ROAD SURFACE TEXTURE DESCRIPTION AND MEASUREMENT IN RELATION TO SKID RESISTANCE

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RINGKASAN

Ketahanan terhadap slip yang dapat disediakan bahan perkerasan sangat tergantung pada karakteristik tekstur permukaan. Istilah "tekstur permukaan" dalam konteks ini tidak berarti komposisi permukaan (banyaknya pengikat, pasir, dsb), tetapi bentuk geometri permukaan jalan tersebut. Fungsi tekstur adalah untuk menyediakan kontak yang erat dengan permukaan ban, untuk menjamin cukup deformasi terhadap karet telapak, dan untuk memudahkan perpindahan air permukaan khususnya bila permukaan ban licin. Tulisan ini menguraikan karakteristik tekstur permukaan (parameter yang digunakan) dan metoda pengukuran.

SUMMARY

The skid resistance which pavement material can provide is strongly dependent on the textural characteristic of the surface. The term "surface texture" in this context does not mean the composition of the surface (so much binder, sand, etc), but the geometrical form of the road surface. The function of the texture is to provide a close contact with the tyre surface, to secure sufficient deformation of the tread rubber, and to facilitate the removal of surface water especially when the tyre surface is smooth. This article describes the characteristics of surface texture (the parameters used) and methods for measurement.

I. INTRODUCTION

Road surface texture refers to the distribution and the geometrical configuration of the individual aggregates on the road surface. The role of macro-texture in removing bulk water has been demonstrated by Wallace and Trollope [1969], whereas the effect of micro texture in reducing the water film (hence establishing dry contact with the tyre surface) was quantitatively studied by Rohde [1976].

The method of measuring the surface texture largely depends on the application in question. Over 20 methods have been used for measurement of surface texture, and it is interesting to note that tests using these methods, have not, on the whole, produced consistent or reproducible quantitative results [Rose at.al (1973)].

II. DESCRIPTION OF SURFACE TEXTURE

The complex and random nature of a road surface makes it difficult to represent the surface characteristics by a general single parameter. Posey [1946], for example, suggested that 3 parameters for a representative length of profile (i.e. histograms of the profile itself and of its slope and curvature), give sufficient information to permit a complex characterization of the texture; whereas Moore [1965] attempted to quantify the "feel" of a texture by expressing its geometrical features as size, spacing and shape factors. In addition, Myers [1962] listed a new series of single elementary parameters to define texture, but carefully indicated that depending on the particular application each of the new parameters might be considered more useful than the others. For example, the RMS (root mean square) of the second derivative of the profile (i.e. its degree of curvature at peaks, or sharpness) would be most appropriate to determine the degree of wear which a surface has undergone. In the following, the parameters which are commonly used for characterization of surface texture, will be described in details.

2.1. Texture Depth

There is a general trend toward increasing friction coefficient and skid numbers when deeper surface textures are encountered. However, the typical scatter of the data about the line of best fit would be of questionable value. The similar results are also obtained when the texture depth is correlated with speed gradients.

The lack of a definitive relationship between texture depth and both skid number and speed gradient was attributed, in part, to the possibility of poor test repeatability [Doty (1975)]. On the other hand, Lees and Katekhda [1974] stated that there is no justification in relating the average texture depth to the drop of friction with speed, since unconnected voids in the surface are included in the measurement while they play no part in dissipating the water between the tyre and the road surface. They argued that disconnected voids act on surface as reservoirs retaining water which aids the lubrications of nearby particles and prevents full deformation of the tyre into the road texture.

The average depth, however, is useful for broad classification of surface texture. In France, for example, texture depth is classified as: very fine ($\leq$ 0.2 mm), fine (0.2mm - 0.4mm), medium (0.4mm - 0.8mm), coarse (0.8mm -1.2 mm), and very coarse (> 1.2 mm). Pavements with very fine-textured are to be prohibited, while very coarse-textured are used in special cases: danger zones following a straight line or frequent frost zones [Elsenaar et.al (1977)]. The other versions of average depth, described in the next section, are shown in Figure 1.

