it is difficult to get all profiles under each wheel of the profilograph for the model, the same profile measured and computed from the SDP were used as the real profile for all wheel paths.

Figure 3.5 shows a recording from the California profilograph, SDP measured profile and the result generated from the mathematical model. The profiles computed from the SDP are also shown in the corresponding figures (SDP computes two profiles in one run. The results presented are computed using profile from the SDP for sample rates of 2 and 10 samples per foot. The Profile Index was also computed for each result using a 0.2 inches blanking band for the California device and 0.1 inches for the Rainhart

Table 3.4
SDP-WRD-Profilograph Correlation Measurements

SECTION NAME	SDP PSI	PROFILOGRAPHS CALIFORNIA BB=0.1	CALIFORNIA BB=0.2	RAINHART BB=0.1	RAINHART BB=0.2	WRD SV	WRD SI
A1A	2.11	111	93.3	81.07	77.14	2835	2.12
A1B	1.84	70.75	60.75	47.25	26.5		
A2A	4.44	7	3	2.5		176	4.33
A2B	4.22	5	2.25	1.75	0.75	232	4.11
A2C	4.21	10.5	4.25	2.75	0.25	249	4.05
A2D	4.28	10.75	3.75	3.25		245	4.06
A2E	4.32	4.75	2	2.75	0.5	205	4.27
A3A	4.17	10.25	2.25	3.5	0.5	205	4.27
A3B	3.99	12.25	7	5.56	1.4	81	3.89
A3C	4.1	13	4.5	4.25	0.5	192	4.26
A3D	4.22	14.75	9.5	7	1.5	148	4.46
A3E	4.16	11.5	2.75	3.75	0.25	169	4.36
A4A	3.88	15.5	6	6.25	0.5	254	4.04
A4B	4	11.25	5.25	3.25	0.25	227	4.12
B1	2.68	51.5	42.25	45.25	27.75	811	3.11
B2A	2.71	78.5	61.5	53.25	37.8	1601	2.57
B2B	3.11	73	55.5	50.5	34.8		
B2C	2.63	78	63.75	56	40	2433	2.24
B3A	2.9	38.5	26.25	32.5	12.5	934	3
B3B	2.87	44.25	29.75	34.5	9.75	764	3.16
B3C	2.73	39.75	26.5	27.5	13.25	612	3.34
B4	2.16	90.5	72.25	60.25	39.5		
B5	3.49	34.5	23.5	17.75	8	555	3.41
B6A	3.6	31.5	21.25	17	7.75	539	3.44
B6B	3.84	35	24	27	8.25	554	3.42
B7A	3.01	42.25	24.5	17.75	7.5	1006	2.94
B7B	3.03	42.75	28.25	26.25	13.75	757	3.17
B7C	3.16	46.75	30.5	22	7.5	724	3.2
B8A	3.21	30	19.5	15.75	9.5	688	3.24
B8B	3.14	28	17.5	13.25	10.5	453	3.58
B8C	3.22	26	18.75	13.6	5.5	631	3.31
D1A	3.79	19.5	11.5	9.75	2.75	524	3.68
D1B	3.7	22.5	12.25	10.25	2.25	1521	3.6
D1C	3.85	18.75	12	10.5	3.5	1120	3.85
D1D	3.9	21	16	9.75	1.25	651	3.92
D1E	4.02	18.75	9.75	8.75	2	302	4.02
D2A	4.51	10.75	5	3.25	2.5	295	4.37
D2B	4.58	9.25	3.75	1.5	1.25	204	4.5
D2C	4.54	6.25	1.75	1	0.25	180	4.3
D2D	4.15	18.5	9.75	7	3.25	317	3.93
D2E	3.97	17.25	9	6	1.75		3.64

