MICROTEXTURE MEASUREMENTS OF PAVEMENT SURFACES

Interim Report

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CONTENTS

ABSTRACT

A review of some texture-measuring techniques was made and a limited number of microtexture measurements of pavement surfaces was obtained with the Clevite BL-185 Surfindicator. This instrument is generally used to measure uniform textures on surfaces such as those found on finished metallic parts.

The results of the investigation revealed that the Surfindicator has some undesirable features for measuring microtextures of pavement surfaces. Based on a limited number of tests, a trend was found between skid numbers at 40 mph and microtexture values; however, the correlation coefficient between the parameters was not very high. Significant differences between the microtextures of some pavement surfaces were determined by the device.

Recommendations are given to continue microtexture measurements with the Surfindicator on a limited basis and to develop another instrment to obtain macrotextures as well as microtextures.

SUMMARY

This interim report presents the preliminary results and findings of an investigation on skid resistance and microtextures of pavements. Based on a limited number of tests with the type of equipment used in the study, poor correlations were found between these two pavement properties. Only a limited future effort is recommended with the particular texture measuring device used in this investigation, and a recommendation is made to develop an improved device.

IMPLEMENTATION STATEMENT

The recommended texture measuring device will be the size of the Texas Highway Department Profilograph, portable and be handled by one person. Tests with this device can be conducted as rapidly as with the Profilograph. Both trace recordings and centerline average heights will be obtained.

The development of the recommended device is within the scope of this research study. Existing technology and skill are available to develop and construct a prototype for future texture measurements and evaluation. Thus the implementation consists mainly in fabricating and obtaining component parts and in assembling the device.

BACKGROUND

The texture of a pavement surface is the character of the surface profile consisting of a series of rather abrupt changes in elevation. Variations in textures can result from the different sizes of aggregates on the surface and from various pavement finishing operations. The textures resulting from construction can be altered by the effects of traffic wear and of the environment. In general, the textures can be categorized into three groups (1): (a) the large-scale macroscopic texture, (b) the small-scale macroscopic texture, and (c) the microscopic texture. The large-scale macroscopic texture describes the average spacing of the peaks or the average peak-to-valley depth of the larger changes in elevation and determines in large measure, the water drainage properties of the pavement surface. The small-scale macroscopic texture is the "grittiness" of the surface caused by cemented sand-sized particles or by sharp projections on the larger aggregates. This macroscopic texture determines the friction properties at any speed (1). The microscopic texture, also influencing the friction properties, is the minute surface characteristics of aggregates in the microinch range. Knowledge of the effects of the macro- and microtextures will be helpful in determining the friction coefficients of pavement surfaces.

In December 1969 the Texas Highway Department forwarded an electronic device which may be applicable for measuring the textures of pavement surfaces under Project 138. The device was the Surfindicator Model BL-185 manufactured by the Clevite Corporation, 4601 North Arden Drive, El Monte, California 91731. This device is generally used to measure the textures of uniformly machined surfaces such as those on metallic products. It is capable of sensing both small-scale macroscopic and microscopic textures. For the purpose of this report, however, the results obtained with the Surfindicator will simply be termed the microtexture in microinches.

A review of some of the available methods of texture measurements was made, and a brief preliminary investigation was conducted to evaluate the device and to determine its applicability to microtexture measurements of pavement surfaces. Results of the investigation with some recommendations are reported.

SOME TEXTURE MEASURING TECHNIQUES

There are many techniques for measuring surface textures with degrees of refinements from the subjective sight and touch method through the stylus tracer with an electronic instrumentation. Some of the techniques described in subsequent paragraphs can be used from microtexture as well as macrotexture measurements. However, the techniques applicable mainly to large-scale macroscopic textures are not included. Descriptions of these may be found elsewhere (2).

Subjective Method, Dial Gauges, and Light

The senses of touch and sight have been used for ages in appraising the texture of finished surfaces. Recent studies indicated that a range of roughness is possible by this subjective method, and that skilled personnel are only slightly better in judging surfaces than unskilled personnel (3).

A system of dial gauges for evaluating the textures of finished surfaces has been developed. The major disadvantage of the dial gauge evaluation is the requirement for a large number of measurements which is laborious and time-consuming (3).

Light can be used in several ways to help analyze surfaces. Variations in textures can be visualized better under some conditions of light. For example, light passing under a straightedge placed on a surface indicates surface texture.

