

Comparative Testing of Strategic Highway Research Program Profilometers

WILLIAM O. HADLEY AND HARVEY ROPER

The comparative testing workshop conducted among the Strategic Highway Research Program (SHRP) profilometers in Austin, Texas, during the week of February 12 through 16, 1990, is described. The workshop involved roughness measurements of six test sites at two different speeds by the Law profilometers from the four SHRP regions. The test sections were selected as representative of smooth, medium, and rough sections. The test program consisted of five individual runs by each profilometer for the two speeds on the six test sections. The testing revealed several data anomalies in the results from the profilometers including random and systematic sensor separation and lost lock. The results contain information that can be useful in interpreting the output of the Law profilometer in the development of surface profile data and pavement roughness IRI Law values. Finally, the experimental design used in the comparative testing, analysis performed, results generated by the analysis, approach to consideration of data anomalies, and recommendations for further studies are discussed.

Comparative testing of the four Strategic Highway Research Program (SHRP) K. J. Law profilometers was undertaken in a February 1990 workshop conducted in the Austin, Texas, area. Four profilometers representing the four SHRP regions participated in the workshop. The testing program was structured as a statistically designed experiment so that an analysis of the workshop results could be used to establish compatibility of the profilometer results, as well as to authenticate those factors (i.e., speed, roughness, vehicles) that significantly influence profilometer results.

THEORY OF OPERATION

The road profilometer uses a noncontact light sensor system to measure the distance between the vehicle frame and the road surface. The profilometer is equipped with two sensors, one in each wheel path. The sensor is composed of a light source, a light receiver, and an electronic enclosure. The light receiver uses a rotating scanning mirror assembly for detecting signals in measuring the road profile.

The relative displacement between the vehicle and the road measured by the noncontact light sensor is one input to the profile equation. The other input is the vehicle motion in the vertical direction, which is provided by a precision servo balanced accelerometer. The difference between the vehicle displacement and the relative motion between the vehicle and the road surface provides the actual raw road profile output.

TEST PROGRAM

The experimental design originally proposed for the profilometer workshop is shown in Figure 1 and includes the factors of profilometer, test section, pavement condition, and vehicle speed. Six 1,056-ft-long test sections were selected from the Austin, Texas, area as representative of smooth (Sections 42 and 43), medium (Sections 31 and 36), and rough (Sections 1 and 4) pavement conditions. General information concerning these test sections is presented in Table 1.

The test program consisted of five individual runs by each profilometer for each cell of the factorial (Figure 1). Because of scheduling considerations, the five runs were performed in two rounds. The first round was completed on February 12th and 13th, the second round on February 15th. The order of section profiling and vehicular speed was selected randomly while all profilometers were directly along the test sections using a left wheel path marking and a wheel path separation of 65 in.

Before initiation of the comparative testing workshop, the six sections were surveyed using a combination of two methods: (a) rod & level survey, and (b) dipstick. Dipstick profile measurements were completed on all six test sections, whereas rod & level profiles were only developed for three test sections, i.e., Sections 4 (rough), 36 (medium), and 42 (smooth).

The rod and level profiles were used to confirm the capability of the dipstick in generating adequate profile results. Both sets of data (i.e., dipstick and rod & level) were analyzed with programs provided by the Face Corporation which produce a roughness measurement identified as the "international roughness index" (IRI) (in inches per mile). A comparison of the IRI values calculated from the results of the dipstick and rod & level surveys for Sections 4, 36, and 42 are shown in Figure 2. Because all points fall along a line of equality, the IRI values obtained from dipstick and rod & level profile measurements are considered comparable. The dipstick measurement values were subsequently used as a control in the comparison of the IRI results developed from the profilometer data.

BACKGROUND AND ANALYSIS LIMITATIONS

The workshop involved four profilometers with a variety of attributes (see Table 2). There were two types of vehicle chassis [van and recreational vehicle (RV)] and two sensor location spacings (65 and 54 in.).

The application of analysis of variance techniques may be limited for some of the desired profile indices because of these differences in vehicles. For instance, the average IRI for the

TABLE 1 GENERAL INFORMATION—
PROFILOMETER WORKSHOP TEST SITES

Section Designation	Relative Roughness	Comments
43	smooth	up grade
42	smooth	down grade
36	medium	down grade
31	medium	upgrade to level
4	rough	upgrade
1	rough	level to upgrade

ROUGHNESS (F)		SMOOTH		MEDIUM		ROUGH	
SECTIONS (R) *	VELOCITY (F)	1	2	1	2	1	2
1	35						
	50						
2	35						
	50						
3	35						
	50						
4	35						
	50						

(F) = Fixed (R) = Random

FIGURE 1 Proposed experimental design—Profilometer Workshop, February 1990.

two wheelpaths (i.e., average of left and right sensors) cannot be adequately considered in an analysis because the right wheel path is not coincident for all profilometers because of the variation in sensor spacing. Because all profilometer operators were instructed to line up the left wheel with the left path markings, the indices that can be investigated fully using the experiment design shown in Figure 1 are limited to the IRI values related to left wheel path information.

