PAVEMENT SERVICEABILITY EQUATIONS USING THE SURFACE DYNAMICS PROFILOMETER

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For a number of years engineers have been interested in evaluating the riding quality of highways in an objective manner. Before the AASHO Road Test, no method was available for accomplishing this evaluation. However, during the planning for the AASHO Road Test, the serviceability-performance concept was developed and reported by Carey and Irick (2). This serviceability concept serves as a basis for most current pavement rating systems. It describes the relationship between the subjective opinion of road users and a set of objective measures of pavement roughness and deterioration. These objective measures are (a) outputs from the available roughness measuring devices that had been developed to respond to pavement longitudinal roughness and (b) deterioration of the pavement surface such as cracking, patching, and rutting in the wheelpaths.

At the Road Test the average rating value for any test section was determined by averaging the individual present serviceability rating (PSR) value given by each of the 15 members of the rating panel. The ratings were based on a linear scale from 0 to 5. A road with a PSR of 0 was considered impassable while a road with a PSR of 5 was perfect. The AASHO panel of raters was asked to rate pavements on which objective measurements were made. A model for predicting the rating values of the panel, called present serviceability index (PSI), was then developed.

The present equipment that seemed to offer the best combination of accuracy and high operating speed was the General Motors road profilometer. In order to use this device, which is presently known as the surface dynamics (SD) profilometer, to evaluate Texas highways it was necessary to develop serviceability equations relating the SD profile to PSR.

THE MEASURING SYSTEM

This profilometer measuring system is completely contained within a panel truck and can operate on any paved surface. The measuring system consists of (a) a set of 2 road wheels, one in each wheelpath directly in line with the vehicle wheels; (b) 2 potentiometers, each connected at the bottom to a yoke extending from the trailing arm directly above the center of a wheel and at the top to the vehicle body; (c) 2 accelerometers, each mounted inside the vehicle directly above the top of the potentiometer; and (d) a special purpose analog computer that has 2 independent circuits, one for each of the 2 profiles, and that integrates the accelerometer signal twice and adds it to the potentiometer signal to produce a road profile for each wheelpath (Fig. 1).

Each road wheel is mounted on a trailing arm beneath the vehicle and is held in contact with the road by a 300-lb force exerted through a torsion bar. The truck mass and

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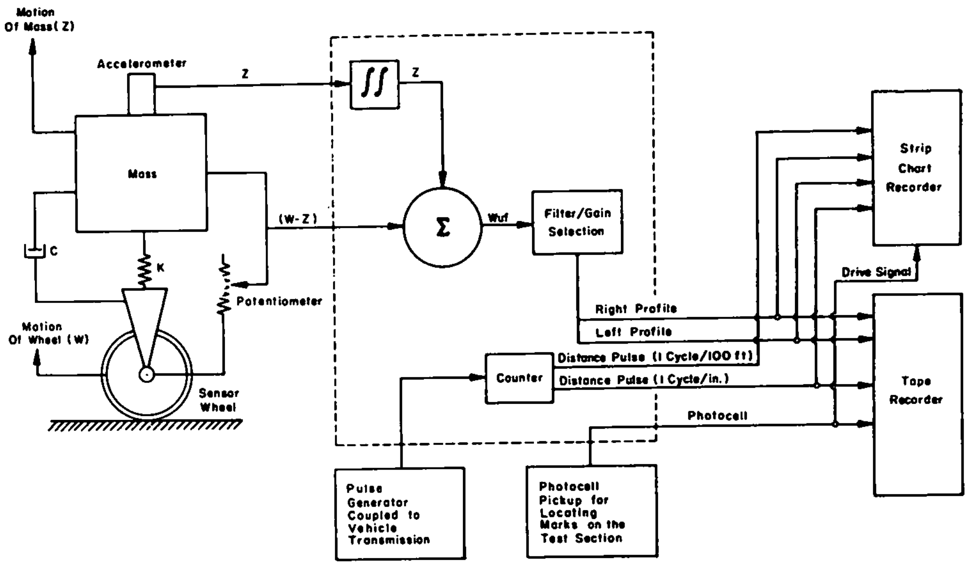

Figure 1. Detailed block diagram of measurement system.

the suspension system form a mechanical filter between the road and the accelerometers. The relative motion between the surface and the vehicle body is measured with the potentiometers while the accelerometers measure the vertical acceleration of the vehicle body. The resulting road profile is the sum of the potentiometer and twice-integrated accelerometer signals.

Because of the large quantity of data generated during only 1 pass of the SD profilometer over a roadway, automatic data handling techniques were considered essential. These techniques are described in detail by Walker et al. (11). The digitized data obtained from the SD profilometer consist of approximately 1 point for each inch of road over which the data are obtained.