A method called light sectioning is a simple method used to obtain a representation of a surface texture. In this method, a beam of light is passed between two parallel, optically flat plates spaced by means of shims. The resulting slit of light is focused on the surface at an angle, and the reflection which is the apparent profile height is photographed through a microscope. The actual profile height is then mathematically determined.

Stylus Tracer

A technique using a stylus tracer is the most accurate method of surface texture analysis (3). In this technique, a stylus is passed over the surface to be evaluated. By electrical, mechanical, or optical connection to the stylus, the response is transferred to a recorder or to an averaging meter. The result is a representation of the surface in the form of a profile picture, profile graph, or an average value.

For a simple mechanical linkage connecting the stylus to a recorder pen, the magnification can be controlled by the lever ratio in the system. In an optical-mechanical instrument, the oscillating stylus is mechanically connected to a tilted mirror which reflects a beam of light to a photographic paper. Thus a trace of the oscillating stylus is recorded. In both the simple mechanical and optical-mechanical techniques the resulting graph must be analyzed to obtain a value of the surface texture.

There are two systems of transferring the stylus response electrically to a recorder or to an averaging device; these are the potential-generating and carrier-modulating systems. In the potential-generating system, the stylus is connected to some mechanism that generates a potential in response to a movement of the stylus much like a phonograph pickup. The voltage output is proportional to the amount of stylus displacement, and the frequency of the a.c. signal is governed by the frequency of the peaks and valleys on the measured surface. Thus, the response is to vertical motion or rate of vertical motion. That is, the pickup generates no voltage if traced over a perfectly flat surface. However, the response is sensitive to variations in the speed of stylus tracing across a textured surface, since the rate of vertical motion of the stylus changes with speed of tracing.

In the carrier-modulating device, the vertical position of the stylus passing over the surface mechanically modulates a carrier, which is generated within the instrument and becomes the signal fed into an amplifier-recorder. Since the stylus responds to position rather than vertical motion or rate of vertical motion, the device is not sensitive to variations in speed of stylus movement across the surface. For this reason, the carrier-modulating devices have been developed to measure textures of homogeneous surfaces but have limited vertical range (4). This may not permit their use in measuring textures of pavement surfaces.

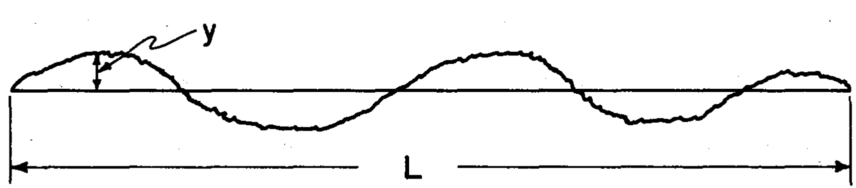
True-Datum and Surface-Datum Pickups

Pickups for the two electronic measuring devices discussed previously fall into two categories: true-datum and surface datum pickups (4). The true-datum pickup measures surface textures with respect to an optically flat datum, nominally parallel to the surface being measured. A continuous plot is obtained of constantly amplified distances between the surface and this datum.

The surface-datum pickup has a shoe or a rider which passes over the surface being measured. This shoe is very near or for some instruments surrounds the stylus. The measurement obtained is a plot of the position of the surface in relation to the shoe.

Surface-Tracer Recordings

Surface-tracer recordings or the results must be evaluated and characterized preferably by a numerical value. Two methods of assessing the surface-tracer recordings mathematically involves integration of the curve representing the surface as shown below. Both methods use a centerline placed through the curve by a least squares fit.



$$H_{CLA} = {}^{1}/_{L} \int_{0}^{L} y\,dL$$

$$H_{RMS} = \sqrt{{}^{1}/_{L} \int_{0}^{L} y^2\,dL}$$

where: H_{CLA} = average distance from the center line to the curve (center line average), and

H_{RMS} = root mean square distance.

Some instruments are equipped with dial gauges indicating the H_{CLA} and H_{RMS}.

Other methods involving simple measurements of tracer recordings include distance between lines representing average peak height and average valley depth or simply the average depth. These measurements neglect the influence of peak spacing (4).

Surfindicator

From the review of available literature (1, 2, 3, 4, 5, 6, 7) and printed information (8), the following characteristics of the Clevite Model BL-185 Surfindicator pictured in Figure 1 can be noted:

1. The Surfindicator is a potential-generating device for measuring, in general, milled, ground or sanded surfaces;

2. It has a stylus with a diamond tip of 0.0005 inch in diameter; the stylus can move vertically through a maximum distance of approximately 0.06 inch.

