

Microtexture diagnostics of asphalt pavement surfaces

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Abstract. The microtexture of asphalt pavement surface is an essential parameter from the traffic safety point of view and it closely relates to a geometrical, petrological and physical properties of aggregate particle used in asphalt pavement. Microtexture has a significant influence for assurance basic friction values between tire and pavement in relation to a skid resistance properties. Therefore, the microtexture detecting methods are necessary. The British pendulum tester measurements have been carried out on selected sections of roads with different asphalt surfaces. Individual grains of aggregates were taken from the surface of each section from the sliding path and also from the core sample after the extraction. The laboratory profilometry measurements have been practiced on these aggregate samples and subsequently the surface microtexture was investigated based on commonly used texture characteristics and the filtration approach was applied in calculation process. The results have shown the degradation of microtexture values occurs due to polishing of aggregate under loading from traffic in relation to the type of used aggregate. Some correlation between BPN values and texture characteristics was found.

1. Introduction

In relation to road safety, the roughness of pavement surface is the most important variable parameter which is characterizing quality of asphalt pavement surface from skid resistance properties point of view. Roughness of pavement surface can be evaluated from physical aspect as a skid resistance or in terms of geometrical aspect as a pavement surface texture. The texture is a function of the pavement surface which assure the basic interaction between tire and pavement. It is defined as a morphological configurations of material particles on the pavement surface. It is a combination of irregularities with different wavelengths and amplitudes within defined range. According to amplitudes and wavelengths of irregularities is texture dividing into three categories: microtexture, macrotexture and megatexture [1].

The Figure 1 describes a particular components of pavement texture and their influence on the fundamental effects which are closely relates to tire and pavement interaction. It is obviously from Figure 1, that friction level is affected by macro and microtexture values. Therefore the sufficient values of these texture components are important for assurance of friction between tire and pavement.

Macrotexture is the degree of roughness defined by the morphological configuration of aggregate particles on pavement surface (wavelengths in range 0.5 to 50 mm) and is mainly responsible for reducing the potential for separation of tire and pavement surface due to hydroplaning and for inducing friction caused by hysteresis for vehicles traveling at high speeds.



Microtexture is the degree of roughness imparted by aggregate particles [2]. According to [3] is microtexture defined as a configuration of particular peaks on the surface of aggregate particle (wavelengths in range 0.5 mm to 1 μm). The main function of asphalt pavement microtexture is to assure basic friction level on microscopic scale (adhesion) and primarily affects the frictional properties of a pavement surface at lower speeds. Its importance also consist in disconnecting of residual water film on the pavement surface. It leads to close contact between tire and pavement surface [4]. The importance of microtexture from the skid resistance point of view is closely presented in [2]. It stands to reason, that type of used aggregates by its petrological and physical properties and their ability to be resisting to the climatic effects and the mechanical abrasion due to traffic loading predetermine the level of asphalt pavement microtexture.

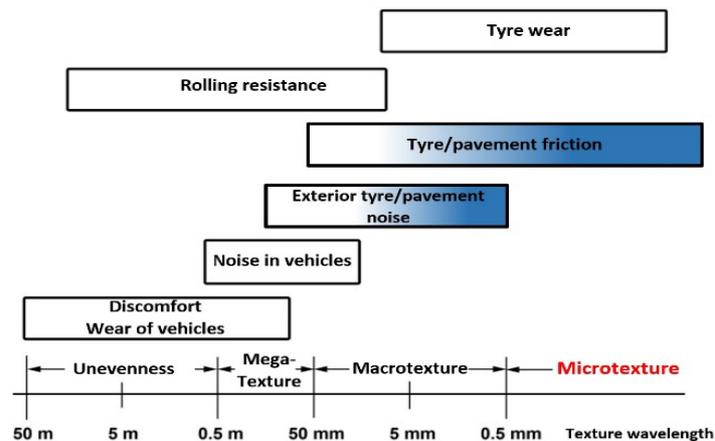


Figure 1. Influence of particular components of pavement texture on tyre/road interaction (a blue shade means a favourable effect of texture over this range, while a white area means an unfavourable effect). [1]

Over the years, a lot of studies have been practised to correlate the different friction and texture measurement methods. The determined correlations are significant in specifying how macro and microtexture influence friction performance between tire and pavement. From aspect of microtexture there are same gaps, because of microtexture wavelength range in micron scale. It is complicated not only because of the accuracy of measurement but also because of their evaluation and then possibility to direct microtexture measurement in the field is still problematic. Currently, there is no way to capture of entire microtexture range on pavements in the service because of laser scanning resolution and optical illusion [5]. Account on that, the indirect measurement techniques related to low slip speed friction such as the pendulum tester (BPT) [6] and dynamic friction tester (DFT) [7] are used as an alternate. Hence, the unavailability of the measuring device which allows direct measurements in real conditions on the pavement surfaces limits research in this field on laboratory conditions.

