

A Report on
A MODIFICATION OF THE AASHO ROAD TEST
SERVICEABILITY INDEX FORMULA

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RESEARCH PROJECT 2-8-62-32 (HPS-1-27)
"Application of AASHO Road Test Results to Texas Conditions"

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A MODIFICATION OF THE AASHO ROAD TEST

SERVICEABILITY INDEX FORMULA

Synopsis

Use of the CHLOE profilometer in Texas indicated that this device for measuring road roughness tends to rank pavements having a coarse textured surface too low on the serviceability scale. To offset this tendency, a hand operated device for measuring coarseness of texture was developed, and a term for textural roughness was added to the AASHO Road Test formula for the serviceability index. The coefficient of the new term was evaluated by analysis of the subjective ratings given 43 flexible pavements by a 12-man panel of Texas highway engineers.

A by-product of the study was the finding that the Texas engineers tended to rate at a lower level than the AASHO Road Test panel. To compensate, local ratings were adjusted upward 10 percent.

The new formula for serviceability index predicted the adjusted ratings with satisfactory accuracy and will be used on this project for calculating the serviceability index for flexible pavements.

1. The Serviceability Index Formula

The objectives of Research Project 2-8-62-32, "Application of the AASHO Road Test Results to Texas Conditions," require the calculation of the serviceability index of each flexible pavement test section from the formula developed at the AASHO Road Test and given below:

$$p = 5.03 - 1.91 \log_{10} (1 + \overline{SV}) - 0.01 \sqrt{C + P} - 1.38 \overline{RD}^2 \quad (1)$$

in which

p = the present serviceability index;

\overline{SV} = the mean of the slope variance in the two wheelpaths, multiplied by 10^6 ;

$C + P$ = a measure of cracking and patching in the pavement surface; and

\overline{RD} = a measure of rutting in the wheelpaths.

The serviceability index, p , is an estimate of the mean subjective rating which would be given the pavement by a cross-section of highway users, and represents the instantaneous ability of the pavement to serve high speed, mixed traffic at the time it is rated.

The index (or the rating) is restricted to values from zero to 5.0. The scale is divided into the five categories described below:

<u>Rating or Index</u>	<u>Description of Pavement</u>
0-1	Very poor
1-2	Poor
2-3	Fair
3-4	Good
4-5	Very good

(A detailed description of the pavement serviceability-performance concept is given in Highway Research Board Special Report 61E, "The AASHO Road Test, Pavement Research," Appendix F.)

2. Effect of Surface Texture on Slope Variance

In Equation 1 the term having the greatest effect on the serviceability index is the slope variance term, $\log(1 + \overline{SV})$. Slope variance at the Road Test was measured by a specially developed instrument known as the AASHO Road Test profilometer. On the present project, slope variance is being measured by the CHLOE profilometer, an instrument also developed at the Road Test but not regularly used there (Figures 1 and 2).

Use of the CHLOE profilometer on Texas pavements has shown that the slope variance arising from roughness of surface texture cannot be distinguished from that



Figure 1. CHLOE profilometer in use. Man behind profilometer records cracking, patching and rut depth, to be used with CHLOE and texturemeter data in calculating serviceability index. Profilometer is loaded in towing vehicle for travel between test sections.