2.2. Centre Line Average Height (CLA)

The CLA is the measure used in BS 1134:1972 to specify the fineness of the surface finish of the machined pieces. It is defined as the average value of departure of the profile from its centre line, whether above or below it. The centre line is defined as a line conforming to the prescribed geometric shape of the profile and parallel to the general direction of the profile throughout the sampling length such that :

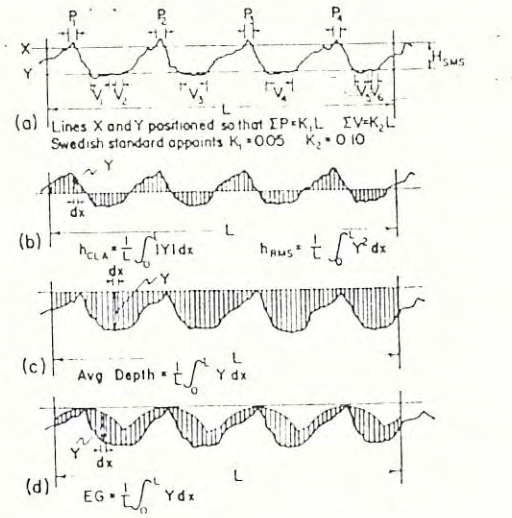
$$\int_0^L ydx\ (y \geq 0) + \int_0^L ydx\ (y < 0) = 0$$

The CLA then is given as:

$$h_{CLA} = \frac{1}{L} \int_0^L ydx$$

where y = f(x) is the equation of the profile (see Figure 1.b).

Fig. 1.
MATHEMATICAL DEFINITION FOR NUMERICAL EVALUATION OF SURFACE TEXTURE. [MARIAN (1962)].



2.3. The Average Depth

The average depth is used (in Europe) as an equivalent of CLA in Britain. Referring to Figure 1.c the average depth from the crest line is given by :

$$h_{AVR} = \frac{1}{L} \int_0^L ydx$$

where y = f(x) is the equation of the profile.

2.4. Root Mean Square

The root mean square height of a profile is given by (see Figure 1.b) :

$$h_{rms} = \sqrt{\frac{1}{L}\int_0^l y^2 dx}$$

This measure accentuates the effect of sharpness and distinguishes between rounded and sawtooth type textures.

2.5. The Swedish Standard

The Swedish standard is numerically greater than the CLA height, average depth or root mean square height. The two lines x and y are positioned so that $\sum P = K_1 L$ and $\sum V = K_2 L$ (Figure 1.a). The Swedish standard specifies that $K_l = 0.05$ and $K_2 = 0.10$. The distance between the parallel line x and y is the measure of surface roughness.

2.6. Profile Ratio

The measure is the ratio of the profile length to the projected length. This bears some relation to texture depth and takes into account the shape of the profile [Sabey (1968)], but does not give any account of the three-dimensional aspect of the surface texture [Lees and Katekhda (1974)]. In addition, the "filtered profile ratio" which is the profile ratio for the tops of the asperities only, over a different depth D, below the line of the peaks can be evaluated (see Figure 2).

2.7. Moore's Bearing Area Method

Moore [1975] used a mathematical expression to represent a single profile. A series of frictions parallel planes are drawn successively below the reference plane at distance δ_l, δ_2 and so on, so that they intersect different number of asperities N_i (see Figure 3). Two equations may be written :

$N_i = C_0\, \delta^m$; $A_i = C_1 + C_2\, \delta^n$

where N_i is the number of asperities intersected by the 1^{th} plane located at distance from the reference plane,

A_i is the total contoured area of asperity intersected by this plane,

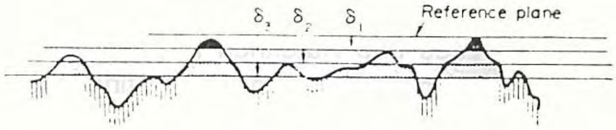
C_i is the plateau area,

C_0, m are constants specifying the height spacing or statistical distribution of the

C_2, n are constants specifying the mean shape of asperities.

He found, for example, that on concrete road surface : m = 2, n = 3.