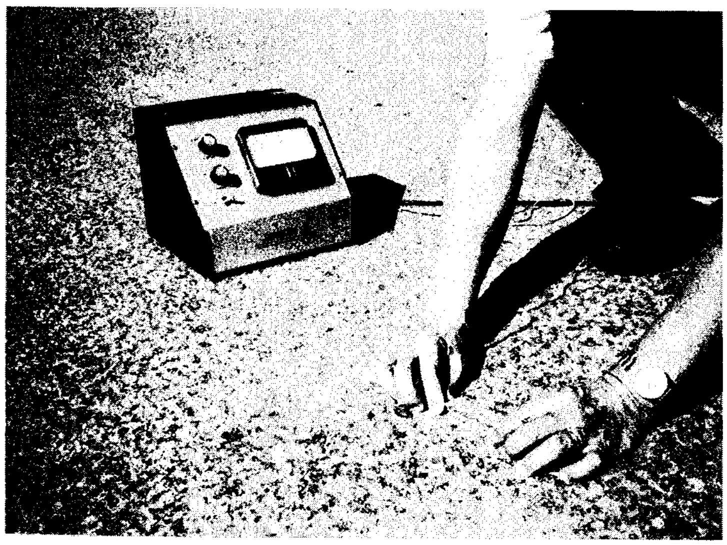


Figure 1. Clevite BL-185 Surfindicator.

3. It provides H_{CLA} or H_{RMS} readings, depending on the calibration, from one to 1,000 microinches on a dial gauge;

4. It provides peak-to-peak spacing cutoff of 0.003, 0.010, and 0.030 inch (0.030 is generally used); and

5. It is reported to provide a limited compensation for variations in readings caused by changes in speed of stylus movement. (A precision constant speed traversing instrument, Surfdrive-70 designed to mechanically traverse the probe used with the BL-185, is available for purchase but was not used in this investigation).

PRELIMINARY MEASUREMENTS WITH SURFINDICATOR

Preliminary microtexture measurements were made with the Clevite Surfindicator BL-185 on the surfaces of 4-inch diameter asphaltic concrete cores and small sawed sections obtained from various highways and marked areas (approximately one foot by two feet) of the standard skid test surfaces at the Texas A&M Research Annex. An extensive program of measuring microtexture of various road surfaces depended on the results of the preliminary measurements and their correlation with skid-resistant values.

Test Procedure

In general the test procedure recommended by the manufacturer was followed in measuring the microtexture of the surfaces with the BL-185 Surfindicator. One change on the Surfindicator was made concerning the datum from which measurements were taken; the shoe on the pickup was removed, and a holder was fabricated so that the pickup sliding in the holder will sense the texture from a true-datum. Briefly, the procedure consisted of providing a brief period of equipment warm-up followed by zeroing and balancing. A standard calibration block with a texture of 125 microinches was then used to calibrate the Surfindicator. The pickup with the holder was placed on the standard surface, and the pickup was moved by hand in a steady oscillating manner with a speed as close as possible to a range from 1/8-inch to 1/4-inch per second. No mechanical means of measuring the speed was available, and the operator had to rely on judgement. The stroke was 3/4-inch. A dial gauge displayed the H_{CLA} reading in microinches. The calibration screw was adjusted until a deliberate increase in the speed of movement caused only a minimum increase in the reading from the standard 125 microinches.

The instrument was separately calibrated at peak-to-peak spacing cutoff of 0.003, 0.010, and 0.030 inch to obtain readings in H_{CLA}. However, the 0.030-inch cutoff value was used for most of the tests, since it is the one normally specified (8). The other cutoff values were used to determine if the results showed similar trend as with the 0.030 cutoff.

A minimum of three texture measurements were taken on each of the test specimens or test locations and were averaged to obtain the results. Test locations were randomly selected on the test specimens and surfaces. However, locations with apparent deep holes were avoided. The number of test specimens available per highway ranged from one to eight. Four test locations per test surface were selected at the Research Annex. For test surfaces and specimens with exposed flat aggregates, measurements were made on the aggregates as well as on the composite surfaces.

