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June 24, 1971

Dr. John W. Hutchinson, Chairman
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Dear Dr. Hutchinson:

The enclosed represents the initial efforts of Task Group 70-3 and is submitted as fulfillment of the immediate objective.

It is anticipated that during this year the Task Group will finalize the enclosed report and prepare a draft of a tentative standard method(s) of Surface Texture Measurement. Due consideration will be given to such features as (1) reliability, (2) repeatability, (3) cost, (4) ease of operation, (5) rapidity of test(s), (6) level of required operator training and/or skill, (7) correlation with friction parameters, and any other aspects of texture measurement methods which the Task Group considers important in selecting a tenative standard method (or combination of methods) of test.

Hopefully the Task Group's efforts will have advanced sufficiently to submit the final report at the June 1972 meeting.

Yours truly,

Jerry G. Rose

Jerry G. Rose
Research Engineer
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JGR: lc

# SUMMARY OF PAVEMENT SURFACE TEXTURE MEASUREMENT METHODS

Prepared for distribution to ASTM Committee E-17 SKID RESISTANCE, Subcommittee 17.23 SURFACE CHARACTERISTICS, by Task Group 70-3 on PAVEMENT TEXTURE MEASUREMENT at the June 28th, 29th, 1971 meeting at the Chalfonte-Hadden Hall Complex, Atlantic City, New Jersey.

Compiled by Jerry G. Rose, Chairman, Task Group 70-3.

This tabular summary represents an expanded version of a draft prepared under the direction of Prof. Bob M. Gallaway of Texas A & M University. The table was compiled from a literature survey conducted during spring 1970. A survey of all states and agencies engaged in quantitative measurements of surface texture would be helpful for updating and finalizing the table. In the meantime, any comments or suggestions concerning any of the tabular entries or other methods of surface texture measurement should be addressed to Dr. J. G. Rose, Research Engineer, Division of Research, Kentucky Department of Highways, 533 South Limestone, Lexington, Kentucky 40508.

| | METHOD AND REFERENCE | RELIABILITY | REPEATABILITY | COST | EASE OF OPERATION | RAPIDITY OF TEST | LEVEL OF OPERATOR SKILL AND/OR TRAINING | COMPARISON WITH SKID RESISTANCE | USERS | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Sand Patch (1) | Poor to Average | Poor to Average | Low | Simple | Fast | Minimal | | British Road Research, Portland Cement Assoc., Connecticut, New Jersey, Florida, Pennsylvania, New York, Pennsylvania State U. | High variations in results. Results have low coefficients with friction parameters. |
| 2 | Modified Sand Patch (2) | Average | Good | Low | Simple | Fast | Minimal | | California, Texas A&M University | Good repeatability within and between operators. Results have low coefficients with friction parameters. |
| 3 | NASA Grease Method (3) | Average | Poor to Average | Low | Simple | Fast | Minimal | | NASA, FAA, Florida | Large variations, little success in correlating with friction parameters. |
| 4a | Stylus Tracer Method Profilograph (2,4,5,6) | Good | Good | High | Moderate | Fast | Moderate | | Pennsylvania State U., Texas A&M University, Texas | Good repeatability. Results have low correlations with friction parameters. |
| 4b | Stylus Tracer Method Surfindicator (7, 19) | Average | Poor to Average | High | Difficult | Average | Moderate | | Texas A & M University | |
| 5 | Texturemeter (2, 8) | Average | Poor to Average | Average | Simple | Fast | Minimal | | Texas A & M University, Arkansas, Pennsylvania, Florida, Texas | Sensitivity & accuracy are not too good. Results have low correlations with friction parameters. |
| 6 | Putty Impression (2, 9) | Average to good | Good | Low | Simple | Fast | Minimal | | Texas A & M University, Alabama | Testing is difficult in cool temperature. Results have low correlations with friction parameters. |