THE RATING SESSIONS

To obtain a sample of the opinion of travelers about specific sections of roads, a panel of 15 raters was formed. The purpose of the panel was to obtain opinions on the riding quality of a group of pavements in order to provide subjective values with which to correlate objective measures of pavement roughness and deterioration.

Selecting a group of people who are representative of those who travel is probably an impossible task. However, Nakamura and Michael (9) showed that a panel consisting of highway engineers does not rate pavements any more consistently than a similar panel consisting of members having varied professional backgrounds. Based on this study and the results shown by Carey and Irick (2), a panel of 15 men and women with different professions and backgrounds and representative of travelers in Texas was chosen. Because the selection of the raters was not completely random, the drivers of the vehicles, who were highway oriented, were designated as a panel to check on the reasonableness of the rating values given by the panel. Each driver rated the test sections along with the panel members included in his vehicle. A PSR value then represented the opinions that a panel of 15 typical road users riding in typical American automobiles have about the riding quality of a 1,200-ft section of roadway.

The first of the 3 rating periods served for orientation and training and was designated as the preliminary rating session. A step-by-step procedure for analysis of the preliminary rating session data allowed consideration and investigation of procedural changes in equipment operation, collection of any additional profile and condition survey information, and alterations in the rating procedure before the 2 full-scale rating periods.

Three raters and a driver occupied each of the 5 vehicles. To determine whether the average of the raters for a particular section could be used to represent the riding quality of the section, an analysis of variance (ANOVA) was performed on these data. A mixed model, cross-classified, nested ANOVA design was used (10). These tests indicated that (a) the PSR value was not affected by the position in the vehicle that the rater occupied, (b) there were no significant differences between the rating values of the men and the women, (c) there were no significant differences between the average rating values of the drivers and the panel, and (d) the raters were able to rerate several sections with no significant differences between the first and the second ratings.

The sites for the 2 rating periods were selected to include 2 different topographical areas of Texas. The first rating period was conducted in the generally flat Houston-Gulf Coast area and the second in the hilly Dallas-Fort Worth area. These diverse regions were selected to allow a large inference space for use of the results from this study. The first rating period was conducted in the Houston area where 49 pavements of varying quality were selected with as wide a range of PSR as possible. The second rating period was conducted in the Dallas-Fort Worth area where 50 pavements of varying quality were selected. For all rating sessions, the raters were asked to occupy the same positions they had in the preliminary rating session so that the conclusions drawn from the preliminary rating period could be checked with more data. The route for each group of raters was assembled separately to ensure that a time-of-day bias was not introduced as a result of having all panel members rate the sections in the same order, even on different days.

The PSR data from these rating periods were subjected to ANOVA techniques. Tests conducted on the results of the ANOVA indicated that (a) the variations among the raters within the seating positions in the vehicle were about the same, (b) there were no significant effects caused by seating positions in the vehicle, (c) overall the drivers and the raters rated the pavements the same, and (d) there were as expected significant rater-to-rater variations.

From tests conducted on the sections that were rated twice, the conclusion can be drawn that rater-to-rater variations were greater than the variations caused by (a) the differences in sex of the raters or (b) the position that the rater occupied in the vehicle. The average of the whole panel could thus be used to represent the PSR for a particular section.

DATA PROCESSING AND ANALYSIS

The roughness data collection phase of this study involved obtaining measurements with the SD profilometer and conducting condition surveys on the selected test sections. The pavement deterioration information collected during the condition survey included the measurement of texture, cracked and patched areas for the entire test section, and rut depths in each wheelpath for the flexible pavements (2, 6, 9). Four filter-speed combinations of filters 2 and 3 run at both 34 and 50 mph were selected for running the preliminary rating session sections. These combinations provide measurement of wavelengths up to 250 ft with no attenuation. Two runs were made at each filter-speed combination resulting in 8 runs per section. Two calibration signals were included with the recorded data runs. The first calibration signal was the scaling factor for the profile data runs, and the second provided a check on the active filtering system of the profile computer.

It seemed necessary that the summary statistic describing roadway roughness be related to features that induce forces on the rider. Roughness index (RI) and slope variance (SV) are 2 such statistics that have found wide acceptance in the highway field (2, 6, 9). Roughness index is the sum of the vertical deviations of the profile throughout the section, and slope variance is the variance of slopes calculated for the length of the section.