Test Results

The average test results of texture measurements with the Surfindicator are plotted in Figures 2 and 3 against the skid numbers obtained

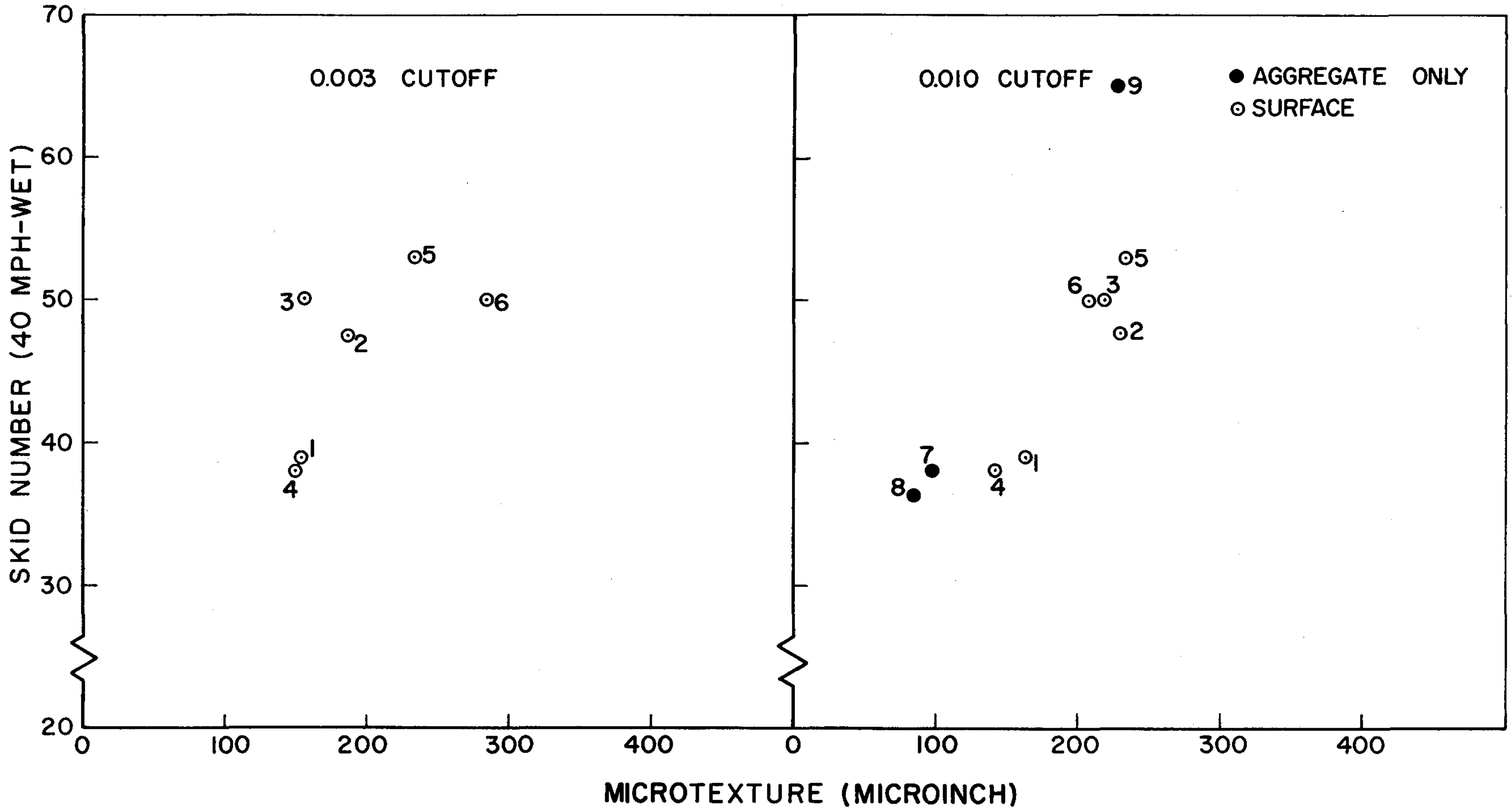


FIGURE 2. SKID NUMBER vs. MICROTEXTURE MEASURED WITH SURFINDICATOR (0.003 & 0.010 CUTOFFS).