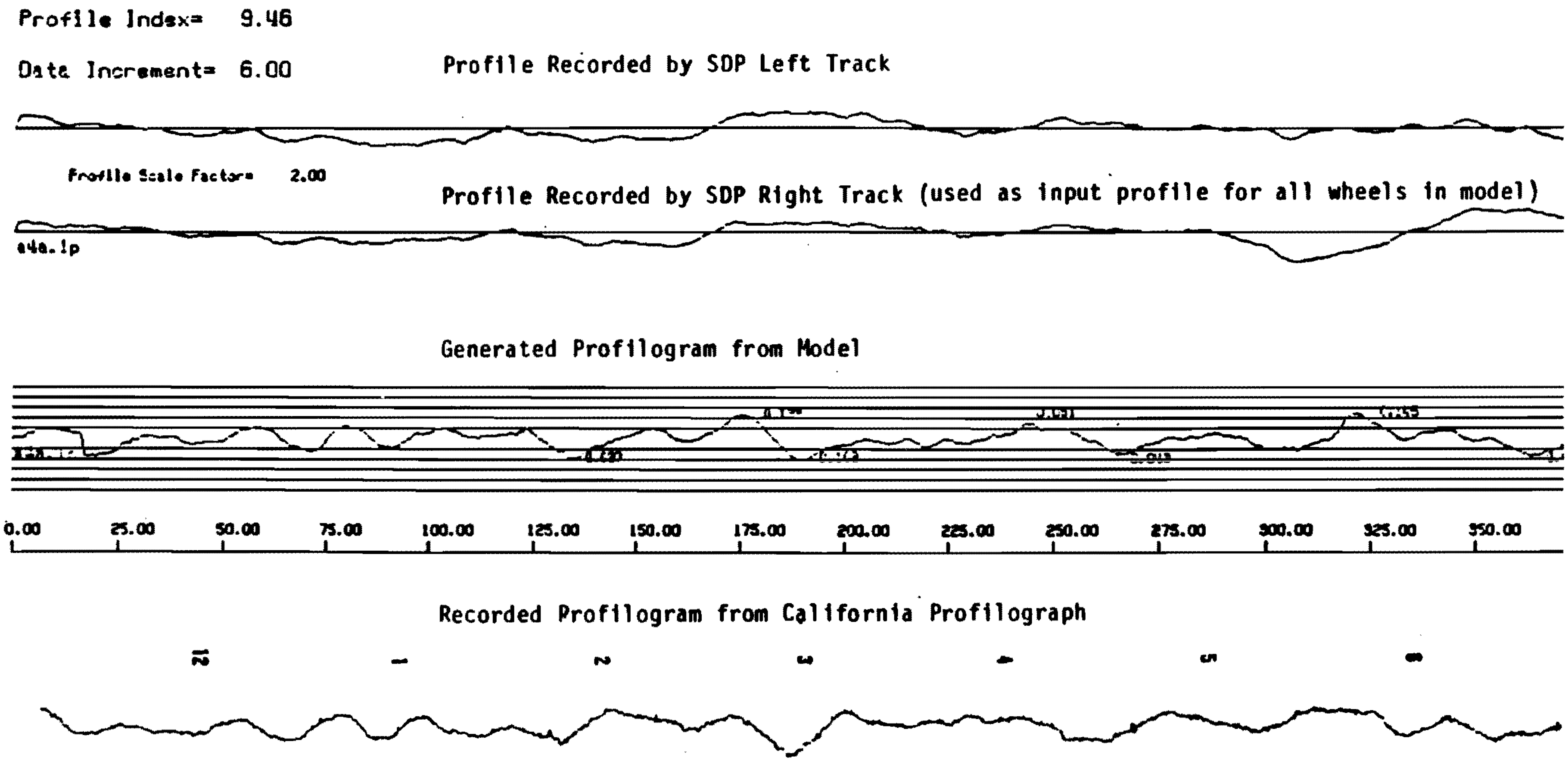

Figure 3.5

Actual and Predicted Profilograph Measurements profilograph.

The mathematical model produced a trace similar to the profilograph recording. The accuracy of the discrete profile fed into the model is the major factor influencing the results. That is, the greater the sample per foot resolution of the profile data used, the better the comparison. The models were used to compute the profile index for all 41 sections and compared to the actual measurements. In general, the results from the computer model are comparable to the real profilograph recordings.

Also computed in the project were the power spectral estimates of the road profile data of these sections, grouped according to PSI. The plot is illustrated in Figure 3-6. The spectral density values appear to be in the same general range of those found by other Profilometers [Ref 11].