| METHOD AND REFERENCE | RELIABILITY | REPEATABILITY | COST | EASE OF OPERATION | RAPIDITY OF TEST | LEVEL OF OPERATOR SKILL AND/OR TRAINING | COMPARISON WITH SKID RESISTANCE | USERS | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|
| 7 Drainage Meter (10) | Good | Good | Average | Moderate | Average | Moderate | | Pennsylvania State U., Royal Aircraft Establishment (England) | Good repeatability. No drainage on some pavements without pressure on water column. Need results of foil-piercing method to determine friction over a large speed range. |
| 8 Foil-Piercing (11) | Good | Good | Low | Simple | Fast | Minimal | | Pennsylvania State University | Shows good correlation with skid number. Need results of drainage meter to determine friction over a large speed area. |
| 9 Linear Traverse Device (12) | Good | Good | High | Difficult | Average | Maximal | | Kansas | Results on surfaces of laboratory prepared samples and of cores are reproducible. More trouble than sterophotographic technique for field measurements on pavement surfaces. |
| 10 Sterophotographic (13) | Good | Good | High | Difficult | Slow | Maximal | | British Road Research, Ontario (Canada), Pennsylvania State University | Good repeatability. Initial equipment is high. Results have fair correlation with friction parameters. |
| 11 Casting or Molding (14) | Good | Good | Moderate | Moderate | Average | Moderate | | Mississippi, B.F. Goodrich Tire Company | Reproduction of surface is of high fidelity. Texture parameters must be obtained from resulting profile or silhouette. |
| 12 Centrifuge Kerosene Equivalent (CKE) (15) | Good | Good | Moderate | Moderate | Slow | Moderate | | California | Texture measurements are made on samples of aggregates and not on pavement surfaces. Good repeatability. Results sensitive to variations in surface texture of aggregates. |
| 13 Wear & Roughness Meter (16) | | | High | Difficult | Slow | Maximal | | Cornell Aeronautical Laboratory | Still in experimental stage. Parts of meter require precise fabrication. |
| 14 Mineralogical Studies & Profilograph Method (17,20) | | | High | Difficult | Slow | Maximal | | Virginia | This method is in a development stage. |
| 15 Photo-Interpretation Method (18,24) | Good | Good | Moderate | Moderate | Slow | Maximal | Good | Ontario (Canada) University of Kentucky | Method relies on subjective rating. Results may vary with operators. Good correlation with measured skid numbers. |
| 16 Subjective (4) | | Poor | Low | Simple | Fast | Minimal | | | |
| 17 Dial Gauges (4) | | | Low | Moderate | Average | Moderate | | | |
| 18 Light (21) | | | Average | Moderate | Fast | Moderate | | | |
| 19 Dry-Bulking (23) | Good | Good | Low | Simple | Fast | Minimal | | Kentucky | Samples of aggregate are used rather than pavement surfaces. Good repeatability. A measure of the particle texture or shape of the aggregate. |

PART II

The following is in essence a paraphrased version of a portion of a THESIS written by Hisao (Tom) Tomita and directed by Prof. Bob M. Gallaway entitled "Effects of Pavement Surface Characteristics and Texture on Skid Resistance" submitted to the Graduate School of Texas A & M University, College Station, Texas, December 1970, in partial fulfillment of the requirements for the Master of Science degree in Civil Engineering.

# TEXTURE MEASUREMENT METHODS

1. Sand Patch Method

In the sand patch method, a known volume of fine, dry sand is spread over a circular area until it is flush with the aggregate tips of the pavement surface. The area of the patch is determined from an average of a number of diameter measurements. The average texture depth, obtained by the ratio of the volume to the area, is considered to be a measure of surface texture (1).

2. Modified Sand-Patch Method

The modified sand-patch method is similar to the sand patch method (1) except that the volume of sand rather than the area is determined. A plate with a cutout of a known area is placed on the pavement surface. A sufficient amount of fine, dry sand is used to fill the cavity. This amount of sand less the amount required when the plate is placed on a perfectly smooth surface like that of a glass plate determines the volume required by the texture. The average texture depth is the ratio of this volume to the area (2).

3. NASA Grease Method

The NASA (National Aeronautics and Space Administration) grease method is similar in principle to the sand patch method.

A selected volume of grease is applied to the pavement surface between parallel lines of masking tape and then worked into the surface voids with an aluminum squeegee faced with a rubber pad having a hardness approximately equivalent to that of a tire tread rubber. An average texture depth of the surface is obtained by dividing the volume of grease by the area covered by the grease (3).

4. Stylus Tracer Method or Profilograph

In the stylus tracer method or the profilograph, a stylus is passed over the surface to be evaluated. By a mechanical, electrical, or an 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 graph, profile picture, or an average value.

For a simple mechanical linkage connecting the stylus to a recorder, the lever ratio in the system controls the magnification. 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 the optical-mechanical techniques, the resulting graph must be analyzed to obtain a value of the surface texture.