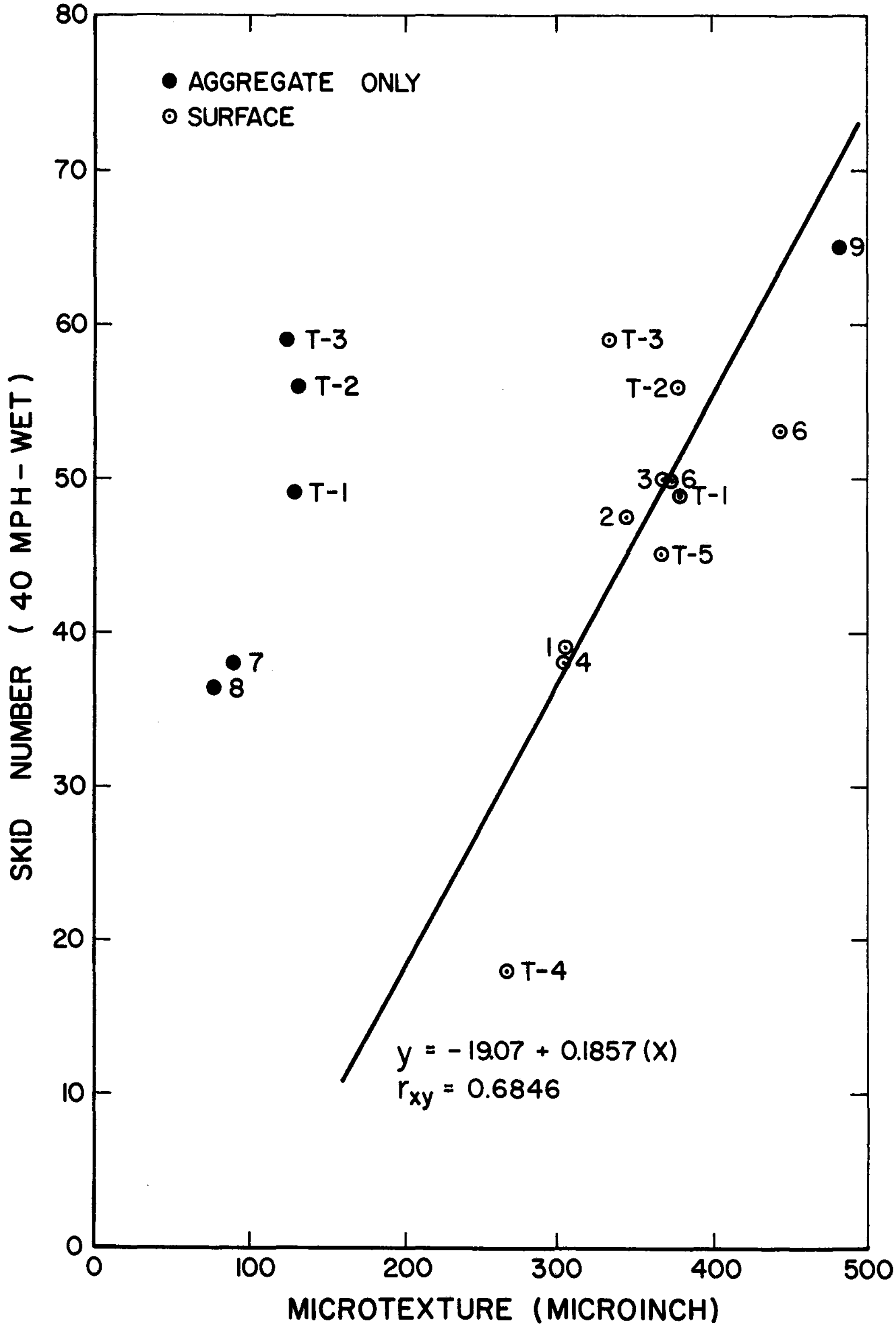


FIGURE 3. SKID NUMBER VS. MICROTEXTURE MEASURED WITH SURFINDICATOR (0.030 CUTOFF).

with a locked-wheel trailer at 40 mph. The skid numbers were not obtained concurrently with the texture measurements. Numbers adjacent to the data points correspond to the types of surface listed in Table 1.

Figure 3 shows a straight line through the results based on a least squares fit together with the regression equation and the correlation coefficient, $r_{xy} = 0.6846$. The results of measurements made on the individual aggregates of the surfaces were excluded from the regression analysis.

Table 2 shows the results of microtexture measurements on the Texas A&M Research Annex test sections. An analysis of variance was performed on the results to obtain an idea of the variances in microtextures associated between test sections and between test locations which are within test sections. For ease of calculations the microtexture values were coded by multiplying by 10^{-2}. No results of measurements on the individual aggregates were included in the analysis.