After choosing methods for summarizing the roughness data, the sampling interval and any smoothing parameters that were appropriate remained to be selected. Close investigation of the available analog records revealed that the right profile data for the preliminary rating session contained a great deal of high-frequency noise. This noise was probably due to the improper cleaning of the FM tape recorder heads. All efforts to salvage the right profile data were unsuccessful, and the analysis was continued by using only the left profile.

Because of the possibility of noise entering the data at any point during the recording state, a running average of data points seemed advisable in order to minimize the effect of any such extraneous signals. In order to make a decision as to which combination or combinations of variables of summary statistic, length of running average, length of base, filter-speed combination, and pavement type were important, an ANOVA was performed. This analysis indicates that within the limits of the data used there were no significant differences between any of the combinations of smoothing and base length. From the scatter diagrams, the combination of 25-point smoothing and 9-point base was selected as showing the best correlation between roughness variables and PSR. This choice of 25-point smoothing was later verified.

Because the complete analysis of the preliminary rating session data was not accomplished before the data for the 2 summer periods were to be collected, the project personnel decided to make SD profilometer runs using filter 1 at speeds of 20 and 34 mph and filter 2 at 50 mph. Two runs were made at each of these filter-speed combinations. The condition survey information for the test sections was expanded to include the measurement of a value for surface texture. The only device readily available for such measurements was developed for use with the CHLOE profilometer by Hudson and Scrivner (6). Plots displaying the condition survey data for flexible pavements showed that there was a general increase of cracking, patching, and rutting with decreasing PSR.

The plot of combined linear and area cracking versus PSR for the rigid pavements showed 2 trends: a linear trend for the concrete pavements with joints reinforced (CPJR) and a curvilinear trend for the concrete pavements continously reinforced (CPCR). Two trends were also evident in the plot of patching versus PSR. The CPCR showed a slight decrease in PSR with increasing patching, while the CPJR with patching showed a slightly steeper negative slope. The average texture versus PSR showed PSR decreasing as texture increases.

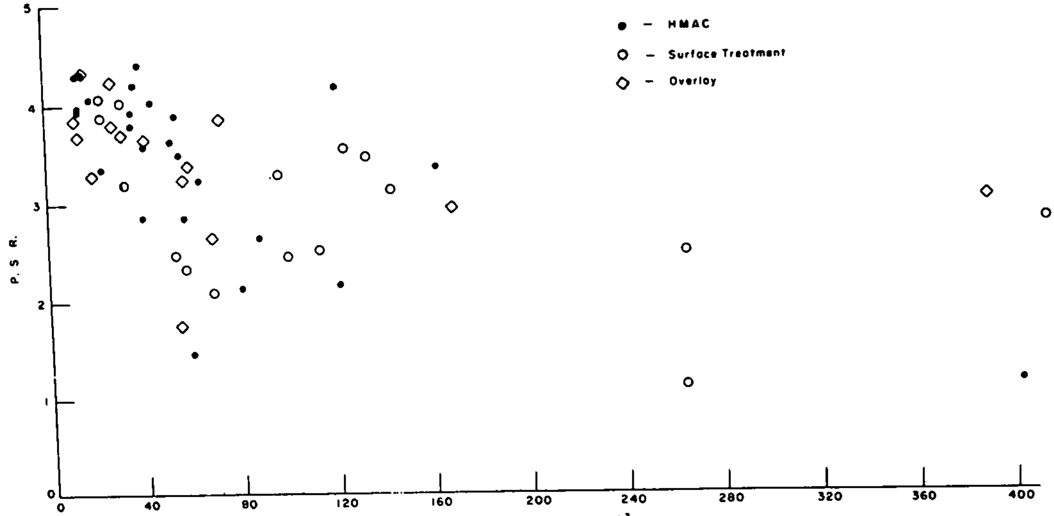

Figure 2. PSR versus cross slope variance for flexible pavements measured at 20 mph.

With profiles for both the right and the left wheelpaths, it was possible to evaluate the effect of vehicle roll on the ratings for each section. The evaluation of the roll component was accomplished by computing the slope between adjacent points on each profile and then determining the variance of these slopes called cross slope variance (XSV) as shown in Figure 2.

The results of the computer runs using program DAP for computing SV and RI are shown in Figures 3 and 4 for the flexible and rigid pavements respectively. Program DAP uses as input previously scaled digital profile data and computes the variance of slopes over a base length specified as an input variable and the sum of the vertical excursions, RI, over the same specified base length. These data were plotted versus PSR based on the speed at which the data were run and whether the pavement was flexible or rigid.

There was a great deal of variation among the data for the 3 speeds. In general, the values of SV and XSV increase as speed increases. It was found from close examination of the plots of SV and RI versus PSR that the 20- and 50-mph data exhibited better correlation between the roughness variables and PSR than did the 34-mph data. The extent of these correlations is discussed next.