A good correlation was found between PSI from the SDP and the profile index from the two profilographs. For all the sections investigated the California profilograph correlated slightly higher to PSI than the Rainhart. The Rainhart profilograph using the 0.1 inch blanking band gave the best results for the smoother pavements.

A good correlation was also found between SI and the slope variance statistic provided by the WRD and the profilographs, as well as, with the SDP (See Figure 3.7, also Ref 10).

Mays Ride Meter Usage

As noted earlier, a major function of the SDP is providing the PSI standard for roughness measurements in the State. The PSI obtained from the SDP profile measurements is used to calibrate the MRM and WRD. It's usage for such applications were successfully continued during the year. It was used in one study conducted by the Department to investigate MRM variations.

Although the inches per mile displacement of the MRM is highly correlated to PSI during calibration, maintaining this high correlation is often a problem, thus not always providing accurate SI measurements. To monitor the MRM devices in operation, several of the devices were brought back to Austin and run over the Austin sections. They had all been calibrated earlier during the year. Table 3.5 provides a list of the residuals of the predicted and actual PSI as measured by the SDP. One of the MRM was found to be inoperative and thus not shown in the figure. The importance of following the control procedures set up by the Department was indicated by the

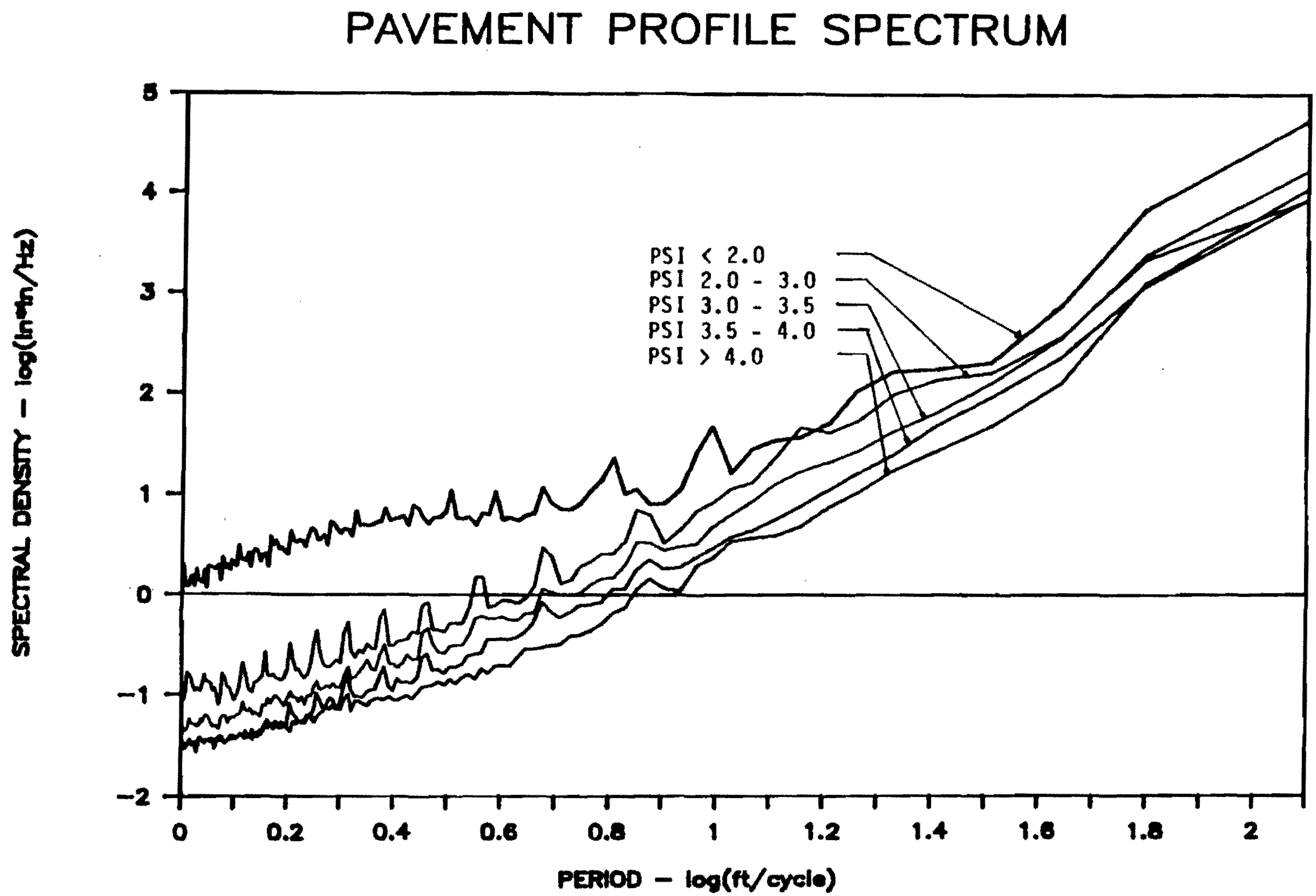

Figure 3.6

Pavement Spectral Density

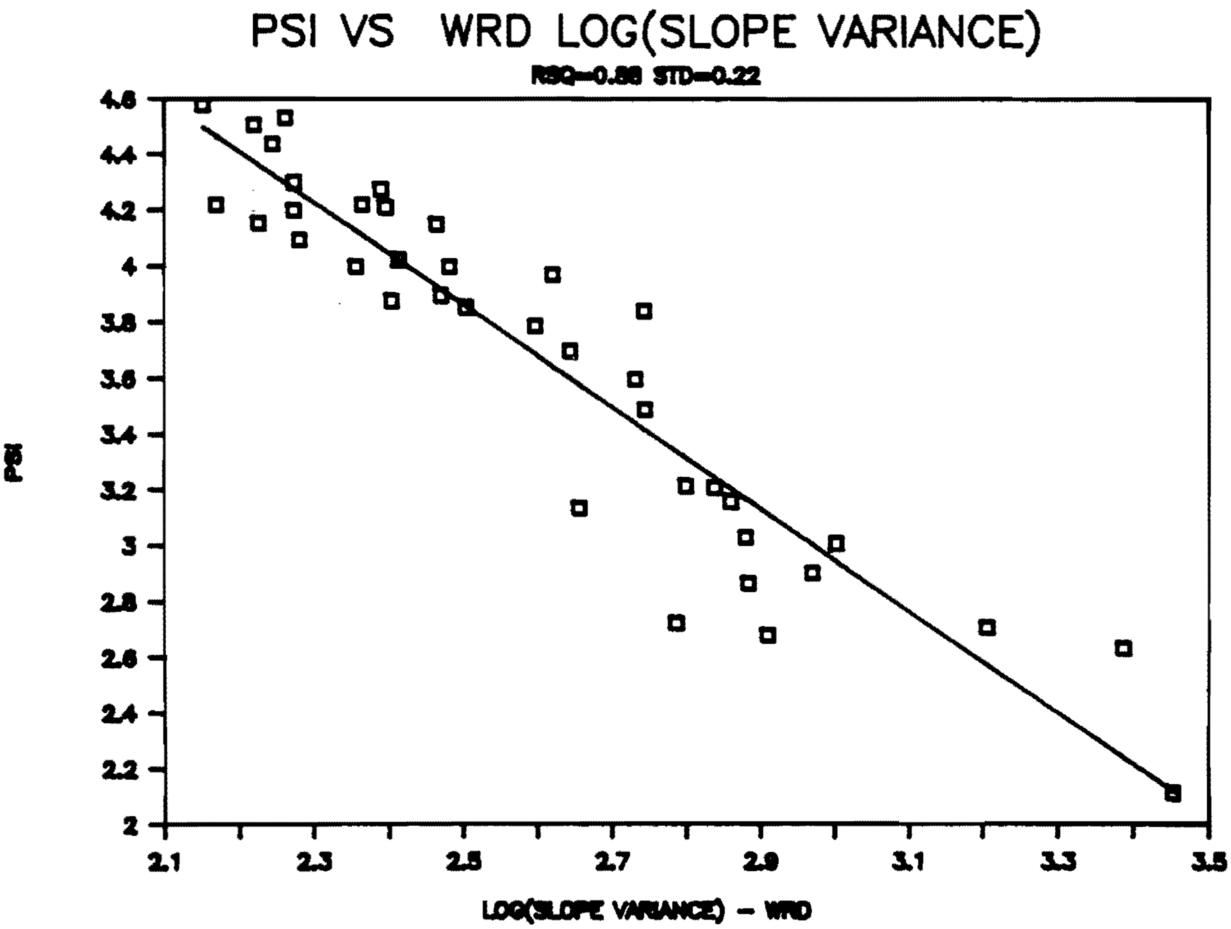

Figure 3.7

PSI vs. WRD log(Slope Variance)

study. The SDP is useful for providing reliable and consistent PSI measurements.