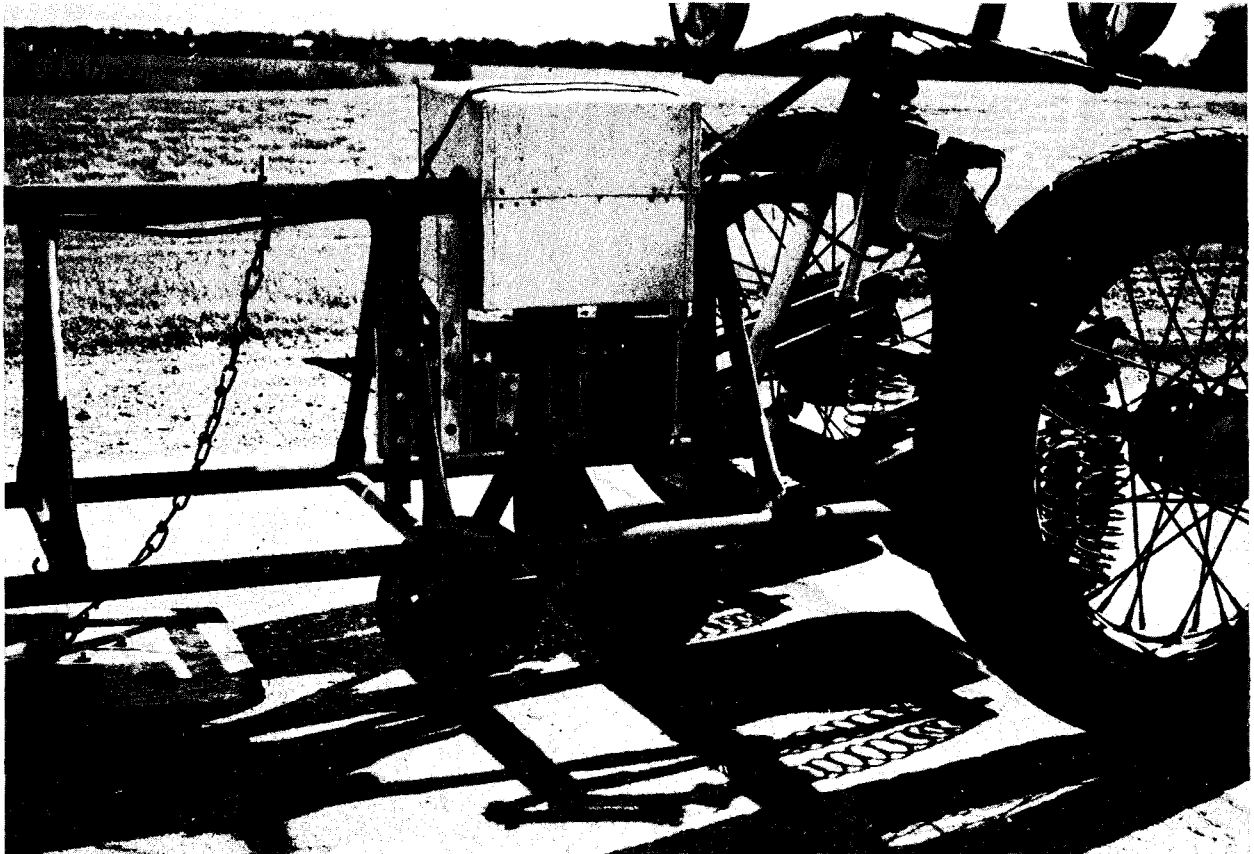


Figure 2. Close-up of the slope wheels of the CHLOE profilometer. The device measures the angle between the trailer tongue and the link between the slope wheels.

resulting from objectionable undulations in the pavement.* As a result, the serviceability indexes computed from CHLOE profilometer readings are generally too low (roughness too high) for rough textured pavements that otherwise exhibit no objectionable roughness.

3. Methods Used in Modifying the Serviceability Index Formula

There being no effective method known to the project staff for damping out the high frequency vibrations of the CHLOE profilometer slope wheel mechanism arising from rough textured surfaces, it was decided to develop a hand operated device for measuring roughness of surface texture, and to add to the Road Test serviceability formula a term for surface texture that would tend to correct the serviceability index when necessary.

The instrument developed for measuring coarseness of texture is pictured in Figures 3 and 4, and is known as a texturemeter. It consists essentially of a series of evenly spaced, parallel rods mounted in a frame. The rods can be moved longitudinally, independently of one another, against spring pressure. At either end of the series of movable rods is a fixed rod rigidly attached to the frame.

Each movable rod is pierced by a hole through which passes a taut string, one end of which is fixed to the frame and the other to the spring loaded stem of a 0.001-inch dial gage mounted on the frame. When the instrument is in use, the rods are held in a vertical position with their ends resting against the pavement surface. If the surface is smooth, the string will form a straight line and the dial will read zero. Any

*The Road Test profilometer was equipped with an electronic component which filtered out high frequency voltage fluctuations arising from roughness of surface texture.