2. Experimental measurements

2.1. Microtexture measurements on the asphalt pavement surfaces

The measurements of friction coefficient by British pendulum tester was carried out in the track on the six selected pavement sections with different asphalt surfaces, because of measured BPN (British pendulum number) values obtained by this device are worldwide used as an indirect representation of microtexture level of pavement surface. It is a standard method, determines skid resistance of pavement surface by measurement of the energy loss when a rubber slider edge is swings across a test surface.

Measurements was practised according to standard EN 13036-4 [6] and carried out on the ten measurement points within each road section in the wheel track on the pavement surface. The mean of these ten *BPN* values gives a representative value of pavement microtexture for each pavement section. The results of *BPN* measurements are presented in the Table 1.

2.2. Laboratory determination of microtexture of aggregates taken from asphalt pavement surfaces

After the BPN measurements, the individual grains of aggregates were taken from the surface of each section from the sliding path and also from the core sample after the extraction. The laboratory contact profilometry measurements have been practiced on these aggregate samples.

Profilometry contact method is commonly used in mechanical engineering as a surface roughness measurement method. Contact profilometer ZEISS Countourecord 1700 allows roughness measurement with a periodic transformation of information about profile during mechanical movements of measurement detector on the investigated surface. In this method, by direct contact of sensor with investigated surface the vertical traverse of measurement detector is transformed on the electrical signal. Electrical signal is subsequent converted on the digital (numerical) signal which represents changes of vertical interval (z-direction) in relation with the x-direction position. The obtained output in the form of profile, is then expressed by x and z coordinates (Figure 3) and represents real contours of the aggregate surface. The measurement accuracy in the longitudinal direction was 1 μm .

2.2.1. Filtration of profile data. However, in addition to microtexture information, the obtained output in the form of profile of investigated particle captures the shape of aggregate particle and the wavelengths and amplitudes that are out of the microtexture range (higher than 0.5 mm). It can lead to influence of results in evaluation process. Therefore, the filtration approach on the principles signal processing was applied in this research. Data filtration can be used to remove components which are irrelevant in regard to required evaluation within microtexture range from obtained profiles.

Filter design and subsequent signal processing is easily implemented in a computing program Matlab. From the purpose of efficient filter choosing, the analysis of filter type was performed in this program. The usage of highpass filter is obviously because of the information about microtexture related to low wavelengths and thus to high frequencies. Butterworth, Chebyshev, Chebyshev inverse and Elliptic highpass filters were analyzed. The Butterworth filter was chosen because of the frequency response of the Butterworth filter is maximally flat and thus has no ripples in the passband and rolls off towards zero in the stopband. Compared with both Chebyshev filters and an Elliptic filter, this filter has a slower roll-off and a more linear phase response in the passband than can achieve other investigated filters. Thereafter, the filter transition band was necessary to define by determination of band-boundary frequencies (passband and stopband frequency) (Figure 2).

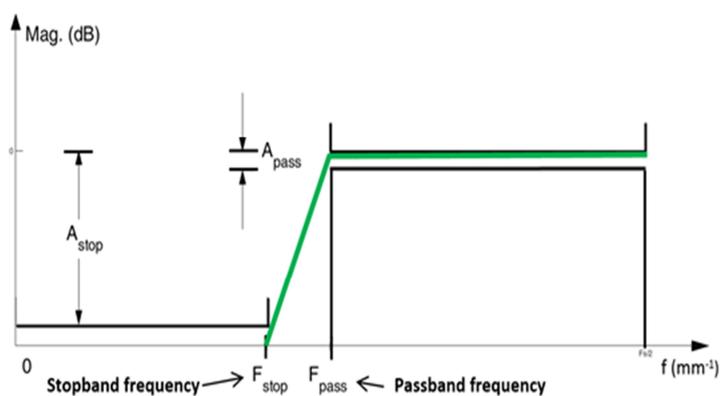


Figure 2. Specification of design. Butterworth highpass filter.

As is shown in the Figure 2, the particular primary profile (Figure 3 black profile y_0) was filtered by different band-boundary frequencies. The best results were achieved for passband frequency $F_{pass} = 2 \text{ mm}^{-1}$ and stopband frequency $F_{stop} = 0.67 \text{ mm}^{-1}$ (Figure 3 red profile y_3). It is equivalent for 0.5 mm and 1.5 mm wavelengths. This filter specification allows removed the wavelengths higher

than 0.5 mm from the investigated profile with the most accuracy (e.g. any deformation at the ends of the profile).