The experiment design required the generation of profilometer output at low (35 mph) and high (50 mph) vehicle speeds over six different road sections (i.e., Austin test sites ATS 1, 4, 31, 36, 42, and 43) with surface roughness considered to be rough, medium, and smooth. Each of the profilometers was scheduled to traverse every road section a minimum of five times at each vehicle speed. As the workshop activities began, it was established that the profilometers could not traverse the rougher roadway sections (i.e., ATS 1 and 4) at 50 mph without possible damage to the larger SHRP RVs; therefore, the high speed for these sections (ATS 1 and 4) was redefined as 45 mph.

The combination of these different factors (i.e., different sensor spacings, speed changes, and chassis type) required that a series of analyses be undertaken to segregate the vehicles and profilometer output into appropriate analysis groups. The University of Texas Center for Transportation Research personnel completed analyses of variance (ANOVA) of various forms of profilometer output for the two cases presented in Table 3.

The first case (i.e., ANOVA I) involved an analysis of the results for all four profilometers generated within the six test sections; the second case (ANOVA II) was structured to include the roughness measurements for all six test sections generated by the three essentially identical profilometers (i.e., profilometer Numbers 1, 2, and 3). The ANOVA results obtained for these two cases are presented in Tables 4 and 5.

The results of the analyses of variance (ANOVAs) indicated conflicting and perplexing conclusions. In both cases,

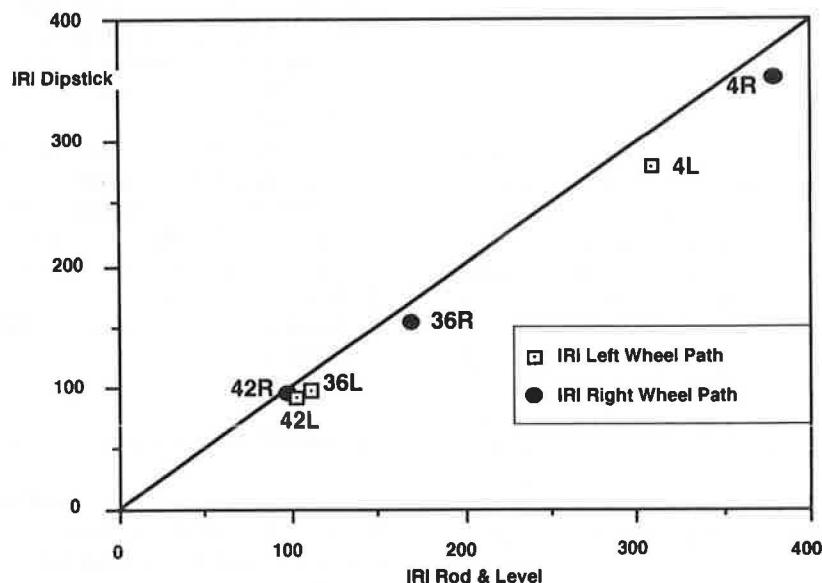


FIGURE 2 Comparison of IRI values generated by the Face dipstick and rod & level surveys.

TABLE 2 PROFILOMETER CHARACTERISTICS

NUMBER	AGENCY	VEHICLE	SEPARATION
		TYPE	BETWEEN SENSORS (inches)
1	SHRP-North Atlantic Region	Recreational Vehicle	65
2	SHRP-Western Region	Recreational Vehicle	65
3	SHRP-Southern Region	Recreational Vehicle	65
4	SHRP-North Central Region	Truck/Van	54

TABLE 3 SUMMARY OF THE IRI ANOVAS PERFORMED

ANALYSIS TYPE	VARIABLES	PROFILOMETERS	SECTIONS
I	LIRI, RIRI	1, 2, 3, 4	All
II	LIRI, RIRI	1, 2, 3	All

TABLE 4 SUMMARY OF THE RESULTS FOR ANOVA TYPE I FOR ALL FOUR PROFILOMETERS

SOURCE OF VARIATIONS	SIGNIFICANT VARIATION IN IRI	
	LEFT WHEEL	RIGHT WHEEL
Rough	Yes	No
Prof	No	No
Rough * Prof	No	Yes
Veloc	No	Yes
Rough * Veloc	No	No
Prof * Veloc	Yes	Yes
Rough * Prof * Veloc	Yes	Yes

TABLE 5 SUMMARY OF THE RESULTS FOR ANOVA TYPE II FOR PROFILOMETERS 1, 2, AND 3

SOURCE OF VARIATION	SIGNIFICANT VARIATION IN IRI	
	LEFT WHEEL	RIGHT WHEEL
Rough	Yes	No
Prof	No	No
Rough * Prof	No	Yes
Veloc	No	Yes
Rough x Veloc	No	Yes
Prof x Veloc	No	No
Rough x Prof x Veloc	No	No

the section roughness (R) was the only variable found to significantly influence the measurement of IRI values for the left wheel path (LWP) by the two combinations of profilometers (i.e., all four units and three identical units). On the other hand, main and combined effects of profilometer, section roughness, and speed appeared to significantly affect the measurement of right wheel path (RWP) IRI values by the profilometers. This latter result, if accepted, could be construed as an indication that the roughness measured by the profilometers was not only influenced by the roughness of the section, but also by the particular profilometer and the vehicular speed at time of measurement. From these results, it appears that the left wheel path (LWP) sensor measurements may be more stable than those for the right wheel path (RWP).