Figure 3. The texturemeter applied to a flat, metal surface for a zero reading.

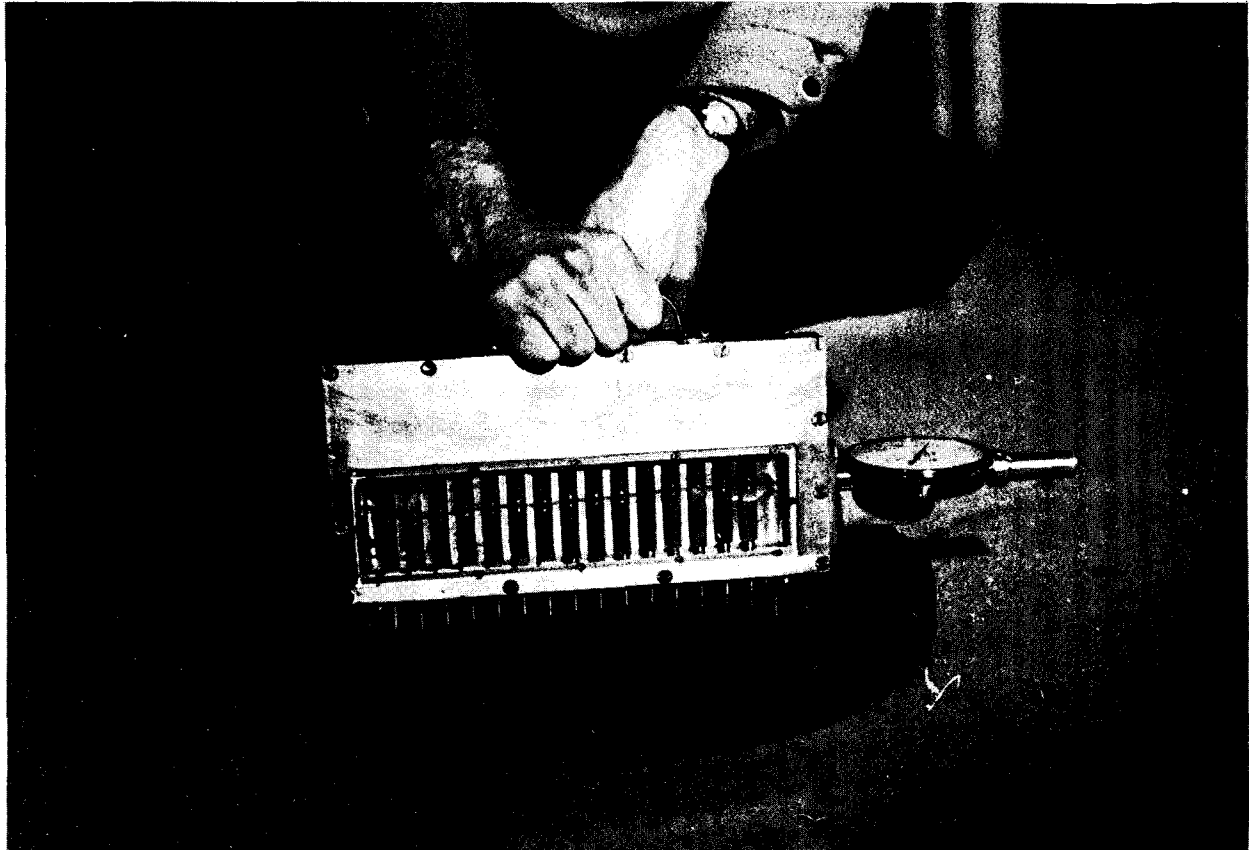


Figure 4. The texturemeter applied to a laboratory specimen of asphaltic concrete. Road surfaces give dial readings ranging from zero to about 100 thousandths of an inch.

irregularities in the surface will cause the string to form a zig-zag line and will result in a reading on the dial. The coarser the texture of the pavement, the larger will be the dial reading.

The readings given by an instrument of this kind are affected by the spacing of the rods and the distance between the fixed supports. In the texturemeter now being used, the rods are spaced at 5/8 inch, and the instrument spans a distance of 10 inches between fixed supports.