MODELING THE PREDICTIVE EQUATIONS

In order to relate quantitatively the condition survey and roughness summary statistic variables to PSR, linear regression analysis techniques were extensively used. The techniques are described by Draper and Smith (3) and Ostle (10). The computer program used for these regression analyses is a stepwise regression program, STEP01, which is available at the Center for Highway Research. This program is a modified version of the stepwise regression program BMD2R (4). The stepwise regression procedure was selected because of the updating procedure used in building the model. At each step in the procedure (a step is reached any time the program adds or deletes a variable from the model), each variable in the model is checked by using a partial F-test criterion to determine if it made a contribution to the model. This provides a judgment of the contribution of each variable as if it were the last one to enter the model, irrespective of its actual point of entrance into the model. Any variable that

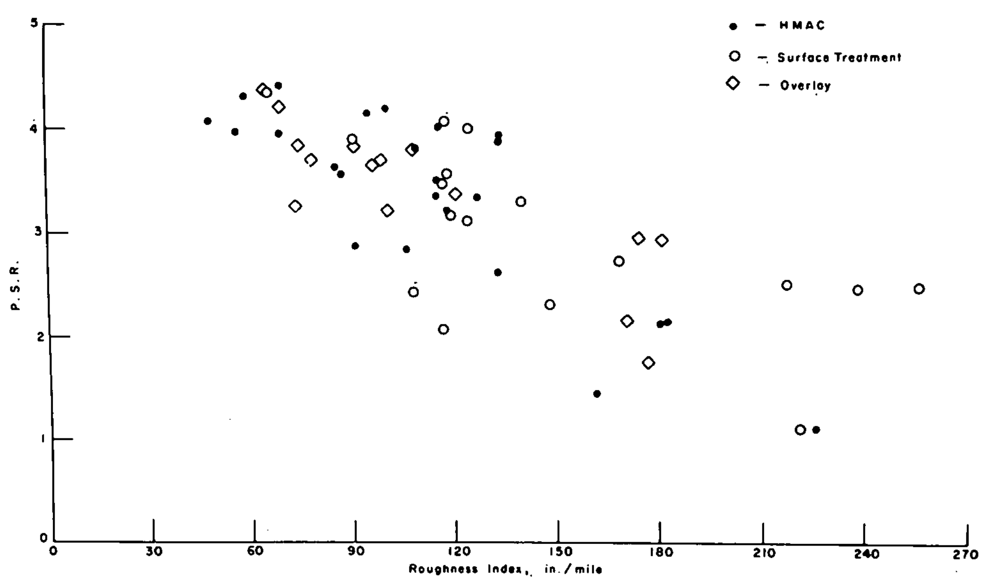

Figure 3. PSR versus roughness index for 56 flexible pavements measured at 20 mph.

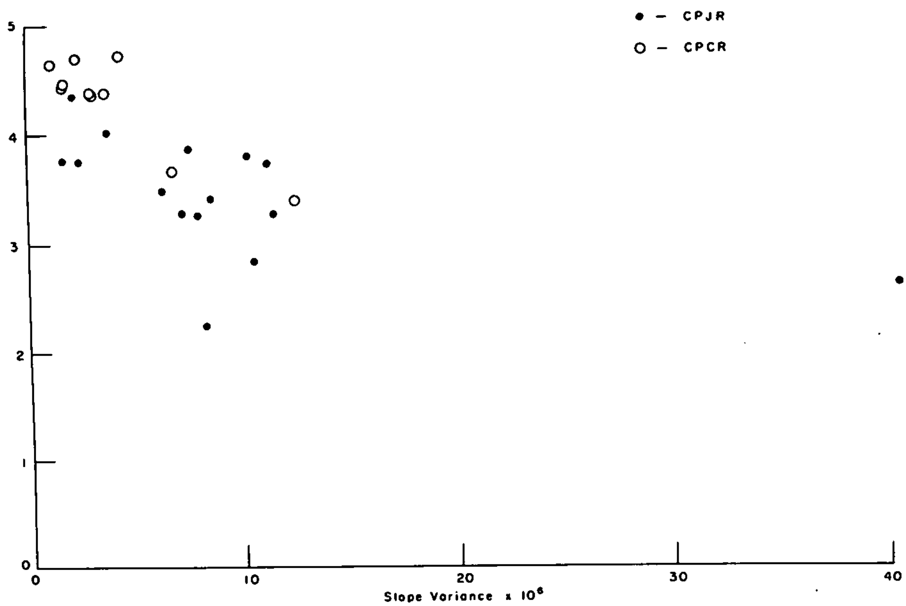

Figure 4. PSR versus slope variance for 25 rigid pavements measured at 20 mph.

is not significant via the partial F-test is removed from the model. The next variable that is entered is the one with the highest F-value at the step. This procedure of adding variables, checking for the contribution of each variable, and deleting any insignificant terms is continued until none of the computed partial F-values is larger than a preselected input value. At this point of termination, the program has constructed from the various independent variables (X's) the group that best predicts the dependent variable (Y).