As a consequence, these ANOVAs were considered to represent an initial evaluation of the profilometer data from

the workshop because only raw data were investigated. In this preliminary phase, there were no attempts to alter the raw data on the basis of observer comments or the possible existence of data anomalies.

SATURATION DATA ANOMALY

Distortion to the noncontact light sensor output caused by application of an external light source to the detectors will cause the signals to saturate. Because of this distortion, the noncontact sensor electronics erroneously interprets the road profile as being closer to the vehicle than the actual road profile. This saturated noncontact signal is then combined with the accelerometer signal and distorts the output of the raw road profile as shown in Figure 3. This example of a saturation spike was extracted from a profilometer run on ATS 36.

LOST LOCK DATA ANOMALY

Another distortion of the raw road profile output is created when the road pulse signal is lost because of the change in road surface reflectivity. As the vehicle proceeds down the lane and the road surface changes from a high light reflective surface to a high light absorbing surface, the road signal pulse is greatly attenuated. In this instance, the noncontact sensor output then reduces to a zero or flat output and the resulting raw road profile output would only consist of the accelerometer output. An example of this type of data anomaly was observed during the same profilometer run on ATS 36 mentioned earlier and is shown in Figure 4. A saturation data anomaly also developed within about 50 ft of the location of the lost lock anomaly.

VARIABILITY IN PROFILE INDICES

The initial ANOVA results raised concerns about the relationships between the profilometer output (or roughness indices developed from profilometer output) and profilometer type, speed, wheel path, and road roughness. The unexpected variability in IRI values fueled the thought that random or systematic data anomalies had been generated during some of the profilometer runs.

Random data anomalies would be defined as those that occur in a random fashion and whose occurrence is not related to a particular vehicle speed, profilometer, wheel path, or test section. An example of randomly generated data anomalies can be observed in Figure 5, which shows a particular profilometer run completed on ATS 36. A subsequent run of the same profilometer resulted in a profile free of data anomalies (see Figure 6).

When these two runs are plotted in the same figure, it is obvious that the profilometer results yielded profiles with essentially the same configuration. The major differences in the two plots are the lost locks observed at a distance of 200 ft from the beginning of the section, the saturation spikes that occur at the 275-ft position and those that occur within the portion of the test section located between 400 and 600 ft. Because the results for runs by other profilometers on the same section (i.e., ATS 36) did not display these data anomalies, then these occurrences would therefore be considered as random.

On the other hand, a systematic data anomaly would be considered those lost locks or saturations that consistently occur on each profilometer run and could be related to a particular profilometer, speed, and location of profile irregularities. For this type of anomaly, it is important to identify the cause for systematic data anomalies particularly if associated with profilometer problems (e.g., sensor problems, ve-

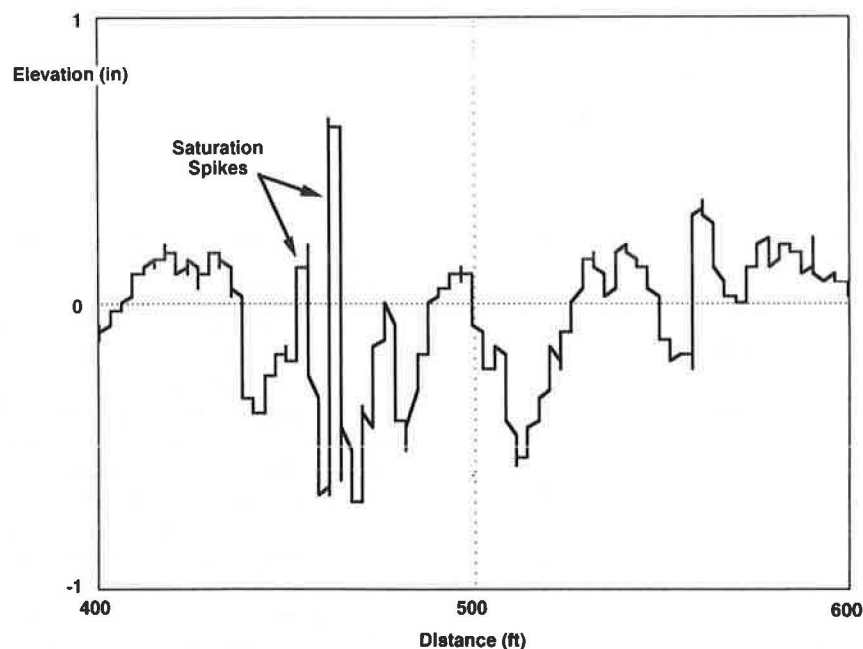


FIGURE 3 Example of saturation data anomaly.