Multiple runs using the WRD in the same Vehicle

During the spring of 1987, five different siometers were each run over ten of the Austin test sections. Each unit was first placed in a 1985 Celebrity, and the dynamic calibration process performed. The SI from the average of three runs were then recorded. The SI values are depicted in Figure 3.8 and given in Table 3.6.

During last year, [Ref 2], the SIometer was continuing run over the Austin test sections to monitor it's repeatability. It was found to give consistent results, both in a 1979 Ford and 1985 Celebrity. Recall that the Austin sections are 0.2 mile in length and the SIometer was originally correlated to the sections two years earlier. In the Spring of 1987, the SIometer was taken to Lufkin to run over several sections of more than 0.2 mile in length. Some of the sections were one mile in length, others longer. It was found that the SIometer or WRD provides consistent results for the Austin test sections, and for sections which are 0.6 mile and longer, where the individual 0.2 mile sections are averaged over the various lengths. For example, Table 3.7 provides the continuous measurements made over a number of the longer sections, where the SI values given are the average of one and two mile consecutive 0.2 mile sections. Variations between repeat runs, even at later dates, were generally found to be about 0.1 to 0.2 of each other. However, the individual 0.2 mile sections could often be 0.5 or more from each other. This same range of SI variation would again be noted later, when tests were being performed on multiple runs between different WRD devices in different cars. Since the additional WRD devices were purchased for PES and as such, measurements are recorded for each 2 mile segment, this characteristic is not a problem. However, it would not be a desirable feature for uses of the SIometer for tight controls on newly constructed pavements, etc.

It has been conjectured that this variation is probably because of the way the SI values are computed. Recall that the primary statistic used by the WRD for predicting PSI from the SDP is a slope variance. Slope variance was selected during the first research efforts [Ref 7] as it could easily be computed in real-time, necessary for continuous SI measurements. However, models used with slope variance during the original rating session [Ref 5] were found to give similar variations between repeat runs when used with the original Table 3.5

Table 3.5
SDP - MRM
SI RESIDUALS

JUNE 1986

SECTION	PSI	Mays Ride Meter 1	2	3	4
55	3.0	-0.7	0.2	0.3	0.4
44	1.1	-0.4	-0.7	0.0	-0.1
35	2.7	-0.4	2.0	0.0	-0.3
36	4.4	0.2	-1.2	-0.3	-0.3
30	2.1	-0.2	0.3	-0.1	0.1
5	3.6	2.5	0.7	0.7	0.6
4	1.4	-0.4	-0.8	-0.3	0.1
3	3.2	-0.3	0.2	-0.1	0.0
6	2.1	-0.4	-0.4	0.1	-0.2
2	1.7	-0.2	-0.3	-0.1	0.0

Residuals

Mays Ride Meter 5	6	7	8
-0.1	0.1	0.2	0.3
-0.1	-0.3	-0.1	-0.2
0.1	0.2	0.2	-0.3
0.0	-0.4	-0.2	-0.3
0.4	0.3	-0.2	-0.7
0.1	0.6	0.5	0.6
0.0	-0.1	-0.2	-0.3
0.1	0.2	1.0	0.1
0.1	-0.1	-0.3	0.0
0.0	0.0	-0.2	0.1
-0.4	-0.4	0.0	0.0