In performing linear regression analyses it has been found that careful study of scatter diagrams of each independent variable versus the dependent variable (PSR) will enable the researcher to determine the transformation that will most probably linearize the data. Such study of the scatter diagrams earlier, relating the condition survey and roughness summary statistics to PSR, led to transformations on some of the condition survey and summary statistic data. Cracking and patching for the rigid pavements were added together as shown in Figure 5. Two trends are obvious in the combined data. A linear trend with a negative slope for the CPJR and a curvilinear trend for the CPCR. To include such data in the regression analyses a "block" term was introduced to distinguish between the 2 types of PCC pavements. A log transformation was performed on the SV and XSV data for the flexible and rigid pavement data measured at 20, 34, and 50 mph.

These attempts to linearize the data are important in linear regression analyses because the analysis uses only a constant coefficient and not a variable in estimating the effect of a term. For example, in considering a model such as

$$Y = B_0 + B_1X + B_2X^2 + e$$

B_0, B_1, and B_2 are defined as the parameters of the model. When referring to the linearity of the model, the reference is to whether the parameters are linear or nonlinear.

The regression analyses follow after linearizing the independent variables as carefully as possible. Ten regression analysis problems were run by using the flexible

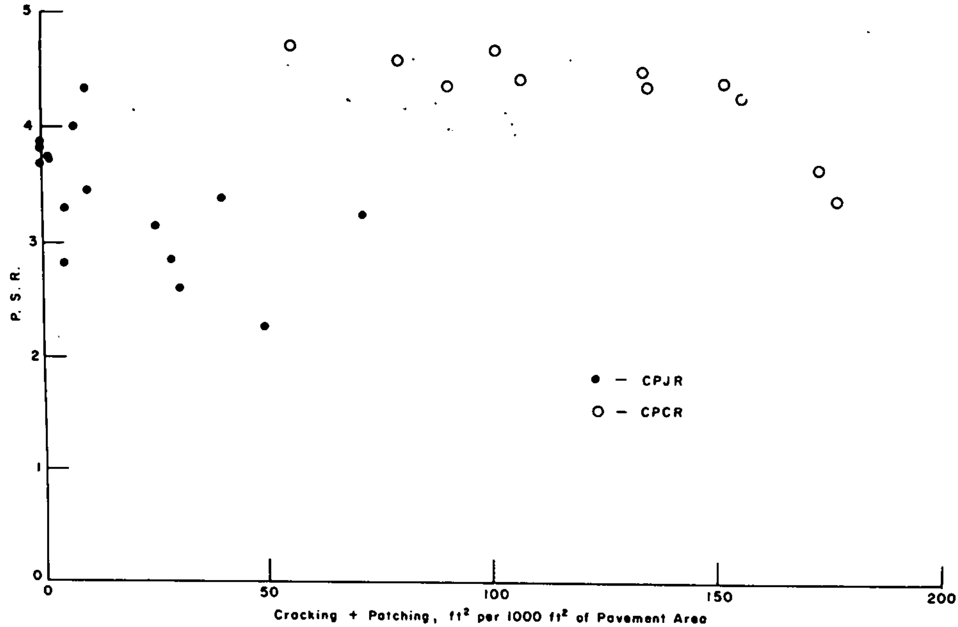

Figure 5. PSR versus cracking plus patching for 28 rigid pavements.

pavement roughness variables and condition survey information and 8 problems were run by using the rigid pavement data.

Eight of the flexible pavement regression problems involved 2 summary statistics (either RI or SV and XSV as discussed in the previous section)as well as cracking (C), patching (P), rut-depth variance (RDV), average rut depth (RD), average texture (T), cracking and patching (C + P), and all the interactions. The other 2 regression analyses involved only 1 summary statistic and selected condition survey variables. These two will be discussed later in the section on validation of the model.