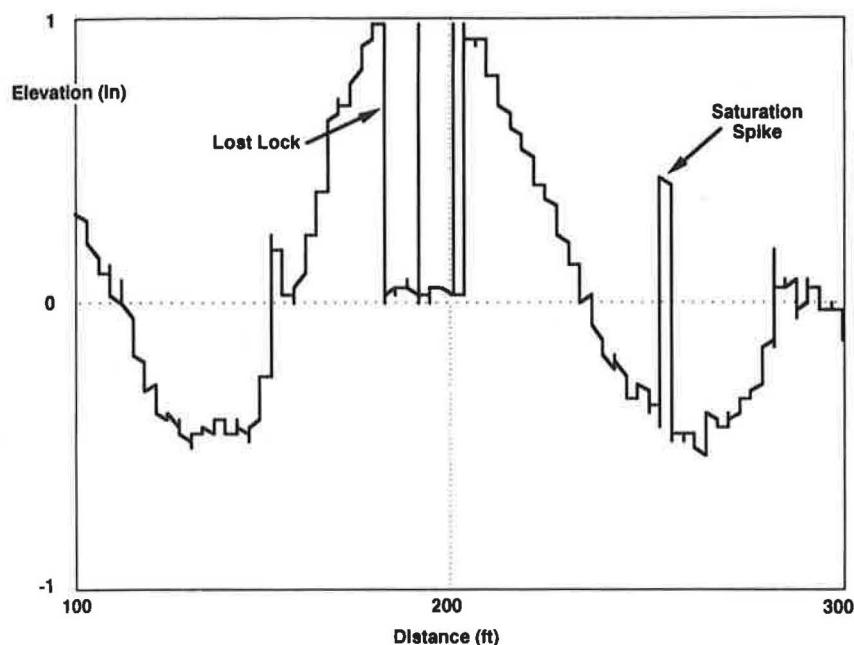


FIGURE 4 Example of lost lock and saturation data anomalies.

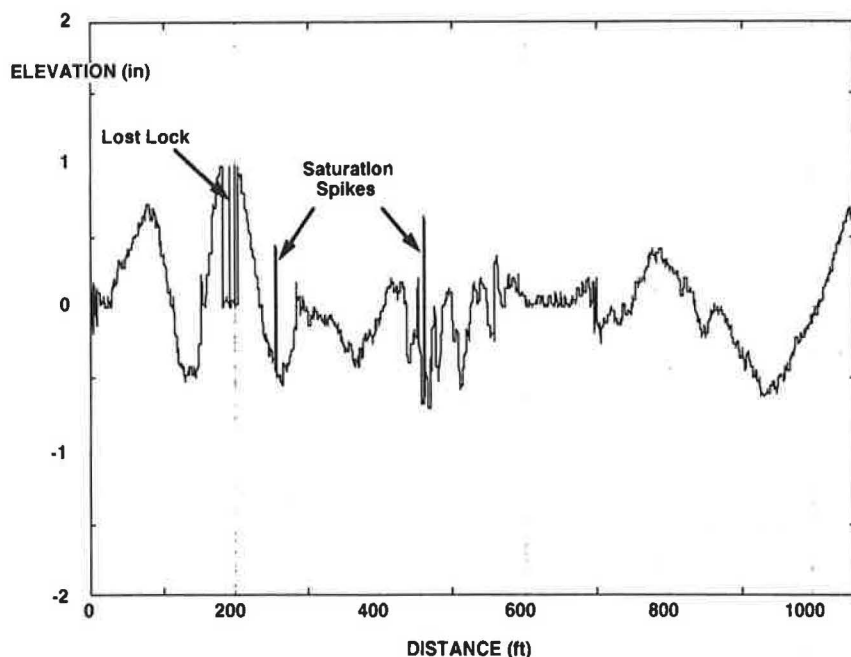


FIGURE 5 Example of randomly generated data anomalies in a profilometer run.

hicle speed, and calibration) so that corrections or adjustments can be completed. On the other hand, data anomaly results created by road roughness alone can be identified and enhanced or filtered as statistically appropriate.

In order to define the relative variability in profilometer roughness values for the various profilometers and test sections, comparisons between dynamically measured roughness values (i.e., IRI values) and those roughness values generated from static dipstick profile were undertaken. As part of this investigation, dipstick IRI values were developed for the first

and second 500-ft sections of each of the six test sections (see Table 6). This was undertaken because the 500-ft pavement section lengths are comparable to the General Pavement Studies (GPS) test sections of the Strategic Highway Research Program's (SHRP's) Long-Term Pavement Performance (LTPP) study. This approach essentially doubles the number of test sections to 12. For convenience, the initial 500-ft sections were designated by a suffix code of "a" added to the test section number (1a, 4a, etc.) while the second 500-ft section was defined by a suffix code of "b" (1b, 4b, etc.).