Discussion of Test Results

As shown in Figures 2 and 3, the skid number generally increases with increase in microtexture as measured by the Surfindicator at the three peak-to-peak spacing cutoffs. Based on the limited number of test results it seems that the slopes of the increasing trend are about the same regardless of the cutoff used. However, higher values of microtextures are obtained at the 0.030-inch cutoff than at the other cutoffs. In addition, as shown in Figure 3, there appears to be a clearly distinguishable difference between the measurements on the individual aggregates and on the composite surface except for the measurement on the worn lightweight

TABLE 1: TYPES OF PAVEMENT SURFACE TESTED WITH SURFINDICATOR

Number	Location	Type
1	US 59 - 5	Crushed gravel, sand, AC-10
2	US 59 - 6	Haydite, Shell, sand, AC-10
3	US 59 - 7	Haydite, crushed gravel, sand, AC-10
4	SH 159	Iron ore, OA 90
5	Dallas District	Dallas Lightweight
6	Dallas District	Eastland Lightweight
7	THD	Polished limestone specimen
8	THD	Polished gravel specimen
9	THD	Worn lightweight specimen
T-1	Research Annex	Rounded River gravel hot mix, 5/8-inch top size
T-2	Research Annex	Crushed river gravel hot mix, 1/4-inch top size
T-3	Research Annex	Crushed limestone hot mix, 1/2-inch top size, Terrazzo finish
T-4	Research Annex	Clay-filled tar emulsion seal (Jennite)
T-5	Research Annex	Rounded river gravel portland cement concrete, 1 1/2-inch top size

TABLE 2: MICROTEXTURE MEASUREMENTS OF TEXAS A&M RESEARCH ANNEX TEST SECTIONS

Test Section

T - 1			
Test Location			
-1	-5	-4	-8
3.20	4.50	4.40	3.75
3.75	3.40	3.50	3.50
4.30	3.60	4.10	3.75
4.30	3.00	3.30	4.20
15.55	14.50	15.30	15.20
60.55			

T - 2			
Test Location			
-1	-5	-4	-8
3.60	3.75	3.00	4.25
3.20	4.00	3.10	3.80
4.20	3.75	3.70	3.40
4.00	3.50	4.00	4.30
15.00	15.00	13.80	15.75
59.55			

T - 3			
Test Location			
-1	-5	-4	-8
3.10	3.50	2.50	3.30
3.00	4.00	2.75	3.50
3.10	3.60	3.80	3.40
3.50	4.20	2.75	3.40
12.70	15.30	11.80	13.60
53.40			

T - 4			
Test Location			
-1	-5	-4	-8
1.80	2.50	3.20	2.20
2.20	2.70	3.00	3.10
2.30	2.90	3.40	2.60
2.50	2.50	3.20	2.60
8.80	10.60	12.80	10.50
42.70			

T - 5			
Test Location			
-1	-5	-4	-8
4.00	3.50	3.20	3.60
4.50	3.70	3.20	3.50
3.50	4.10	4.00	3.70
3.20	3.40	3.50	4.00
15.20	14.70	13.90	14.80
58.60			

Analysis of Variance

Source	df	ss	ms	F	Table F (.01)
Total	79	27.412			
Test Section	4	13.643	3.411	22.206	3.65
Test Location	15	4.552	0.303	1.975	2.20
Error	60	4.216	0.154		

aggregate (No. 9 in Figure 3). Such difference is not too apparent at the 0.010-inch cutoff as shown in Figure 2.

The three cutoff values are provided on the Surfindicator to prevent the recording of texture values caused by the peak-to-peak spacings above the cutoff values. If the electric impulses are too infrequent, the lag, inertia, and damping necessary for proper averaging prevent the true indications. For the Surfindicator the minimum frequency is provided by the 0.030-inch cutoff. The difference in the texture values found between the surface and aggregate measurements at the 0.030-inch cutoff indicates that peak-to-peak spacings on the aggregates are shorter than the spacings for the surfaces. At the 0.010-inch cutoff, however, the longer spacings of the surfaces are not sensed by the Surfindicator. Thus, the texture values for the surfaces and aggregates are not very different at the 0.010-inch cutoff.