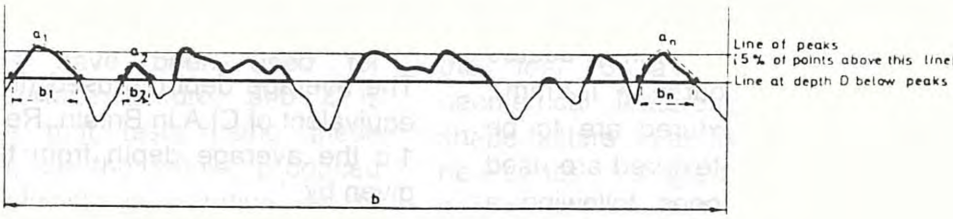
Fig. 3.
MOORE'S BEARING AREA METHOD
[MOORE (1975)].



2.8. Mean Width of Surface Voids

The parameter can be obtained from the asperity density prints. It was found to correlate with the steepness of the friction speed curve, the closer the surface the steeper the negative sloped curve [Schulze and Bechmann (1962)].

Fig. 2.
PROFILE RATIO AND "FILTERED PROFILE RATIO". [SABEY (1968)]



Profile ratio = $\frac{\text{total length of profile a}}{\text{length of base line b}}$

'Filtered profile ratio' for depth D

$\emptyset_D = \frac{\text{sum of lengths of profile above depth D}}{\text{sum of baseline lengths}} = \frac{\sum_1^n a_r}{\sum_1^n b_r}$.

2.9. Mean Hydraulic Radius (MHR)

Moore [1966] measured the drainage capacity of a surface in terms of the mean hydraulic radius :

$$MHR = M \sqrt[4]{v/tN^{0.5}}$$

where M is the instrument constant,
v is viscosity of water,
t is the recorded time for a fixed volume of water to drain,
N is the number of asperities per square inch of surface texture.
He then used the MHR to predict the wet sliding coefficient of road surface.

Fig. 4.
DEFINITION OF SURFACE CHARACTERISTICS.
[YANDELL (1969)].

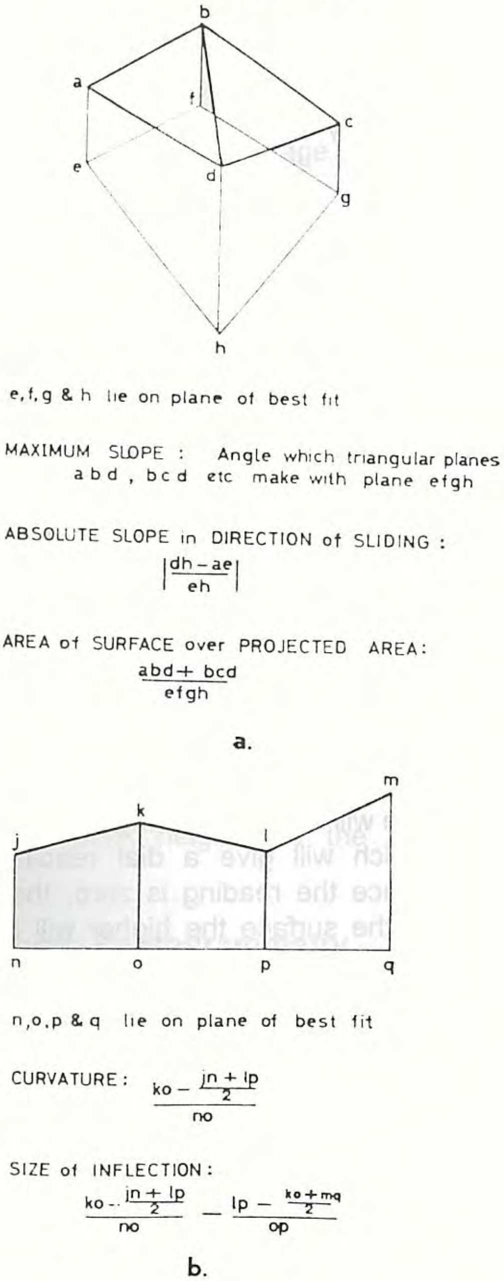
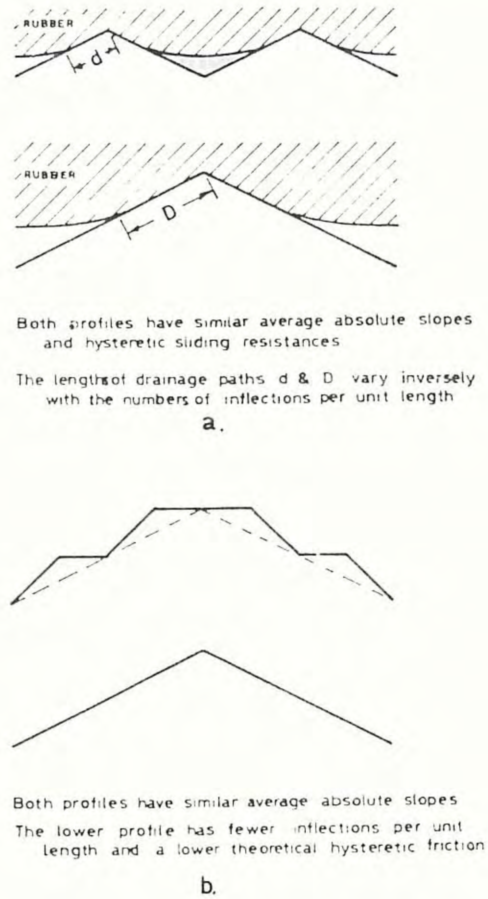