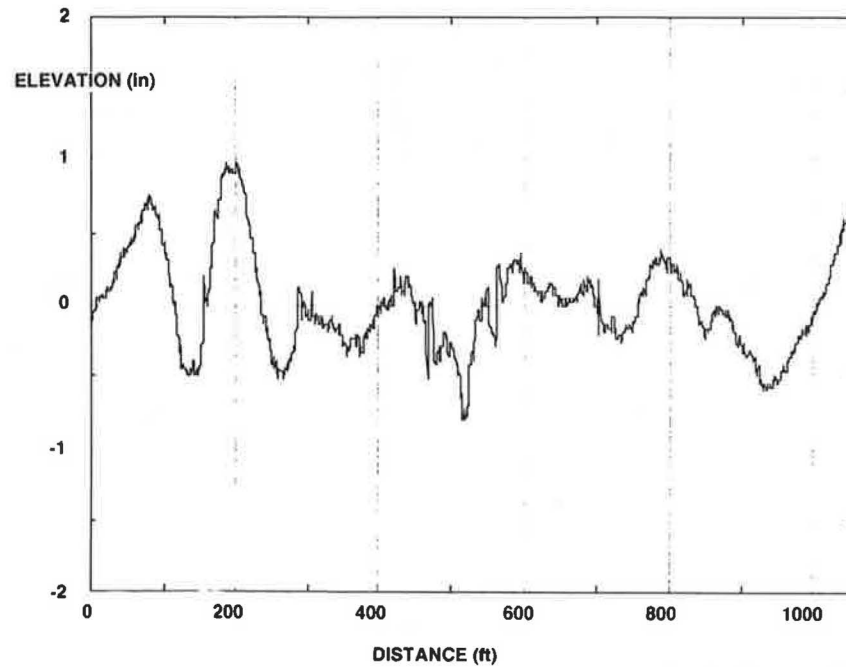


FIGURE 6 Example of profilometer run free of data anomalies.

TABLE 6 DIPSTICK IRI VALUES FOR AUSTIN TEST SECTIONS

ATS	1 - 500'	501 - 1000'	Combined
43	105.2	90.8	98.0
42	101.3	98.3	99.8
36	158.6	120.9	139.7
31	191.0	215.5	203.3
1	312.2	169.2	240.7
4	218.2	409.4	313.8

From Table 6, it can be seen that the dipstick IRI values range from a low of 90.8 for Test Section 43b (i.e., the 501- to 1,000-ft section of 43) to a high of 409.4 for Test Section 4b. Furthermore, there are four sites with IRI values of about 100 (i.e., 43b, 42b, 42a, and 43a), four with IRI values between 100 and 200 (i.e., 36b, 36a, 1b, and 31a) and four with IRI values greater than 200 (i.e., 31b, 4a, 1a, and 4b). The results presented in Table 6 quantify the roughness of each of the sections and essentially replace the qualitative measures for roughness (i.e., smooth, medium, and rough) identified in the original experiment design (Figure 1).

Comparisons of test section dipstick and profilometer roughness values are presented in Tables 7–9 for average IRI values (i.e., average of left and right wheel paths), LWP IRI values, and RWP IRI values, respectively. Table 7 indicates that there is reasonable agreement between average IRI values for the dipstick and profilometer for 8 of the 12 sites. The four sites with apparent differences in the profilometer-dipstick comparisons are occurrences of Sections 1b, 31b, 1a,

and 4b. A possible correlation between the data anomalies and rougher pavement sections might be inferred from the results presented in Table 7.

However, there is no direct way to ascertain from the average IRI results whether the differences are related to problems with the LWP, RWP, or both wheel paths. Therefore, IRI comparisons were developed separately for the LWP (Table 8) and right wheel path (Table 9) results. In these two comparisons, it can be observed that only the results for test Section 1a are significantly different for the LWP, whereas the results for Sections 1b, 31b, 1a, and 4b are significantly different for the RWP measurements. The differences in IRI values for these latter four sections range from 50 to 140 percent higher than the dipstick values.

Because good agreement between profilometer and dipstick IRI values was obtained for 8 of the 12 test sites, it can be surmised that there are significant, possibly systematic, concentrations of data anomalies in those four sections with profilometer-generated IRI values significantly different from

TABLE 7 TEST SECTION ROUGHNESS COMPARISON OF AVERAGE IRI VALUES

Site	Dipstick	Profilometers
43b	90.8	96.1
42b	98.3	102.7
42a	101.3	106.5
43a	105.2	90.2
36b	120.9	111.2
36a	158.6	156.0
1b	169.2	239.6
31a	191.0	207.4
31b	215.5	384.5
4a	218.2	258.2
1a	312.2	518.6
4b	409.4	730.5

————— represents significant difference

TABLE 8 TEST SECTION ROUGHNESS COMPARISON OF LWP IRI VALUES

Site	Dipstick	Profilometers
43b	78.8	96.1
43a	92.9	70.6
36b	95.4	86.8
42b	97.4	92.8
42a	98.7	76.5
36a	125.2	83.1
31a	145.5	125.6
31b	164.1	143.6
1b	174.0	170.0
4a	193.3	188.0
1a	275.8	406.9
4b	362.7	368.9

————— represents significant difference

dipstick IRI values. Random data anomalies are still expected events for any of the profilometer runs (see Figure 7).

INVESTIGATION OF WINDOWS

In order to investigate, identify, and locate concentrations of data anomalies, the profile data and corresponding IRI value for both profilometer and dipstick were divided into equally

TABLE 9 TEST SECTION ROUGHNESS COMPARISON OF RWP IRI VALUES

Site	Dipstick	Profilometers
42b	99.1	112.5
43b	102.8	117.6
42a	103.9	136.4
43a	117.5	110.0
36b	146.3	135.8
1b	164.3	309.1
36a	191.9	228.9
31a	236.6	289.9
4a	243.0	328.4
31b	266.8	625.3
1a	348.6	630.3
4b	456.1	1092.1

————— represents significant difference

sized portions designated as "windows." For each window, the comparisons between dynamic profilometer and static dipstick IRI values could be made and the location of possible data anomalies more closely identified. For this investigation, 100-ft windows were selected. These identified locations could subsequently be confirmed by comparing profilometer and dipstick profiles.