It was postulated that the serviceability rating, R , of a test section could be estimated from the following mathematical model involving textural roughness:

$$R = p + A_0 + A_1 \log(1 + T) \quad (2)$$

where p is given by Equation 1, T is the mean reading of the texturemeter in the two wheelpaths in thousandths of an inch, and A_0 and A_1 are constants to be determined by analysis of the subjective ratings given a number of selected test sections by a rating panel.

4. Selection and Rating of Test Sections

To provide ratings and other data required by the analysis mentioned in the previous paragraph, forty-three 2400-foot flexible pavement test sections in District 9, for which CHLOE profilometer data were already available, were selected and rated by a 12-man panel in December, 1962, and January, 1963. Texture measurements on each section were made in January, 1963. Mean ratings, R , and texturemeter readings, T , are summarized in Table 1.

TABLE 1

Test Section	R	p	R - p	T	R'	p'	R' - p'	p _c	Error (R' - p _c)
<u>Asphaltic Concrete Surface</u>									
15-6-1	4.1	4.4	-0.3	2.4	4.5	4.2	0.3	4.4	0.1
15-7-1	4.0	4.2	-0.2	4.0	4.4	4.1	0.3	4.5	-0.1
15-7-2	3.8	3.9	-0.1	6.9	4.2	3.8	0.4	4.3	-0.1
15-14-1	3.9	4.0	-0.1	2.8	4.3	3.9	0.4	4.2	0.1
15-14-2	2.7	3.2	-0.5	1.4	3.0	3.2	-0.2	3.3	-0.3
15-14-3	3.6	4.6	-1.0	1.1	4.0	4.4	-0.4	4.5	-0.5
231-3-1	3.9	4.3	-0.4	0.8	4.3	4.2	0.1	4.2	0.1
231-4-1	4.0	4.4	-0.4	1.0	4.4	4.2	0.2	4.3	0.1
251-1-1	3.3	3.5	-0.2	4.2	3.6	3.4	0.2	3.8	-0.2
251-2-1	4.0	4.3	-0.3	2.0	4.4	4.1	0.3	4.3	0.1
251-3-1	4.0	4.2	-0.2	3.9	4.4	4.0	0.4	4.4	0.0
258-7-1	3.8	4.4	-0.6	0.3	4.2	4.2	0.0	4.1	0.1
258-7-2	3.6	4.0	-0.4	0.0	4.0	3.9	0.1	3.7	0.3
258-7-3	3.2	3.8	-0.6	0.1	3.5	3.6	-0.1	3.5	0.0
382-2-1	3.8	3.6	0.2	2.2	4.2	3.5	0.7	3.7	0.5
183-3-1	4.1	4.8	-0.7	3.8	4.5	4.4	0.1	4.8	-0.3
184-3-1	4.0	4.6	-0.6	1.0	4.4	4.4	0.0	4.5	-0.1
209-7-1	3.9	4.4	-0.5	1.9	4.3	4.3	0.0	4.5	-0.2
413-2-1	4.0	4.5	-0.5	1.1	4.4	4.3	0.1	4.4	0.0
833-4-1	4.0	4.6	-0.6	1.8	4.4	4.4	0.0	4.6	-0.2
833-4-2	3.8	4.4	-0.6	1.8	4.2	4.2	0.0	4.4	-0.2
209-3-1*	3.5	4.6	-1.1	3.2	3.9	4.4	-0.5	4.7	-0.8
209-3-2*	3.6	4.6	-1.0	3.2	4.0	4.4	-0.4	4.7	-0.7
<u>Surface Treatments</u>									
55-2-1	3.5	2.3	1.2	31.9	3.9	2.3	1.6	3.3	0.6
209-2-1	2.6	2.2	0.4	38.6	2.9	2.2	0.7	3.3	-0.4
386-3-1	2.7	2.2	0.5	46.5	3.0	2.2	0.8	3.4	-0.4
386-3-2	3.2	2.2	1.0	54.3	3.5	2.2	1.3	3.4	0.1
386-4-1	2.6	2.1	0.5	25.0	2.9	2.1	0.8	3.1	-0.2
386-4-2	2.6	2.1	0.5	12.0	2.9	2.1	0.8	2.8	0.1
398-5-1	2.7	2.6	0.1	11.6	3.0	2.5	0.5	3.2	-0.2
519-3-1	3.2	2.4	0.8	27.7	3.5	2.4	1.1	3.4	0.1
590-2-1	3.1	2.6	0.5	10.9	3.4	2.6	0.8	3.3	0.1
836-2-1	3.0	3.3	-0.3	2.1	3.3	3.2	0.1	3.4	-0.1
836-2-2	3.0	2.8	0.2	1.6	3.3	2.8	0.5	3.0	0.3
1665-1-1	2.5	1.8	0.7	43.2	2.8	1.8	1.0	3.0	-0.2
2305-1-1	2.3	2.0	0.3	19.1	2.5	2.0	0.5	2.9	-0.4
2395-1-1	2.6	2.3	0.3	5.0	2.9	2.3	0.6	2.7	0.2
656-1-1	3.6	2.4	1.2	40.0	4.0	2.4	1.6	3.5	0.5
833-7-1	3.4	2.5	0.9	19.2	3.7	2.4	1.3	3.3	0.4
1078-2-1	3.5	2.8	0.7	14.5	3.8	2.8	1.0	3.6	0.2
2625-1-1	3.5	2.8	0.7	25.6	3.8	2.8	1.0	3.8	0.0
1054-4-1*	2.4	2.6	-0.2	29.4	2.6	2.6	0.0	3.6	-1.0
1594-2-1*	2.5	2.8	-0.3	24.1	2.8	2.8	0.0	3.8	-1.0