Fig. 5.
INFLUENCE OF THE NUMBER INFLECTIONS.
[YANDELL. (1969)].



2.10. Parameter used by Yandell

Yandell [1969] represented the pertinent characteristics of the road surface texture by the following parameters :

a. Texture depth.
b. Maximum slope.
c. Average absolute slope in the direction of sliding.
d. Surface area per unit projected area.
e. Distribution of surface.
f. Curvature.
g. Number of inflection.

These parameters can be used for many purposes, such as on the calculation of the hysteresis friction, the polishing of road stones, and the abrasion of rubber. Some of them are illustrated in Figures 4-5. One important parameter, the average absolute slope, is found to have good correlation with coefficient of hysteresis friction. It is used with the damping factor of rubber in the mechano-lattice analysis to predict the coefficient of hysteretic friction.

III. THE MEASUREMENT OF SURFACE TEXTURE

The road surface texture is normally categorized by two features, the large scale or macro-texture which represents the easily visible asperities in the surface and the fine scale or micro-texture which describes the harshness or state of polish of the stone surface. (See Figure 6).

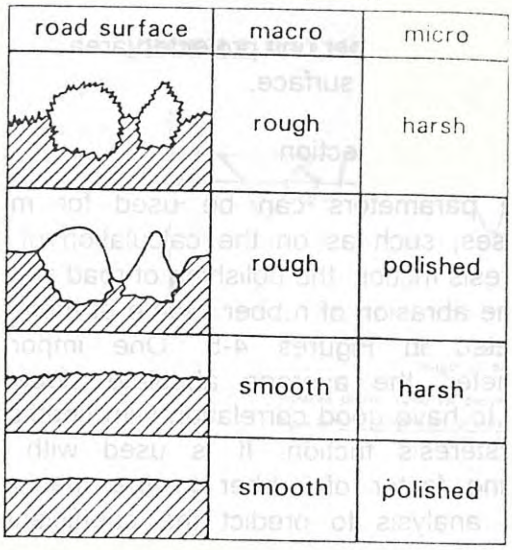
Some of the important and commonly used methods of measuring the road surface texture will be described below; which can be broadly classified into four categories [Taneerananon (1981)].

a. Volumetric: Sand patch, Grease smear, and Silicone putty.
b. Profile: Texturemeter, Row of needles, Stylus, and Profilograph.
c. Photography : Stereo-photogrammetry, and Stereo-photo interpretation.
d. Miscellaneous : Outflow meter, Surface prints, Laser beam, and Texture friction meter.

3.1. Sand Patch

It involves spreading a known volume of sand over a circular area until flush with the tips of the asperities. Average texture depth, the ratio of volume to area, is the measure of surface texture. It is rather simple test, but it evaluates macrotexture only (the size of the sand used prevents the very fine channels from being measured).