IRI window values were generated for Sections 1a and 1b, which represent two of the four sections considered to be candidate sections for concentrations of data anomalies (see Tables 8 and 9). The IRI values for each individual profilometer and the mean IRI value for all four profilometers are also included in these tables. Based on dipstick IRI values, Section 1b with an average IRI of 169.2 would fall in a medium roughness category, whereas Section 1a with an average IRI value of 312.2 would be considered a rough section.

The IRI results for LWP and RWP of Section 1b are presented in Tables 10 and 11, respectively. As expected for this medium roughness category, the ATS 1b LWP IRI results (Table 10) for the dipstick and profilometer are in good agreement. In addition, the IRI values from profilometer to profilometer appear to be reasonable.

On the other hand, comparisons between dipstick and profilometer IRI values for 100 windows of the RWP of Section 1b (Table 11) reveal that there are large IRI differences for the 201- to 300-ft window. The IRI values for the individual profilometers within this same window indicate that measurement problems developed for all four profilometers. There was good agreement between dipstick and profilometer IRI values for the remaining four 100-ft windows (i.e., 1-100, 101-200, 301-400, and 401-500 ft).

The IRI results for the LWPs and RWPs of section 1a are tabulated in Tables 12 and 13, respectively. From Table 12, it is apparent that there are profilometer measurement problems for only one of the windows (i.e., 101-200 ft) because

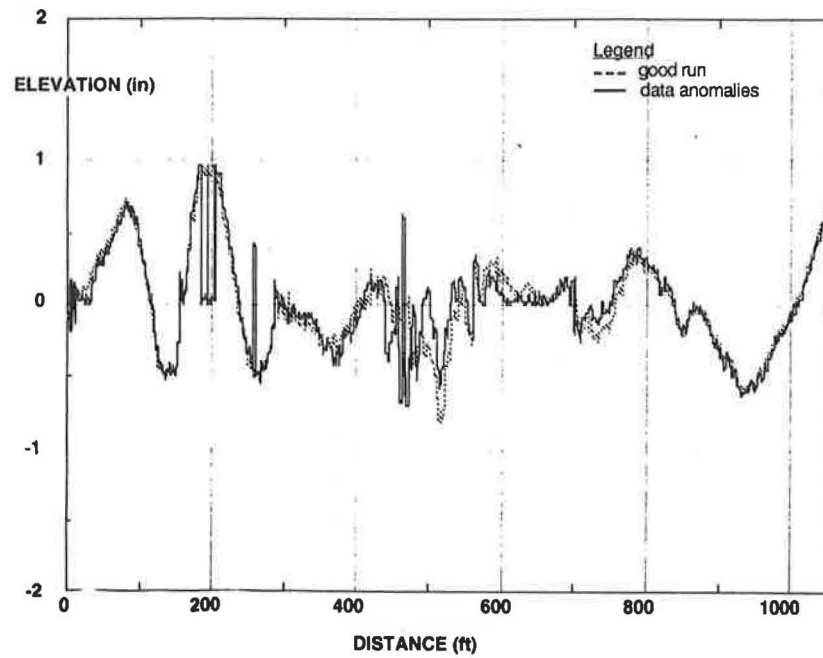


FIGURE 7 Comparison of profilometer runs—good versus anomali ed run.

TABLE 10 IRI COMPARISONS FOR SECTION 1b, LWP, 100-ft WINDOWS

Window	Dipstick	Average	IRIs from Profilometers			
			1	2	3	4
1-100	173.8	162.9	177.8	166.6	180.6	126.7
101-200	185.5	187.9	192.2	184.2	208.4	169.8
201-300	184.6	187.5	189.2	174.5	222.2	163.4
301-400	164.6	162.1	175.0	165.6	156.1	151.7
401-500	161.4	149.6	148.8	153.6	150.4	145.7
AVERAGE:	174.0	170.0	176.7	168.9	182.9	151.5

TABLE 11 IRI COMPARISONS FOR SECTION 1b, RWP, 100-ft WINDOWS

Window	Dipstick	Average	IRIs from Profilometers			
			1	2	3	4
1-100	151.5	176.4	177.9	165.2	198.4	163.9
101-200	142.3	149.1	144.6	135.5	154.8	161.3
201-300	154.3	808.5	929.2	751.8	929.5	624.4
301-400	222.3	190.4	192.1	207.2	199.7	162.5
401-500	151.1	221.1	241.7	211.7	240.9	190.1
AVERAGE:	164.3	309.1	337.1	294.3	344.5	260.1

TABLE 12 IRI COMPARISONS FOR SECTION 1a, LWP, 100-ft WINDOWS

Window	Dipstick	Average	IRIs from Profilometers			
			1	2	3	4
1-100	429.8	450.4	463.2	463.8	541.8	332.6
101-200	369.9	986.5	977.5	667.7	1233.1	1067.8
201-300	214.0	220.1	217.0	211.8	219.3	232.2
301-400	230.8	238.3	245.2	227.0	251.8	229.3
401-500	134.6	139.4	150.2	134.3	155.6	117.3
AVERAGE:	275.8	406.9	410.6	340.9	480.3	395.8