* Data from this section not used in analysis.

Each value of T in the table is the average of 40 readings by the texturemeter, 20 in each 2400-foot wheelpath.

The rating, R, of a section was calculated as follows:

An average of the 12 individual ratings was calculated. If one or more individual ratings deviated from the average by 0.8 or more, those ratings were eliminated, and the average of the remaining ratings was taken as the rating for the section. Under this procedure, the number of ratings averaged to obtain the mean for a section varied from 9 to 12, the most frequently occurring number being 11.

5. Analysis

For use in a regression analysis, Equation 2 was rearranged as follows:

$$R - p = A_0 + A_1 \log(1 + T) \quad (3)$$

Values of R - p were plotted as ordinates, and $\log(1 + T)$ as abscissa in Figure 5. Also shown in the figure is a plot of Equation 4 obtained from the regression analysis.

$$R - p = - 0.77 + \log (1 + T) \quad (4)$$

The squared correlation coefficient was 0.78 and the standard deviation was 0.28.

Data for sections 209-3-1, 209-3-2, 1054-4-1, and 1594-2-1 were not used in this and the succeeding analysis because of the fact that the R - p values for these sections deviated from the values predicted by Equation 4 by an amount considerably in excess of two standard deviations. The reason for the unusually low

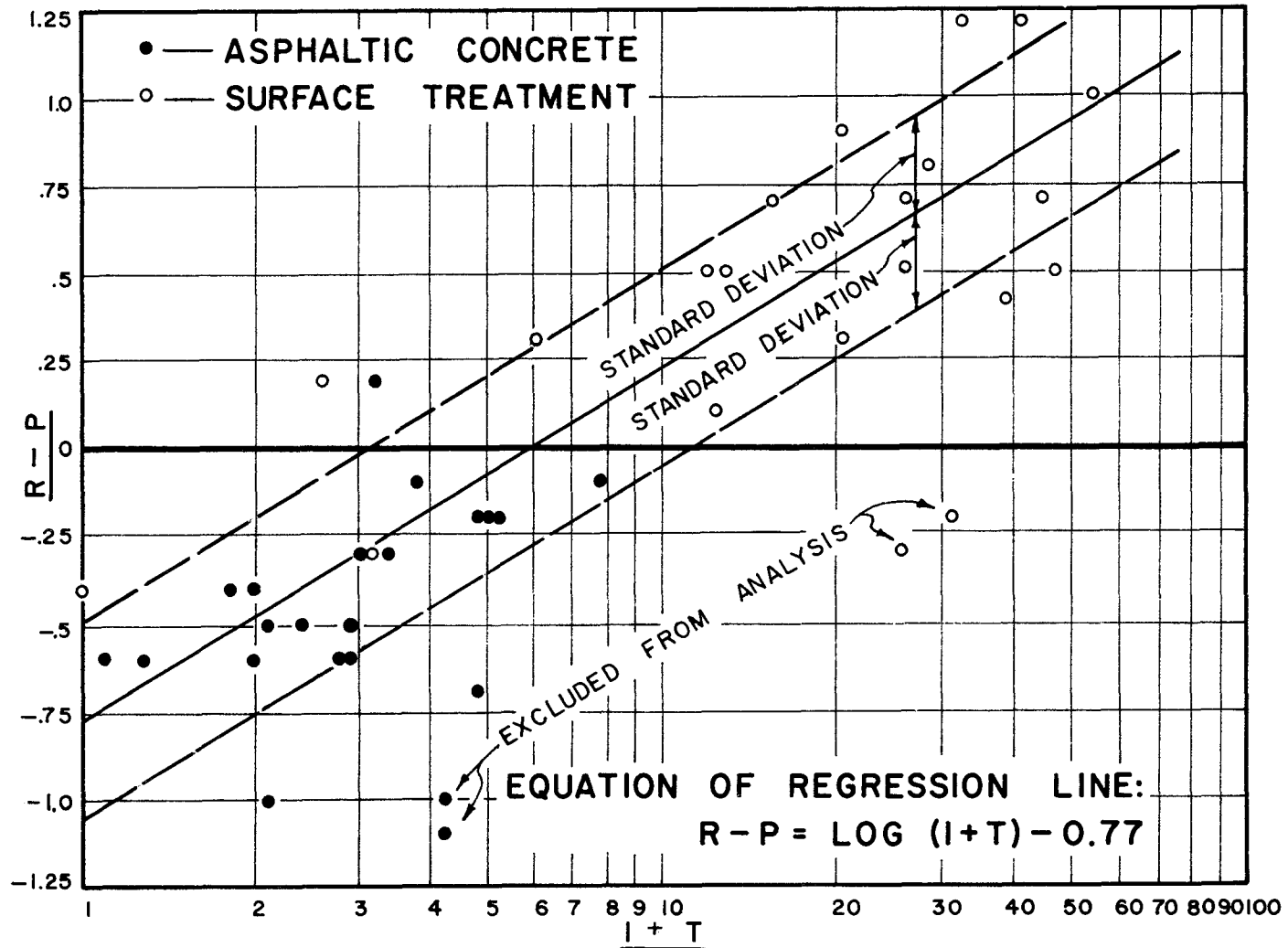


Figure 5. Difference between rating and serviceability index as a function of roughness of surface texture. Data are from Table 1.

ratings--or unusually high serviceability indexes--for these sections was not apparent. As time permits, further study of these sections will be made.

6. Adjustment of Data

It will be seen from Equation 4 that when $T = 0$, as for a very smooth textured pavement, the serviceability index, p , exceeds the rating, R , by nearly 0.8 of a rating unit. Thus, in those instances where texture had no effect on the profilometer, either the subjective ratings were too low, or the serviceability indexes computed from the profilometer were too high, or both of these conditions existed.

It was obvious that most members of the rating panel were hesitant to rate any pavement in the "very good" category, as evidenced by the maximum panel mean of 4.1. It was the opinion of the Project Supervisor (a former AASHO Road Test staff member), shared by Mr. W. R. Hudson (Texas Highway Department representative on this project and also a former Road Test staff member), that the Road Test panel would have rated several of the District 9 pavements in the neighborhood of 4.5. In order to establish agreement between the national and the local panel, it was concluded that all local ratings should be adjusted upward by 10 percent, so that the maximum mean rating of 4.1 would be increased to 4.5, and other ratings would be increased proportionately. The column headed R' in Table 1 gives the adjusted values of the rating.