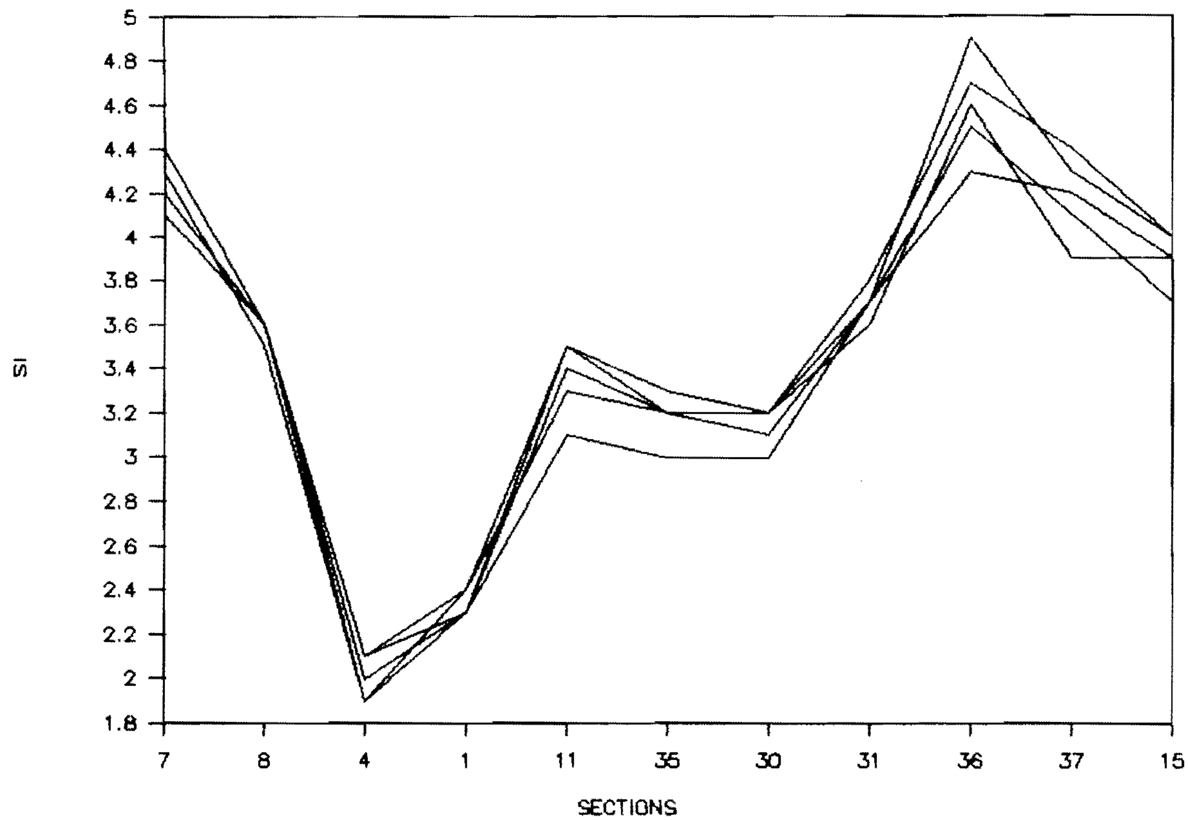

Figure 3.8

Multiple WRD Runs

Table 3.6
Multiple WRD Runs

SIOMETERS

514	515	516	517	1
4.2	4.2	4.1	4.3	4.4
3.6	3.6	3.6	3.5	3.6
1.9	2.1	2	1.9	2.1
2.4	2.3	2.3	2.3	2.4
3.3	3.5	3.1	3.4	3.5
3.2	3.2	3	3.2	3.3
3.2	3.2	3	3.1	3.2
3.6	3.8	3.7	3.7	3.7
4.6	4.7	4.5	4.3	4.9
3.9	4.4	4.1	4.2	4.3
3.9	4	3.7	3.9	4

Table 3.7
Continuous WRD Runs

JUNE-JULY 1987

SH103 1 MILE SECTION

6/16/87	6/17/87	6/30/87	COMMENTS
3.4	3.4	3.4	
3.9	3.7	3.7	(HEAVY TRAFFIC)
3.6	3.5	3.7	
3.6	3.9	3.6	
3.7	3.5	3.3	(BRIDGE)

FM1277 1 MILE SECTIONS

6/16/87	6/30/87	7/1/87
3.4	3.3	3.3
3.4	3.2	3.2
3.6	3.7	3.4
3.7	3.5	3.5
3.1	3.2	3.2