The best predictive equation can be chosen on the basis of the highest correlation coefficient and smallest standard error of estimate if there is a sufficient number of degrees of freedom in the residual sum of squares. This study provides such a case because the degrees of freedom for residuals of the flexible pavements was at least 45 while the degrees of freedom for the rigid pavements residual was at least 18. The best predictive equation for flexible pavements involves log SV and log XSV for measurements made with filter 2 at 50 mph. This equation was selected over one other equation because it involved fewer terms in the model. For flexible pavements the best equation is

$$\begin{aligned} PSI = 4.57 - 0.27(\log SV) - 0.41(\log XSV) + 0.08(T) + 0.24(\log SV)(RD) \\ - 0.11(\log SV)(T) - 0.00001(C)(P) - 0.00069(P)(T) \end{aligned} \quad (1)$$

where

PSI = present serviceability index (predicted PSR);
log SV = $\log_{10}(SV \times 10^6)$;
log XSV = $\log_{10}(XSV \times 10^3)$:
T = average texture, 0.001 in.;
RD = average rut depth, 0.1 in.;
C = cracking, sq ft/1,000 sq ft of pavement area; and
P = patching. sq ft/1,000 sq ft of pavement area.

For this equation R = 0.88, and the standard error of estimate is 0.40. The standard error of estimate is an estimate of the standard deviation. This means that the PSI will be within ±0.40 of the PSR 68 percent of the time and ±0.80 of the PSR 95 percent of the time. An examination of the residuals ($Y - Y_{estimated}$ or PSR - PSI) was conducted, and the plots exhibited no abnormalities.

Eight regression analysis problems were run by using the rigid pavement roughness variables and condition survey data. Seven of the problems were run by using 2 roughness statistics, condition survey variables and interactions. The best predictive equation involves roughness data measured with filter 2 at 50 mph. The best rigid pavement equation is

$$PSI = 4.53 - 1.21(\log SV) - 0.00004(C + P)_C^2 + 1.21\,(PT) -0.0067(\log SV)(C + P)_J + 0.39(\log SV)(\log XSV) \qquad (2)$$

where

PSI = present serviceability index (predicted PSR);
log SV = $\log_{10}$ (SV × 10^6);
log XSV = $\log_{10}$ (XSV × 10^3);
$(C + P)_C$ = cracking plus patching for CPCR;
$(C + P)_J$ = cracking plus patching for CPJR; and
PT = pavement type (PT = 1.0 for CPCR and 0.0 for CPJR).

In this equation R = 0.94, and the standard error of estimate is 0.23.

These values for the rigid pavements indicate a better correlation among PSR and the roughness and condition survey variables for the rigid pavements than for the flexible pavements. An examination of the residuals for this model was conducted, and the data exhibited no abnormalities.

In these regression analyses no test was made for lack of fit for the model. This test was not made because the basic assumption of no error in the independent variables was not met. It was felt that, because the regression procedure assumes that all errors are in the Y's, i.e., the PSR values, when in fact these replicate rating errors are very small, this test would not be meaningful. This does mean that the use of these equations outside the range of data used in this analysis should be avoided.

An estimate as to the predictive quality of the flexible pavement equation may be found by using the preliminary rating session data as a check. This was accomplished by taking the left profile data for the 2 summer rating sessions and the condition survey information, except for texture, and performing a regression analysis to develop an additional predictive equation. The roughness variable used in this regression analysis was log SV, which is the same one used in the best predictive equation for flexible pavements (Eq. 1). This equation was developed by using the data from rating periods 1 and 2 that were run with filter 2 at 50 mph. The resulting equation is

$$PSI = 4.32 - 1.06(\log SV) - 0.0052(C + P) + 0.0029(\log SV)(C + P) \qquad (3)$$

where the variables are as defined previously. In this equation R = 0.75, and the standard error of estimate is 0.54.

By using the log SV and condition survey information for the 17 sections of the preliminary rating session as input values for Eq. 3, the predicted PSI values were calculated and are given in Table 1. The differences between the predicted value (PSI) and the mean panel rating (PSR) for each of the 17 sections are also given in Table 1. It can be shown from the tabulated data that 5 of the values have differences greater than 1 standard deviation and 2 have differences greater than 2 standard deviations. The existence of these differences may be explained partly by a change that was made in the

TABLE 1

COMPARISON BETWEEN PSI AND PSR FOR THE PRELIMINARY RATING SESSION DATA MEASURED WITH FILTER 2 AT 50 MPH

Section	Average SV x 10^6	Log SV	Cracking Plus Patching	PSR	PSI	Residual (PSR - PSI)
1	4.61	0.66	475	3.0	2.0	1.0
2	5.48	0.74	0	3.0	3.6	-0.6
3	5.01	0.70	50	3.7	3.4	0.3
4	17.25	1.24	0	3.0	3.0	0
5	5.16	0.71	0	4.0	3.6	0.4
6	13.41	1.13	23	2.3	3.1	-0.8
7	8.56	0.93	0	3.4	3.3	0.1
8	12.27	1.09	0	3.2	3.1	0.1
10	9.67	0.99	0	2.2	3.3	-1.1
11	4.63	0.67	7	3.9	3.6	0.3
12	20.59	1.31	340	1.8	2.6	-0.8
14	3.20	0.51	0	3.7	3.8	-0.1
16	14.29	1.16	0	3.0	3.1	-0.1
17	19.93	1.30	28	2.5	2.9	-0.4
18	2.41	0.38	0	3.8	3.9	-0.1
19	3.97	0.60	0	3.9	3.7	0.2
20	3.02	0.48	0	4.1	3.8	0.3