On the other hand, examination of the profilometer data showed that this instrument had in several instances yielded serviceability indexes for subsections (1200-foot half-sections) as high as 4.9 or 5.0. It was felt that these were too high,

and that until the instrument could again be correlated with the Road Test profilometer, the serviceability indexes calculated from CHLOE data should be adjusted downward.

The original study correlating the CHLOE with the Road Test profilometer showed that a constant, 3×10^6 , should be subtracted from the CHLOE slope variance in order to make its output agree with that of the Road Test instrument. This correction was used in calculating the values of p given in Table 1.

In order to achieve the desired reduction in serviceability index, the values of p' given in Table 1 were calculated using a correction constant of 2.5×10^6 . Values of p' are somewhat less (one to two tenths, usually) than the corresponding values of p , when p is above 3.0. Below 3.0, the effect of the change in the constant correction is practically negligible.

7. Analysis of Adjusted Data

A plot of $R' - p'$ versus $\log(1 + T)$ is shown in Figure 6. The best fitting line through the data has the equation

$$R' - p' = -0.18 + 0.81 \log(1 + T) \quad (5)$$

The squared correlation coefficient was 0.70 and the standard deviation was 0.28.

Equation 5 may be written as follows:

$$R' = p' - 0.18 + 0.81 \log(1 + T) \quad (6)$$

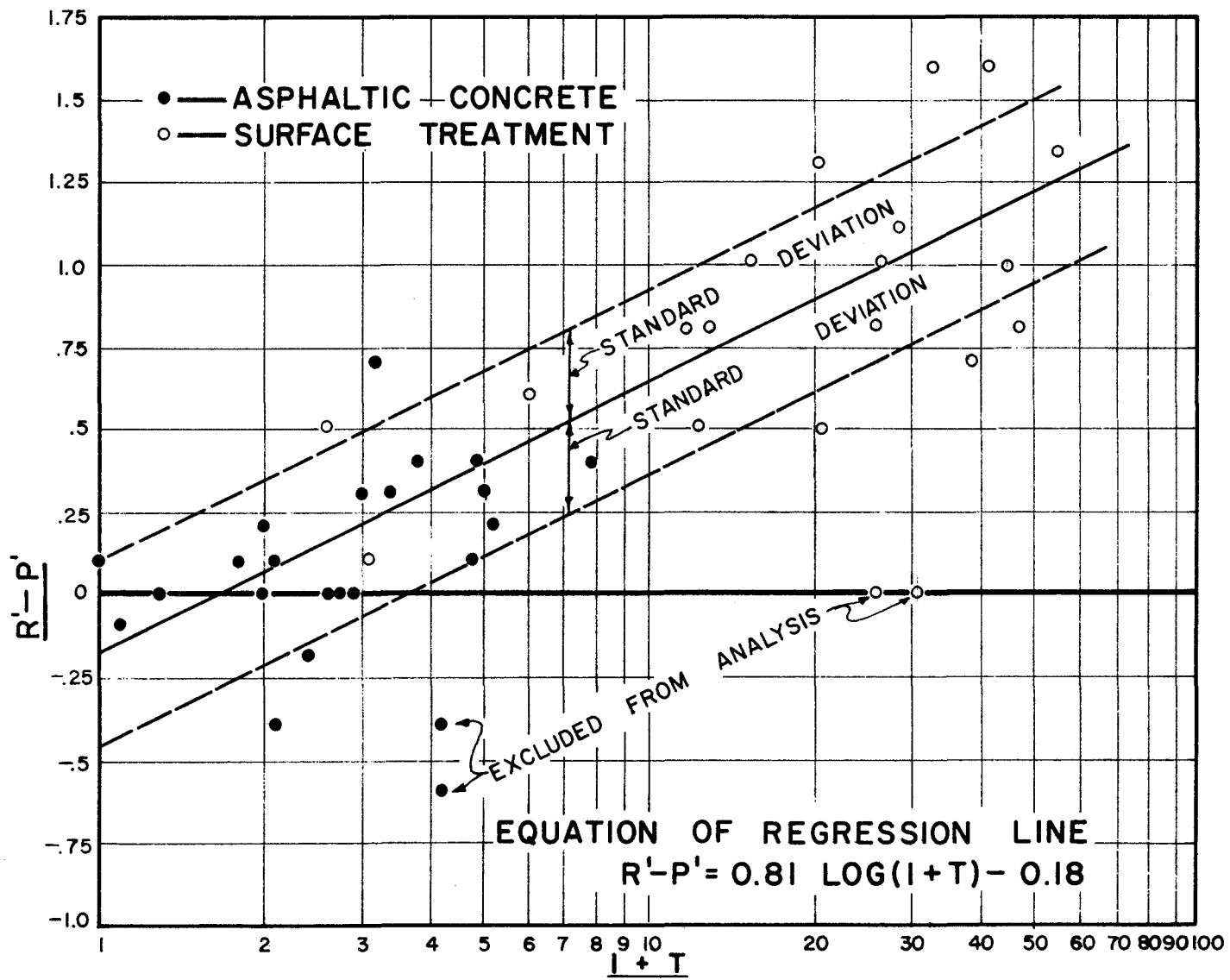


Figure 6. Difference between adjusted rating and adjusted serviceability index as a function of roughness of surface texture. Data are from Table 1.

where, according to Equation 1,

$$p' = 5.03 - 1.91 \log(1 + \overline{SV}) - 0.01 \sqrt{C + P} - 1.38 \overline{RD}^2, \text{ and}$$

$$\overline{SV} = [\text{CHLOE slope variance} - 2.5] \times 10^6.$$

Let p_C = the serviceability index corrected for surface texture.

Then according to Equation 6,

$$p_C = 4.85 - 1.91 \log(1 + \overline{SV}) + 0.81 \log(1 + T) - 0.01 \sqrt{C + P} - 1.38 \overline{RD}^2 \quad (7)$$

where $\overline{SV} = [\text{CHLOE slope variance} - 2.5] \times 10^6$

and all other terms are as previously defined.

According to the analysis of the adjusted data, Equation 7 predicts the adjusted ratings (actual rating + 10%) with a root mean square residual of 0.28. This error compares favorably with the error of 0.38 reported for Equation 1 in the reference previously cited, but would have been increased somewhat had the four sections eliminated from the analysis been included.