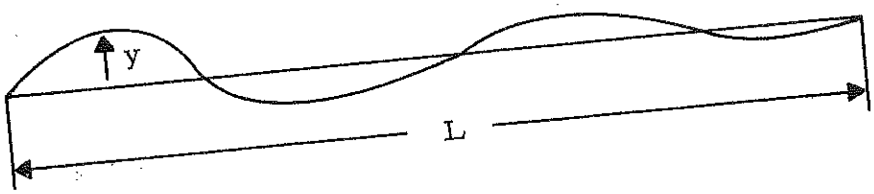
There are two systems of transferring the stylus response electrically to a recorder or to an averaging device; these are the potential-generating and the carrier-modulating systems (4). In the potential-generating system, the stylus is connected to a mechanism that generates a potential in response 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 the vertical motion or the 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 the speed of tracing.

In the carrier-modulating system, 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 the position rather than the vertical motion or the rate of vertical motion, the device is not sensitive to variations in the speed of stylus movement across the surface. For this reason, the carrier-modulating device is preferred over the potential-generating device (4). Carrier-modulating devices have been developed to measure textures of homogenous surfaces but have limited vertical range (5). This may not permit their use in measuring textures of pavement surfaces.

There are two types of pickups that contain the styli for the two electronic systems discussed previously: (1) true-datum pickup and (2) surface-datum pickup (5). The true-datum pickup measures surface textures with respect to an optically flat datum line, nominally parallel to the surface being measured. A continuous plot of constantly amplified distances between the surface and this datum line is obtained.

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

The surface-tracer recording or the result must be analyzed 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 (5). Both methods use a centerline placed through the curve by a least squares fit.




The two equations are:

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

and

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

where $H_{CLA}$ = average distance from the centerline to the curve (centerline average), and

$H_{RMS}$ = root mean square distance.

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

Other methods of analyzing tracer recordings include the distance between lines representing the average peak height and the average valley depth or simply the average depth. These results neglect the influence of peak spacing (5).

4a THD Profilograph. The Profilograph developed by the Texas Highway Department is an example of a stylus tracer method (4, 5) with a mechanical linkage system and a true-datum pickup (2, 6). The mechanical linkage system magnifies the vertical movement of the stylus, and the resulting profile is recorded on a chart. In addition, the upward vertical excursions are recorded on a counter as the cumulative vertical peak heights of the surface texture through the length traversed by the stylus. A reading of 29 digits on this counter represents one inch of cumulative vertical movement of the stylus. The average peak height of the asperities in inches is obtained by dividing 29 times the number of peaks into the counter reading. A peak has been arbitrarily defined as any magnified asperity with a minimum height of 1/16-inch and a maximum base length of 1/4-inch or any multiple set of these dimensions. Any asperity with less than the minimum dimension is omitted.

4b Surfindicator. A proprietary device called the Surfindicator is an example of a stylus tracer method with an electrical system of transferring the stylus response to an averaging device. Various models of this device are manufactured by the Clevite Corporation. The device is generally used to measure the uniform textures of machined surfaces such as those on metallic products.

The Surfindicator Model BL-185 consists of a surface datum pickup with a stylus, some associated electronics, and a dial guage for displaying the $H_{CLA}$ or $H_{RMS}$ readings from one to 1,000 microinches (7, 19). The stylus has a conical diamond tip with a radius of 0.0005 inch. A maximum movement of the stylus of approximately 1/16-inch is permitted with respect to a shoe near the stylus. Thus, it appears that small-scale macrotextures as well as microtextures can be "sensed" by the stylus. The BL-185 is a potential-generating device, and consequently, a variation in readings is caused by changes in the speed of traversing the stylus. However, a limited compensation is provided in the electronics to minimize this variation (7). Three peak-to-peak spacing cutoffs of 0.003-0.010-, and 0.030 inch are provided for the purpose of accuracy of measurements.

A setting on any one of these cutoffs eliminates the signals from the peak-to-peak spacings on the surface above the cutoff value. Thus, the setting of the device on the 0.030 inch takes into consideration signals from all peak-to-peak spacings on the surface up to a maximum of 0.030 inch.

5. Texturemeter

The texturemeter, developed originally to correct roughometer readings of highways, consists essentially of 17 evenly spaced parallel rods mounted in a frame (2, 8). All rods can move either as a unit against spring pressure or independently of each other, except for the end rods that are fixed. Each moveable rod has a hole through which a taunt string is passed. One end of the string is fixed to the frame and the other is tied to the spring loaded stem of a 0.001-inch dial gauge mounted on the frame. In testing, 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 gauge will read zero. Any measureable irregularities in the surface will cause relative motions of the rods and the string will form a zig-zag line resulting in a dial reading; the coarser the pavement texture, the higher the dial reading. The dial readings given by an instrument of this kind are affected by the size and spacing of the rods and by the distance spanned by these rods. For the Texture-meter, the rods are spaced at 5/8-inch, and the fixed supports are 10 inches apart.