profile computer between the runs made for the preliminary rating session in February 1968, and rating periods 1 and 2 in the following summer. The high frequency range of the profile computer was extended from about 75 cps (for preliminary rating session) to 250 cps (for rating periods 1 and 2). This extension of the range exceeded the natural frequency of the road-following wheel and probably affected the subsequent data.

As another check on the equation for flexible pavements, a group of 6 raters who had rated during some or all of the previous sessions rated 5 flexible pavements of various quality in the Austin area. The SD profilometer was used to make profile measurements, and condition survey data were recorded for these sections. These data are given in Table 2.

Summary statistics were run on these data, and the resulting statistics and condition survey information were substituted into Eq. 3 for the computation of PSI's. Equation 3 was used because only the left profile data were available at the time of measurement. One of the accelerometers was being repaired by the manufacturer. The resulting PSR values are also given in Table 2. The residual column shows that 2 out of the 5 residuals (difference between PSR and PSI) were greater than 0.5 (the estimated standard deviation). This means that 60 percent of the values are within 0.5 of the proper value that is not abnormal. These results would then suggest that the predicted values for flexible pavements are within a reasonable range.

No rigid pavements were included in either the preliminary rating session or in the 5 test sections in the Austin area. Therefore, no checks are available on the rigid pavement equation at the present time, and the checks that have been proposed for the flexible pavements are not rigorous.

The validity of the equations presented in this report cannot be ensured until several sections of both the flexible and rigid type are measured with the SD profilometer while

TABLE 2

ROUGHNESS DATA FOR 5 FLEXIBLE PAVEMENT TEST SECTIONS IN THE AUSTIN AREA MEASURED WITH FILTER 2 AT 50 MPH

Section	Average SV x 10^6	Log SV	Cracking	Patching	PSR	PSI	Residual (PSR - PSI)
1	255.7	2.408	3.6	48.3	1.75	1.00	0.75
2	45.1	1.654	0.5	0	2.36	2.75	-0.38
3	9.4	0.973	0	200.0	2.97	2.34	0.63
4	23.6	1.372	60.5	0	2.10	2.31	-0.21
5	8.8	0.944	69.4	0	3.87	3.44	0.43

all equipment is operational and then rated by a small panel of raters and the differences compared. Such validation should be accomplished as soon as possible.

The variability of summary statistics obtained from the SD profilometer is of importance in determining the usefulness of these measurements in estimating the change of PSI with time on roadway sections of interest. Because the most useful application of the SD profilometer will be in evaluating roughness to determine PSI, the variability of the log of SV was investigated. The log transformation on SV was used in Eqs. 1 and 2 for flexible and rigid pavements respectively. The standard deviations of the log SV values for both the flexible and rigid pavements were calculated. The standard deviation for the log SV of the flexible pavements was 0.124, while the standard deviation for the log SV of the rigid pavements was 0.085. To determine the effect of these variations on the PSI values for a typical flexible and rigid section, 2 sections were selected for which the PSI was calculated from Eqs. 1 and 2. By using the measured SV and condition survey data, the standard deviation of the log SV was added to each and the new PSI calculated. These values are as follows:

	Flexible Pavement	Rigid Pavement
PSI with log SV	4.09	4.04
PSI with log SV + σ_{SV}	4.08	3.98

There are practically no differences between the values calculated by using SV versus the values calculated by using SV plus 1 standard deviation.

To obtain an indication of the repeatability of the PSI values calculated by using Eqs. 1 and 2 versus the PSR values, 10 sections that were rated twice by the rating panel and run twice with the SD profilometer were selected for a correlation study. The PSI's were calculated for data from each run of the profilometer and the condition survey information. The correlation of the PSI for the first run with the PSI from the second run was 92 percent, while the correlation of the first PSR value with the second PSR was 96 percent. From this information it can be concluded that the rating panel can repeat its rating value with slightly more accuracy than can the SD profilometer. However, it is quite likely that variation between 2 different panels would be much higher. Also run-to-run variation would be higher for a smaller panel. The implication of such information is that data from the SD profilometer can be used for estimating PSR values using the developed equations with about the same accuracy as can a rating panel. However, because it would be impractical to use such a large rating panel for routine work, we can conclude that the profilometer is the better approach to the problem.