TABLE 13 IRI COMPARISONS FOR SECTION 1a, RWP, 100-ft WINDOWS

Window	Dipstick	Average	IRIs from Profilometers			
			1	2	3	4
1-100	583.3	1195.2	1312.6	1180.5	1420.6	866.9
101-200	564.3	1171.3	990.9	1167.9	1656.3	870.3
201-300	148.1	207.7	225.0	204.5	199.1	202.2
301-400	268.4	399.5	446.0	388.4	292.7	470.9
401-500	179.0	178.0	171.1	164.7	176.4	199.9
AVERAGE:	348.6	630.3	629.1	621.2	749.0	522.0

the dipstick IRI value (369.9) and average profilometer IRI value (986.5) are so drastically different. The problem apparently developed for all four profilometers because the profilometer IRI values ranged from 667.7 to 1,233.1 for the same window (i.e., 101–200 ft). The data measurement problem is apparently isolated in this section of roadway (i.e., 101–200 ft), because there is good agreement between the dipstick and profilometer IRI values for the other four windows (i.e., 1–100, 201–300, 301–400, and 401–500 ft).

The comparisons of RWP IRI values for Section 1a are presented in Table 13. This information is representative of the rougher sections (i.e., RWP-1a has an IRI value of 348.6) in the profilometer workshop. On the basis of the tabulated values in this table, measurement problems (e.g., concentrated data anomalies) were obviously encountered for the first two windows (i.e., 1–100, and 101–200 ft). The results for the other two windows (i.e., 201–300 and 301–400 ft) may indicate that minor measurement problems (e.g., random data anomalies) were encountered in other portions of the test section. Finally, only the last window (i.e., 401–500 ft) yielded comparable results between dipstick and profilometer IRI values for the RWP. There is no doubt that the greatest differences between dipstick IRI values and profilometer IRI values occurred in the RWP of Section 1a.

ROAD PROFILE CONSIDERATIONS

For test Section 1a it was suspected that the relative positions of the vertical profiles along the LWPs and RWPs for certain portions of the test sections were such that the profilometers developed side-to-side movement (rocking) of such magnitude that sunlight could penetrate underneath the vehicle skirt, creating light saturation of the sensors. This suspicion was investigated by comparing the LWP and RWP profiles of the first two windows of Section 1a as measured by the dipstick (see Figure 8).

Figure 8 shows that there is general conformance between the two wheel path profiles. However, intermittent cross slope reversals occur between 75 and 200 ft from the beginning of the section and an apparent bump or upheaval of the RWP approximately 50 ft from the start of Section 1a.

The profilometer dynamic wheel path profiles for the initial 200 ft of test Section 1a were generated and are presented in Figures 9 and 10 for the LWPs and RWPs, respectively. Figure 9 indicates that sensor saturation developed for the LWP at positions along the section from 20 to 50 ft and at 125 to 200 ft from the beginning of the section.

Similar results can be observed in Figure 10 for the RWP. Saturation is apparent and extends over a large portion of the

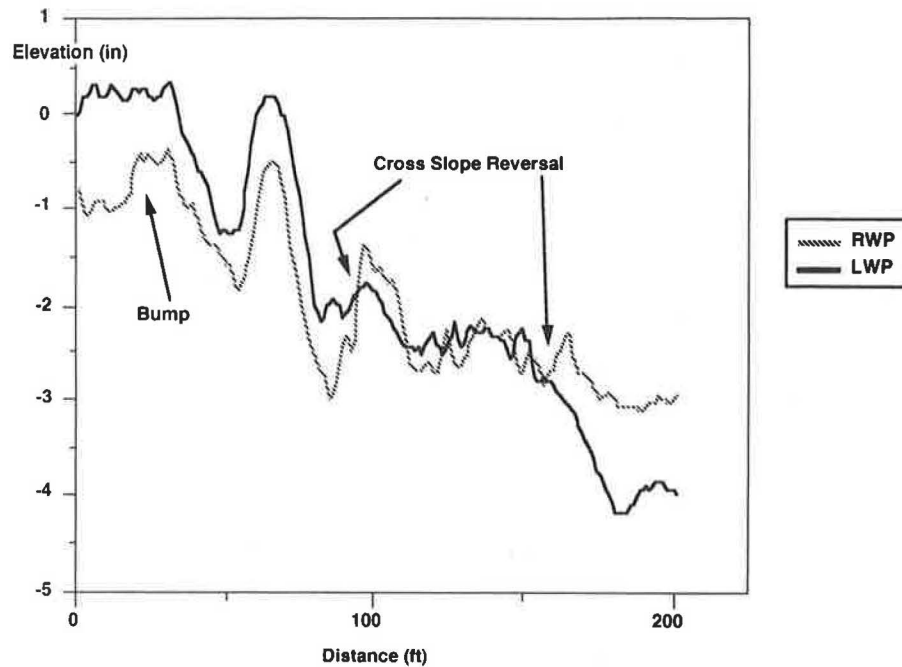


FIGURE 8 Comparison of LWP and RWP profiles using dipstick.