Fig .6.
ILLUSTRATION OF TERMS OF THE ROAD SURFACE TEXTURE. [SABEY et.al (1970), SCHLOSSER (1977)].



3.2. Grease Smear

The principle is same with the sand patch but the grease is applied instead of sand. The method is used usually for obtaining the texture depth of fine textured road surfaces, as it has better ability than the sand to fill the narrow channel of the surface [Smith and Fuller (1969)].

3.3. Silicone Putty

It is similar in principle to the sand patch and grease smear method. A known volume of silicone putty is formed into an approximate sphere and placed on the road surface. A recess in a plate is centered over the putty, and the plate is pressed down in firm contact with the surface. Average diameter of the deformed putty is recorded. When tested on a smooth flat surface with no texture, the silicone putty will completely fill the recess. Therefore, a decrease in the measured diameter indicates an increase in texture depth. This procedure was used by researchers (at Texas Transportation Institute) to evaluate macrotexture [Rose et.al (1973)].

3.4. Texturemeter

The instrument, developed at Texas Transportation Institute, consists mainly of a series of evenly spaced, vertical, parallel rods mounted in a frame [Rose et.al (1973)]. All except two rods can be moved vertically against spring pressure and independently of one another. One rod at each end of the device is fixed to the frame for support. Each movable rod has a hole through which a taut 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 extensiometer mounted on the frame. When the frame is pressed onto the road surface, any irregularities in the surface will cause the string to form a zig-zag line which will give a dial reading. On smooth surface the reading is zero, therefore the coarser the surface the higher will be the dial reading.

3.5. Row of Needles

A row, 15 cm long of closely spaced needles guided by a frame is dropped vertically onto the road surface. The profile measured as depicted by the tips of the needles is then photographed. The accuracy is limited by the thickness and spacing of the needles [Astrov (1962)].

3.6. Stylus

The method is well known and widely used in mechanical engineering. It gives more information about a surface than other methods for most surface types [Richards (1967-68)]. Moore [1966] developed a stylus device to measure the coarse texture of the road surface. Vertical movement of the stylus are sensed by an electric linear variable differential transformer and fed into an oscillograph. Similar apparatus was designed by Yandell to measure the fine texture of the road asperities [Taneerananon (1981)].

There are, however, some difficulties associated with the stylus method. The conical shape of the stylus prevents reentrant angles from being detected. If the radius is large fine crevices will be missed, measurement of troughs and peaks will be exaggerated. Too fine radius may cause damage to the surface by ploughing. An optimum angle and sharpness then must be selected, to obtain a compromise between the conflicting requirements of not ploughing (or sticking) and true reproduction of the surface profile.

3.7. Profilograph

This instrument is designed to scribe a magnified profile of road texture as a feeler probe is drawn across the surface [Rose et.al (1973)]. A mechanical linkage system magnifies vertical movement of the probe, and the resulting profile is recorded on a chart. In addition, upward vertical deflection of the probe are recorded on a counter as the cumulative vertical peak heights of the surface texture through the length transversed by the probe. Average peak height is obtained by dividing cumulative peak heights by the number of peaks.

3.8. Stereo-Photogrammetry

Two photographs of the macro-texture taken vertically from two distinct points give sufficient information to produce stereo-photograph which are measured with a comparator and parallel bar. The height readings are accurate to 0.01 inch [Sabey and Lupton (1967)]. Yandell and Gopalan [1976] used stereo-pairs from a scanning electron microscope to measure very fine texture.

3.9. Stereo-Photo Interpretation

This method was developed by Schonfeld [1970,1974]. Colour stereo-photographic transparencies or prints of approximately 6 inch square sections of road surfaces are obtained and viewed through a micro-stereoscope or mirror-stereoscope. Texture elements of the surface are classified visually and are rated subjectively according to an established severity rating for each of several parameters.

3.10. Outflow Meter

Moore [1965] described a simple apparatus by which could be measured the drainage capacity of a surface in terms of MHR (mean hydraulic radius). The instrument is a transparent cylinder, about 5 inch diameter and 12 inch height with a rubber ring glued to the bottom face. The cylinder is loaded onto the road surface so the rubber ring will drape over the aggregate pieces in a way that simulates the draping of tyre tread. There is no pressure applied on the water except its weight. The time taken for a known volume of water to drain away is recorded. The short duration of time or high rate of flow is associated with high macro-texture or high permeability of the pavement or both.