DISCUSSION OF FINDINGS

The analyses involving the rating values from the panel showed that (a) the average of all rating values could be used to represent the collective opinion of the panel for each test section; (b) the PSR value is not affected by the position in the vehicle that the rater occupied; (c) there were no significant differences between the rating values of the men and the women; (d) there were no significant differences between the average rating values of the drivers and the panel; and (e) the raters were able to rerate several sections with no significant differences between the first and the second rating.

A set of programs was developed for computing the summary statistics of SV, XSV, and RI. Those programs use input data that were digitized by using an A-D program developed by Walker et al. (11). The digitized data were processed through a compatibility program before being used to compute the summary statistics. This is the first set of general programs that have been developed for this purpose.

A set of equations for predicting the PSR for both flexible and rigid pavements by using slope variance and condition survey variables have been developed. Neither equation has been rigorously checked, but comparisons of results on a few test sections indicate that the predicted (PSI) values are reasonable. One additional check on several sections that were rated at 2 different times by the rating panel and run twice with the

SD profilometer indicates that the 2 predicted (PSI) values are in agreement as are the two PSR values given by the rating panel. This would indicate that the repeatability of the PSI values using profilometer data is about the same as the repeatability of the rating panel itself.

The profilometer provides an accurate analog signal that represents the road profile. These data in digital form are amenable to many statistical or nonstatistical analyses. Data of this type are available for the first time. The digitized profile data have been used as input values of road profile in a model to predict dynamic forces on the pavement surface caused by pavement roughness. Comparisons of these predicted dynamic loads to measured dynamic loads on a test section where both roughness measurements via the SD profilometer and dynamic loads via a scale for weighing vehicles in motion were obtained and showed very close agreement (1).

However, many difficulties have been encountered with the equipment and the operation of the data collection and analyses phases of the study. Most of these difficulties have been associated with noise problems from tape flutter or photocell crosstalk and maintenance problems with the sensor wheels and potentiometers. The noise problems have been minimized (a) by placing a switch in the photocell circuit to break the circuit after the initial begin-of-section signal is obtained and (b) by removing the tape recorder from the shock mounts and placing it on an air cushion. The maintenance problems with the sensor wheels and potentiometers could be eliminated if a noncontact probe were developed. Technology now seems to be available for developing such a noncontact probe and several organizations are conducting research in this area.

SUMMARY AND RECOMMENDATIONS

Summary

This paper describes the procedures involved in conducting a rating session and the recording of profile and condition survey data necessary to relate the subjective opinion of a panel of typical road users to measurable roadway characteristics. The description of summary statistics used to represent the longitudinal and transverse profiles with 2 numbers is included as are the necessary transformations for linearizing these data for use in linear regression programs. Finally, 2 equations are recommended for use with the SD profilometer, one each for flexible and rigid pavements. An idea of the accuracy of the predictive equation for flexible pavements was obtained by comparing the PSR's for the preliminary rating session sections with the predicted value using the developed equation. An additional check on the predictive quality of the equations for both flexible and rigid pavements was made by comparing the correlations of ratings given at 2 different times by the panel on 10 sections with the predicted ratings from the developed equations. This check showed that the equations were about as accurate as the panel of raters in predicting the second rating value.

The profile measurements are very accurate but are expensive to obtain, and analysis is very time consuming. However, the magnitude of these problems might be decreased considerably if the present sensors were replaced with some type of noncontact probe. The predictive ability of the equations would be refined if these problem areas were minimized.

Continued use of the equipment will help eliminate problems. For example, the electrical noise problem has been greatly reduced by relocating the tape recorder and laying it on an inflated mat. The photocell noise was eliminated by installing a switch that breaks the circuit between the photocell and the Brush strip chart recorder after the begin-of-section mark is sensed.

Recommendations

As with any empirical finding, the developed equations should be verified with additional data. This could be accomplished by selecting several test sections, both flexible and rigid, for obtaining profilometer measurements and at the same time selecting several of the original panel members to drive over and rate the same pavement sections. The differences between the predicted PSI and the mean panel PSR should be within ±1 standard deviation 67 percent of the time.

An investigation into the possibility of replacing the present road-following wheel and linear potentiometer with a noncontact probe for measurement of the relative displacement between the road surface and the profilometer vehicle might help eliminate the major source of equipment difficulty. A reevaluation of the rating session profile data with a noise filter would be desirable.

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