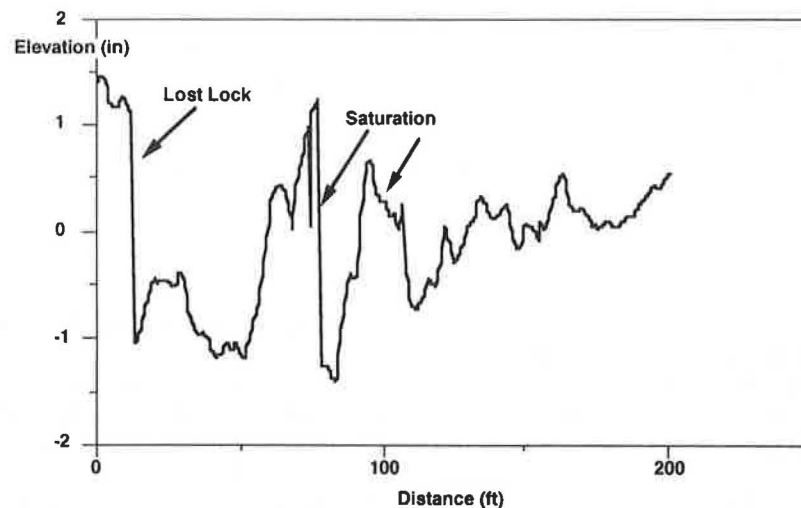


FIGURE 9 Dynamic profile for first 200 ft of ATS 1a, LWP.

first 200 ft of test Section 1a. In this case (i.e., RWP), the saturation seems to be more extensive when compared with the LWP results (Figure 9). This observation is also reflected in the IRI values presented in Tables 12 and 13 for the first two 100-ft windows.

The suspicion of the existence of a concentration of systematic saturation in test Section 1a was confirmed when the dynamic elevation profiles were plotted. It is further confirmed from this that localized aberrations in the longitudinal wheel path profiles (e.g., cross slope reversals, upheavals and chuck holes) can result in measurement difficulties because of the creation of sensor saturation.

It should also be noted that saturation spikes, more than likely, exist in all the profilometer data at different locations

along the various test sections, as evident in the 101–200, 201–300, and 401–500-ft windows for Profilometer 2 (Figure 5). A greater number of saturation spikes would be expected in the rougher sections.

CONCLUSIONS

On the basis of the results of this comparative profilometer study, it is concluded that

- IRI roughness measurements are more stable for the LWP than for the RWP;
- Data anomalies including saturation spikes and lost locks exist in a number of the profilometer runs;

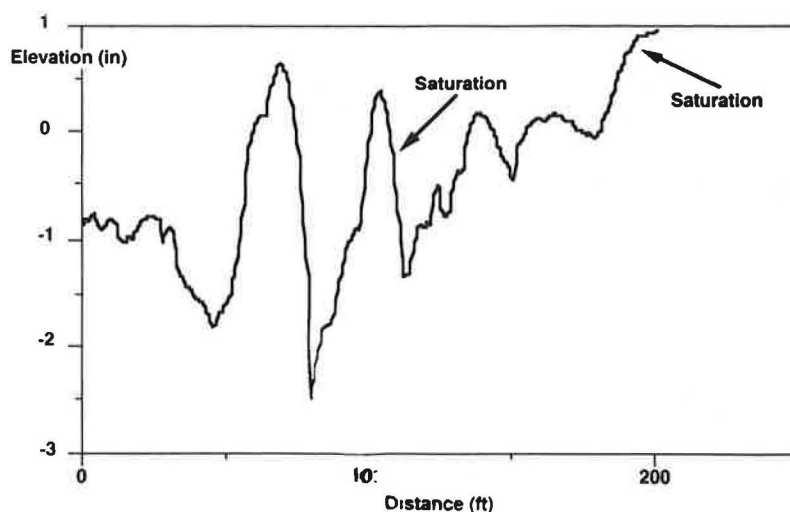


FIGURE 10 Dynamic profile for first 200 ft of ATS 1a, RWP.

- Localized aberrations in the wheel path longitudinal profiles can result in development of saturation spikes;
- Run-to-run comparisons using 100-ft windows can be used to identify random and systematic data anomalies (e.g., saturation spikes and lost locks); and
- Data enhancement or filtering is likely needed to cleanse profilometer roughness data so that appropriate comparisons can be made.

RECOMMENDATIONS FOR FURTHER ANALYSIS

Because the dynamic profile information is expected to be a major indicator of pavement performance in SHRP LTPP, it is essential that further analysis of the 1990 Profilometer Workshop results be undertaken on some form of statistically enhanced or cleansed profile indices. It is, therefore, recommended that

- Profilometer data be scrutinized or filtered to eliminate effects of data anomalies and that a second analysis be undertaken.

- Regression equations be developed to relate the performance of the various profilometers on the basis of a variety of roughness indices.
- The relationship between dipstick and profilometer profile index values be developed.

ACKNOWLEDGMENTS

The research in this paper was sponsored by SHRP, and appreciation is extended to the cooperative effort of SHRP personnel.

The contents reflect the views of the authors who are responsible for the findings and the accuracy of the data presented herein. The publication of this article does not necessarily indicate approval or endorsement by the National Academy of Sciences, by the Federal Highway Administration, or by any state highway or transportation department of the findings, opinions, conclusions, or recommendations either inferred or specifically expressed herein.

Publication of this paper sponsored by Committee on Surface Properties-Vehicle Interaction.