Values of p_C computed from Equation 7 are given in the next to last column of Table 1. Prediction errors are shown in the last column.

8. Conclusions

The following conclusions appear to be justified by the data and analysis presented above:

1. The local rating panel tended to rate pavements at a slightly lower level than the AASHO Road Test rating panel. The tendency was most noticeable in the case of pavements in the "very good" category.

2. The texturemeter or a similar device is a necessary tool for use with the CHLOE profilometer on coarse textured pavements such as surface treatments.

3. The modified formula for the serviceability index (Equation 7) is believed to be satisfactory for the purposes of this project and should be used for calculating the serviceability index of flexible pavements in lieu of the original AASHO Road Test formula (Equation 1), since about half of the flexible pavement test sections have a coarse textured surface.

4. The CHLOE profilometer in use on this project should again be correlated with the AASHO Road Test profilometer. If the correlation between the two instruments is found to have changed, it may be necessary to make corresponding changes in the coefficients of Equation 7.

9. Acknowledgments

The author is indebted to Mr. James H. Aiken, District Engineer, District 9, and other engineers of the Texas Highway Department listed below who participated in the work of rating the pavements, as well as to other members of the project staff.

The texturemeter was designed by staff members working in cooperation with Mr. Josef Budig, Scientific Instrument Maker, Research and Instrument Shop, Texas Engineering Experiment Station, who constructed the first experimental model. The model used in this study was constructed in the Texas Highway Department's Equipment Division shops under the supervision of Mr. Paul Hancock. Mr. W. R. Hudson of the Highway Department contributed valuable suggestions leading to improvements in the second model.

Members of the rating panel were the following: J. E. Kelly, S. P. Gilbert, G. C. Cleveland, John Neubauer, R. E. Burns, W.W. Miller, and John Nichols, all of District 9 of the Texas Highway Department; W. R. Hudson, John Nixon, and P. B. Rapstine of the Highway Design Division, Texas Highway Department; F. H. Scrivner and E. L. Hlavaty of the project staff.