6. Putty Impression Method

The putty impression method was initially developed as a means of providing surface texture correction factors for nuclear density measurements of asphalt concrete pavements (2, 9). A 6-inch diameter by 1-inch thick metal plate and 15.90 grams of silicone putty, commonly called "Silly Putty", are the two items necessary in this method. One side of the metal plate has a 4-inch diameter by 1/16-inch deep recess.

The silicone putty is formed into an approximate sphere and is placed on the pavement surface. The recess in the plate is centered over the putty and the plate is pressed down in firm contact with the surface. An alternate method is to stick the sphere on the center of the recess in the plate and to press the plate firmly against the surface. When tested on a smooth, flat surface that has no texture, the 15.90-gram sphere will completely fill the 4-inch by 1/16-inch recess. A decrease in the diameter of the putty is associated with an increase in the texture depth of the pavement surface. An average texture depth based on volume per unit area is determined from an average of four diameter measurements by

$$T_P = \frac{1}{D^2} - 0.0625$$

Where $T_P$ = average texture depth, and

$D$ = average diameter of the putty.

## 7. Drainage Meter

The drainage meter is a transparent cylinder about 5 inches in diameter and 12 inches in height with a rubber ring glued to the bottom face. The cylinder is placed on the pavement surface and is loaded so that the rubber ring will drape over the aggregate particles much like a tire tread element. Water is poured into the cylinder, and the time required for a known volume of water to escape through any pores in the pavement and between the rubber ring and the pavement surface is measured. The water in the cylinder can be pressurized or be under atmospheric pressure. Short durations of time or high rates of flow are associated with high macrotextures and/or high permerabilities of pavement materials (10).

## 8. Foil Piercing Method

In the foil peircing method, a piece of aluminum foil placed on the pavement is given an impact by a rubber-tipped rod released from a predetermined height. An imprint of the surface texture is "engraved" in the foil by the impact. Some piercings of the foil are caused by the sharper-tipped aggregate particles. The density of the number of piercings per square inch is found by counting the punctures on the foil or on a photo negative made from the foil. High densities of punctures are generally found to be associated with high skid numbers (11).

## 9. Linear Traverse Method

The linear traverse method employs a motorized lathe and a stereo microscope with the shaft of a potentiometer attached to the microscope focusing shaft. The potentiometer is fixed to the body of the microscope so that the only movement possible is in the potentiometer shaft. A low constant voltage is fed into the potentiometer; the output is fed through an amplifier to a strip chart recorder.

In measuring the texture, the sample is placed on the end of the lathe, and the equipment is referenced both vertically and horizontally. The sample is moved transversely under the microscope, and the operator keeps the microscope in constant focus on the surface of the sample. Focusing on the varying surface elevation results in corresponding changes in the potentiometer output voltage. The end result is an amplified tracing of the surface texture of the sample (12).

## 10. Stereophotographic Method

In the stereophotographic method, stereo pairs of photographs are taken by a specially designed camera with a single lens. The pair of photographs is obtained by moving the lens laterally a fixed amount in a plane parallel to the pavement surface. Measurements of the parallax between the two photographs are made on a stereocomparator. Records of the surface profile are obtained by measuring the relative heights of successive points at 0.025-cm intervals along lines on the surface with the aid of a parallax bar.

The micrometer readings of the parallax are converted into binary form on punched tape by gearing a combination of optical and mechanical digitizers to the micrometer. By selecting, amplifying, integrating, and decoding through appropriate electronic units adjacent to the stereocomparator, the output in a binary form is obtained on paper tape for analysis on a computer. The computer provides a printout of tape readings in a tabular form and a plot of the tape readings with a certain horizontal-to-vertical scale ratio. Surface textures of the order of 0.01 inch can be shown on the plot (13).

One way of assessing the surface profile is by the profile ratio, a ratio of the length of the profile to the length of the straight baseline. High profile ratios are generally associated with low percentages of decrease in skid resistance with increase in speed (13).

## 11. Casting or Molding Method

In the casting or molding method, a casting material such as a low melting-point metal or a plaster is used with a form to obtain a negative of the pavement surface. A positive is then made from the negative. The surface of the positive is painted and is immediately wiped with a sponge. This removes the paint from the top of the surface areas and gives a measure of contrast. Detailed studies of the surface textures are then conducted in the laboratory. One study involves drawing magnified shadow images of the cross-sectional profiles projected onto a paper screen. Measurements of the drainage area per unit length of the pavement surface are made from these silhouettes (14).