A theoretical relation between MHR and the slope of friction/speed lines was obtained using stated assumption [Moore (1966)]. The method shows good discriminating ability [Orchard et.al (1970)]. However, the disadvantages of this apparatus are: (a) It uses a thin rubber ring which might be affected by an odd particle or cavity in a manner not representative of drainage in a typical tyre contact patch [Lees and Katekhda (1974)]; (b) The variability of the readings on very smooth surfaces is high [Moore (1968)].

A number of modifications have been made to the outflow meter. The high pressure outflow meter, differs from the original device in that width of the rubber ring has been increased, time measurement has been automated and the water is pressurized as opposed to gravity flow [Henry and Hegmon (1975)]. A modification incorporating an elliptical rubber plate in place of the circular rubber annulus, is aimed to study the drainage paths lengths for different directions [Lees and Katekhda (1974)].

3.11. Surface Prints

Meyer [1964] obtained the asperity density prints by placing an aluminium foil on the surface and providing a controlled impact onto a rubber disc placed on top of the foil. The sharp asperities pierce the foil and the number of piercings per unit area is the measure of texture.

3.12. Laser Beam

This method was described by Gee et.al [1975]. The principal elements are laser source and receiver. Both are off-the-shelf items. Light is emitted from the laser and is incident on the road surface. The light reflected from the surface is generally scattered in all directions. The polarization (alignment of the electric field vector) is also changed after scattering. That is, linearly polarized light will experience "depolarization", where reflected light is no longer linearly polarized, but is elliptically polarized. The degree of ellipticity is a function of road surface characteristics, and is represented by the ratio of the minor and major axes of the polarization ellipse. The higher ratio indicates coarser texture.

The method appears simple and apparently suited for operation from a moving car. The correlation coefficient between laser depolarization ratio and skid number, however, is only about 0.5-0.6 [Gee et.al (1975)]. Another apparatus, the Swedish Laser Road surface tester (RST), can measure both fine and rough macro-texture, where the RST root mean square fine macro-texture is correlated far better with sand patch texture depth than rough macro-texture. When the result of RST is compared with the measurement by the Sideways Coefficient Routine Investigation Machine (SCRIM), no signifficant correlation was achieved [Jameson et.al (1988)].

Similar to RST is Multifunction Road Monitor (MRM) from UK, or Multi Laser Profilometer (MLP) from Australia, which can measure texture depth simultaneously with other measurements such as profile, rut depth, horizontal curvature, etc. A portable device, TRRL Mini Texture Meter, is one of the equipment utilized by Indonesian Institute of Road Engineering for measuring texture depth.

3.13. Texture Friction Meter

Yandell and Mee have developed a device, that is a small computer controlled instrument that can accurately sample pavement surface texture to give in seconds the sideways and loced-wheel friction for several travelling speeds. It analyses a television image of a sharp knife shaped laser beam which shines on the road surface as the test vehicle moves along the road. The computer simulates a pneumatic tyre travelling on that measured wet texture ['Uniken' (1989)]. The Indonesian Toll Road Company (PT. Jasa Marga) already owns this device.

IV. CONCLUSION

1. The road surface texture is generally divided into two scales : macro-texture and micro-texture. In quantitative study, however, the road surface texture could be divided into more than two scales.

2. Several parameters which are used in representing road surface texture have been described in details. Those common parameters are: texture depth, centre line average height, the average depth, root mean square, the Swedish standard, profile ratio, Moore's bearing area method, mean width of surface voids, mean hydraulic radius, and Yandell's parameter.

3. It is usually difficult to represent the surface characteristics by a general single parameter. Depending on the particular application each of the parameters might be considered more useful than the others.

4. Numerous methods have been developed to measure road surface texture. These methods can be broadly classified into four categories : volumetrics, profile, photography and miscellaneous. More practical and accurate results are generally can be obtained by using laser technique in comparison with others.

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