US69 (LUFKIN) 1 MILE AVERAGE

6/19/87	6/30/87	7/1/87
4.2	4.2	4.1
4.1	4.1	3.8
4.3	4	4.1
4.2	4.2	4.2
4.3	4	4.1

FM2109 (LUFKIN) 1 MILE AVERAGE

6/16/87	6/30/87
2.8	2.9
2.8	2.7
3.3	3.2
3.4	3.1
2.8	2.9

US 59 (LUFKIN) 2 MILE AVERAGE

6/17/87	6/17/98	6/17/87	6/30/87	7/1/87
4.2	4.3	4.4	4.2	4.3
4.6	4.7	4.5	4.4	4.5

SH94 (LUFKIN) 2 MILE AVERAGE

6/16/87	6/30/87	7/1/87
3.6	3.5	3.6
3.7	3.6	3.6
4.2	4.2	4.1

profilometer. The second major problem in the way the Siometer computes SI is that in the manner the high pass filter is implemented, necessary in order to remove the long wave lengths(hills and errors introduced in the accelerometer). In order to minimize the complexity and time requirements of the SI computations, the initial filter coefficients are initialized to zero for each 0.2 mile section. That is, for each 0.2 mile section measured, the first 200 feet or so is affected by the response of the filter as it is abruptly reacts to acceleration values differ from zero. This same characteristic is also noted in the SDP, however, the SDP adjusts for this by allowing the filter to settle before measurements begin. Since the first usage of the SIometer was for the 0.2 mile Austin sections, and since the roughness characteristics for these sections are essentially the same before the section as within the section (homogeneous roughness), this response was built in and accounted for by the regression or correlation procedures. However, for other sections not having such homogeneous characteristics, any differences in the way the vehicle is responding at the time the section measurement begins, will tend to make the SI value very sensitive. These differences tend to average out in the longer sections.

Speed Variation Studies

One major objective of the implementation project was to try to minimize WRD measuring speed variations. The variable speed algorithm wasn't implemented until the end of the project and therefore only a few tests were conducted to determine it's usefulness. Five sections were each measured at speeds of 30, 40, 50 and 60 MPH. For the 0.2 mile sections little differences were noted, the greatest occurring at 30 MPH. During measurements made at the Profile Measurement Conference in Colorado, no differences were noted for the 0.6 and 0.8 mile sections. Additional research is needed, however, to further investigate the method used for speed corrections.

New Correlation with SDP

Figure 3.9 illustrates the correlation of the new WRD units with the SDP. This new model was necessary as the model developed in the fall of 1985 was done so with an accelerometer with a different voltage level for acceleration measurements than used with the newly purchased devices. The current model is the one being used for the 1987 PES measurements. Additionally, in the original model the accelerometer was held down in the trunk by a sand bag. For this data, the unit was clamped firmly to the trunk. Because this introduced higher frequency engine noise and other