## 12. Centrifuge Kerosene Equivalent (CKE) Method

The CKE method provides a value for the surface texture and the particle shape characteristics of the aggregates used for seal coats and asphalt concrete. A 100-gram sample of washed and dried aggregates passing a No. 3 sieve and retained on a No. 4 sieve is saturated in kerosene for ten minutes and is centrifuged for two minutes at 400 times gravity. The sample is weighed to the nearest 0.1 gram and is submerged in SAE #10 lubricating oil, raised immediately, and is allowed to drain. The difference in weights after centrifuging and after draining represents a surface factor for the sample. This factor, after applying a specific gravity correction, is designated $K_s$. The range of $K_s$ values for mineral aggregates is from 1.1 to 3.0, the high values being associated with high angularity and high surface texture (15).

## 13. Wear and Roughness Meter Method

The wear and roughness meter method measures a mean wear height and a mean texture and provides a plot of the surface profile from which the maximum depth and distribution of peaks of the surface can be observed.

The instrument is contained in a light-tight case with an internal support frame. Within the case, a horizontal array of identical sensing plungers is mounted in such a manner as to permit a movement in the vertical direction only. The top surfaces of the plungers have a mirror finish and are inclined at an angle of 45 degrees to the vertical axis. A light from a tubular lamp is collimated by a parabolic mirror and deflected by a small 45-degree mirror through a horizontal slit. The light beam is then reflected by the top surfaces of the plungers toward a photocell which is as long as the stack of plungers and is inclined at an angle so as to magnify the width of the collimated beam from the plungers by a factor of ten.

When the points of the plungers are in contact with a smooth, flat surface, the light is projected by the tops of the plungers as a parallel band with smooth edges on the photocell. When the plungers contact a rough or textured surface, the light pattern at the photocell reproduces the surface profile with a magnification of ten. A maximum meter reading is obtained when testing on a smooth, flat surface, and a lower maximum reading is obtained on a textured surface. The difference between the two maxima is the roughness of the textured surface (16).

## 14. Mineralogical Studies and Profilograph Method

In this combined mineralogical studies and texture measuring method, a thorough knowledge of the polish susceptibility of various aggregates is acquired. In addition, both macro- and microtextures are evaluated in light of aggregate wearing characteristics under traffic.

A qualified geologist conducts petrographic analyses of aggregate samples from the rock quarries supplying aggregates for pavements. Based on these analyses, various road surfaces are selected for testing. Texture measurements are made using the profilograph, and skid tests are conducted. Cored specimens are visually described and microscopically examined to obtain a variety of information related to the surface characteristics. The information includes aggregate type, percent exposed aggregate, texture, harshness, particle geometry, polish, and microscopic identification of minerals. The surface profiles are analyzed and correlated with skid test results to evaluate the importance of large-scale textures. Qualitative evaluation of the role of microtextures of the aggregates on skid resistance is made from microscopic observations of thin sections obtained from the surfaces of the cores (17, 20).

## 15. Photo Interpretation Method

In the photo interpretation method, the skid numbers are obtained from values of various pavement surface texture parameters. Color stereo-photographs of approximately 6-inch square sections of pavement surfaces are obtained by means described previously in the stereophotographic method. The transparencies are viewed through a microstereoscope and also through a standard microscope with a three times linear magnification.

The texture elements of the pavement surface are visually classified and are subjectively rated according to the established severity rating for each of seven parameters. The parameters include the height, width, angularity, density, and the small-scale texture of the projection. In addition, the small-scale texture and the number of cavities found in the background surface are considered.

An established relationship between the severity of each of the seven parameters and friction weights in tabular form is used to estimate the skid number of the pavement surface. The basis used in establishing the relationship was mainly trial and error. However, a correlation coefficient of 0.9 has been reported between the skid numbers obtained from skid tests and those obtained from photo interpretations (18).

## 16. Subjective Method

The subjective method of using the senses of touch and sight has been used for ages in appraising the texture of finished surfaces. Recent studies indicated that a range of textures can possibly be estimated by this subjective method, and that skilled personnel are only slightly better in judging surface textures than unskilled personnel (4).

## 17. Dial Gauges

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 (4).

## 18. Light

Light can be used in several ways to help analyze surfaces. Variations in textures can be better visualized under some conditions of light. For example, light passing under a straightedge placed on a surface indicates the magnitude of the surface texture (21).

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.

## 19. Dry-Bulking Method

One-size fractions of fine aggregates are carefully poured into a vessel of known volume and the solid volume of aggregates is computed from its weight and specific gravity - thus, yielding a percentage of voids. The more angular or textured the aggregate, the higher the void percentage. This is an indirect method of shape (texture) evaluation of aggregate (23).

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