As previously mentioned, the regression equation for the straight line with the correlation coefficient shown in Figure 3 was based on the measurements made on the surfaces and not on the individual aggregates. A considerable scatter in the data can be seen. This scatter is caused by the sensitivity of the instrument to variation in speed of stylus tracing and the random or nonuniform textures of pavement surfaces. A qualitative effect of the nonuniformity can be observed by the difference in the degree of needle fluctuations on the dial gauge of the Surfindicator when testing on pavement surfaces and on the calibration block which has a uniform texture. The range of fluctuation was as much as 100 microinches for some surfaces tested. Thus only average values estimated from the fluctuating readings were possible for many of the measurements recorded as the microtextures of the pavement surfaces.

The r_{xy} = 0.6846 shown in Figure 3 indicates that the linear correlation or association is not good between the skid number at 40 mph and the microtexture as measured by the Surfindicator. Additional data, if taken, may increase the coefficient and show a higher measure of strength of the linear relationship; however, there is a possibility of a decrease in the coefficient. An approximate value of 100 r_{xy}^2 is 47. This means that 47 percent of the variation in skid number is accounted by the differences in the microtexture measured by the Surfindicator. The low value indicates that the variation in skid number is affected by other factors beside the microtexture or that the true effect of the microtexture is not being obtained or measured by the Surfindicator. However, the results of the F-tests shown in Table 2 indicate a significant difference between the Research Annex test surfaces at the 0.99 confidence interval. Thus, the Surfindicator appears to be capable of measuring the differences in microtextures of pavement surfaces. The results of F-tests between test locations on a given test surface show no significant difference at the 0.99 confidence interval. This indicates low differences in texture values from location to location on each of the test surfaces.

SUMMARY AND FINDINGS

An investigation was conducted to obtain an appraisal of the value of the Clevite BL-185 Surfindicator, a texture measuring device. The investigation consisted of a review of some texture measuring techniques and a limited number of microtexture measurements with the BL-185 Surfindicator.

It was found from the investigation that the Surfindicator was built primarily to measure textures of uniform surfaces such as machined, ground, or sanded metallic parts with a roughness up to 1,000 microinches. As such, the instrument has some undesirable features for measuring microtextures of pavement surfaces. The major undesirable features include the sensitivity to speed of tracing or of stylus movement, and the readings displayed on a dial gauge. The possible effects of these features result in fluctuating readings and in obtaining unrealistic measures of microtextures.

The measured microtexture values increased with increasing skid numbers, but the results of a statistical analysis did not indicate a high correlation between skid number and microtexture. Results of another statistical analysis indicated, however, that the Surfindicator is capable of showing differences in microtextures of test surfaces pavement at the Research Annex.

RECOMMENDATIONS

Based on the results of this investigation, the following recommendations are made:

1. Further microtexture measurements with the BL-185 Surfindicator should be limited to occasions when testing can be done with a minimum of cost. That is, an extensive microtexture testing program on surfaces of various test sections together with skid measurements appears unwarranted at this time. However, if possible, testing with the Surfindicator should be considered and included as additional work associated with other test programs.

2. A texture-measuring device should be developed incorporating all the desirable features found in this investigation and others based on past experience. Such a device would incorporate the following features:

a) A framework similar to the THD Profilograph,

b) A mechanism consisting of LVDT, oscillating device, and an interchangeable pointer mounted on the framework, and,

c) Appropriate electronics and a recorder to record the tracings of the surface profile, and the centerline average heights or the distribution of the various texture heights in a given traverse length.

In the operation of the device, the mechanism will move along a plane nominally parallel to the surface. The oscillating device will move the pointer up and down with a certain amplitude during the translation to prevent any binding of the pointer. In this device the lowest point of the traced surface should be higher than the lowest position of the pointer. Tracings and center line average heights will be recorded with two sizes of the pointer, the larger measuring macrotexture and the smaller measuring both the macro- and microtextures. Difference of the two measurements should provide the microtexture of the pavement surface.

3. Consideration should be given to the extent to which the tire tread rubber "wets" the surface aggregate as it passes or is dragged over the road surface. In general the device visualized should reflect only that part of the pavement microtexture that would normally be touched by the tire rubber. If, for example, the surface being evaluated possessed considerable macrotexture, actual rubber contact would be limited primarily to the upper segments of the large stones in the pavement surface; whereas on a relatively smooth surface with little macrotexture, the tire rubber might "wet" or contact essentially all the surface as it passed over it.

Additionally, such factors as tire tread depth, tread configuration, rubber hardness, tire inflation pressure, vehicle speed, and environmental effects among others would influence the evaluation. Careful study of the effect of these parameters appears warranted.

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