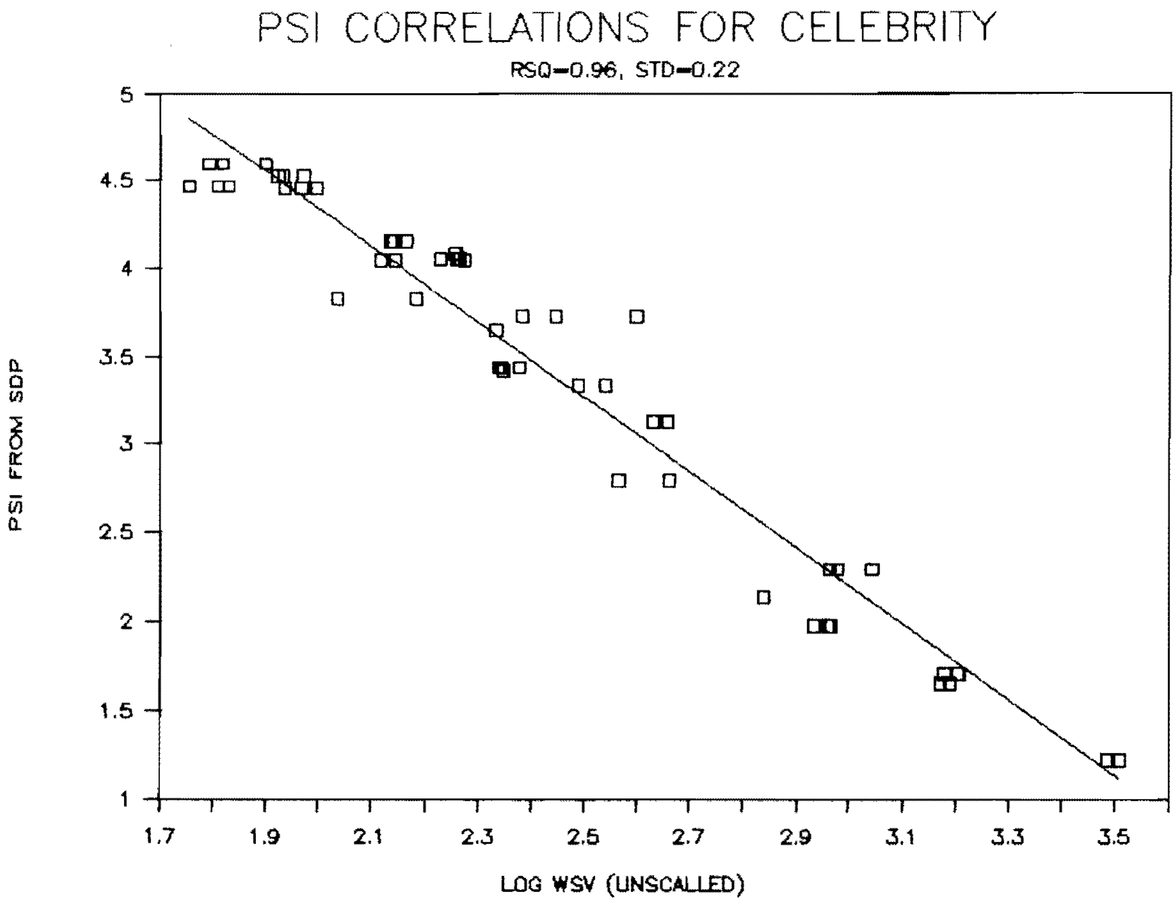

Figure 3.9

WRD - SDP Correlation

vibrations not felt when sand bagged, a new model had to account for these frequencies. The results of the correlation is indicated in the figure.

Predicted Profile

The WRD provides roughness statistics from an estimated profile. Since initially, profile was not desired by the TSDHPT it was not provided by the current units. However, as usage of this device has increased, there has become a desire to collect the profile signature. It is anticipated, that the newer versions of the WRD will provide an estimated profile. Such data could be used for those applications requiring much greater resolution than the current 0.2 mile average SI measurement.

CHAPTER 4

SUMMARY AND CONCLUSIONS

The Surface Dynamics Profilometer was upgraded to include non-contact or laser probes. The SDP has been successfully used with these non-contact probes during the past year for periodic measurements of the Austin Test sections. The system has been used for other various profile and roughness measurements. Comparisons of PSI from sections measured with the non-contact probes and the road following wheels have indicated little differences. The system has been successfully used for other various profile and roughness measurements. Some problems have been found in long continuous profile measurements.

The SDP was successfully used in a correlation study between PSI and profile index obtained from the California and Rainhart Profilographs. The non-contact probes were used in this study. Recent runs have been made with the SDP at 50 MPH and initial comparisons with the 20 MPH measurements have indicated similar results.

Two of the self-calibrating roughness units were used in the last phases of the 1986 PES roughness data collection with good results. Slight modifications to the measurement procedures were made for implementation in the 1987 PES data collection. Six of these roughness units will be used in the 1987 data collection. The interface software has been improved by both project and D-18 personal to provide for quick transfer of roughness data files from the unit to the main-frame computer used for PES.

A more complete PSI correlation model has been developed. Program modifications have been made to allow for variable measurement speeds between 30 and 55 MPH.

Improvements to the SDP are still needed for its ability to measure long data sections. The WRD currently uses an estimate of slope variance for it's primary roughness statistic. This measure has been found to be more sensitive to variations than root mean square. The WRD needs to be investigated to determine if the root mean square of the second derivative of the predicted profile would be a better statistic.

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