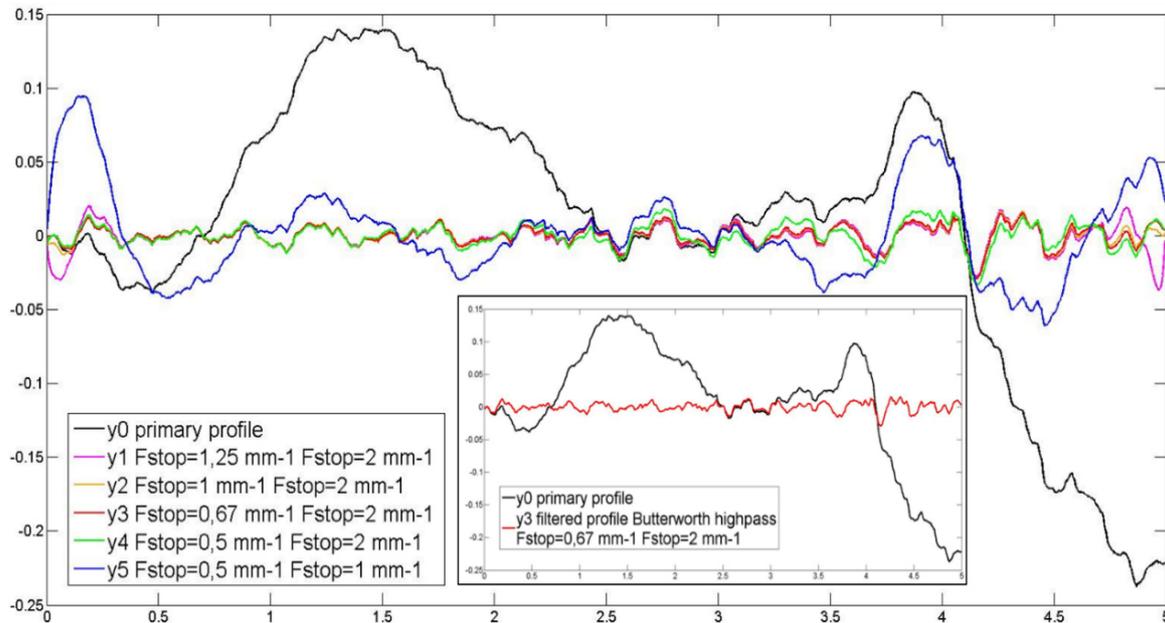


Figure 3. Comparison of resultant profiles filtered with different band-boundary frequencies.

2.2.2. Used statistical texture characteristics. Commonly used statistical surface texture characteristics can be used to evaluate microtexture of aggregate particle from filtered profiles.

These statistical texture characteristics defined in [8,9] presented a group of profile evaluation characteristics related with vertical coordinates distribution of surface profile and reflected basic description of irregularities of investigated profile.

The statistical characteristics mean arithmetic deviation Ra (1) and root mean square Rq (2) characterize an absolute measure of the surface texture. Characteristics Ra gives a very good overall description of height variations but it is not sensitive to small changes in profile whereas characteristics Rq is more sensitive to deviations from the main line than Ra [10].

$$Ra = \frac{1}{n} \sum_{i=1}^n |y_i - \bar{y}| \quad (1)$$

Where: Ra = mean arithmetic deviation of a profile (μm), y_i = the individual values of the profile (μm), \bar{y} = average value (μm), n = number of points.

$$Rq = \sqrt{\frac{1}{n} \sum_{i=1}^n (y_i - \bar{y})^2} \quad (2)$$

Where: Rq = root mean square (μm), y_i = the individual values of the profile (μm), \bar{y} = average value (μm), n = number of points.

Variance characteristic σ^2 (3) defines a level of high variability.

$$\sigma^2 = \frac{1}{n} \sum_{i=1}^n (y_i - \bar{y})^2 \quad (3)$$

Where: σ^2 = variance of profile (μm), y_i = the individual values of the profile (μm), \bar{y} = average value (μm), n = number of points.

The Rsk characteristics (4) describes the symmetry of the heights on the mean line and allows defining so called „positive” surface texture and „negative” surface texture [11].

$$Rsk = Rq^{-3} \cdot \frac{1}{n} \sum_{i=1}^n (y_i - \bar{y})^3 \quad (4)$$

Where: R_{sk} = skewness - asymmetry of the profile (-), Rq = root mean square (μm), y_i = the individual values of the profile (μm), \bar{y} = average value (μm), n = number of points.

The Rku characteristics (5) describes the probability density sharpness of the profile. It indicates the presence of disproportionately height peaks or deep valleys and is important for defining a wear conditions.

$$Rku = Rq^{-4} \cdot \frac{1}{n} \sum_{i=1}^n (y_i - \bar{y})^4 \quad (5)$$

Where: R_{ku} = kurtosis (-), Rq = root mean square (μm), y_i = the individual values of the profile (μm), \bar{y} = average value (μm), n = number of points.

The MPD characteristics (6) expresses mean depth of profile. The baseline for MPD calculation was chosen 100 μm .

$$MPD = \frac{(M1+M2)}{2} - PP \quad (6)$$

Where: MPD = mean profile depth (μm), $M1$ = maximum profile value of first half of baseline (μm), $M2$ = maximum profile value of second half of baseline (μm), PP = average profile value of second half of baseline (μm).

The algorithm for profile filtration process and calculation of above described characteristics was created in the Matlab program. Data processing was performed in two steps. In first step, primary data from the profilometry measurements was filtered to remove the wavelengths that are out of the microtexture range. In second step, the statistical texture characteristics were calculated from the secondary (filtered) data. It was supposed that the filtration process allows more accurately determination of microtexture by this method. Its applicability in the asphalt pavement microtexture investigation was tested on the aggregate grains taken from the pavement surfaces.

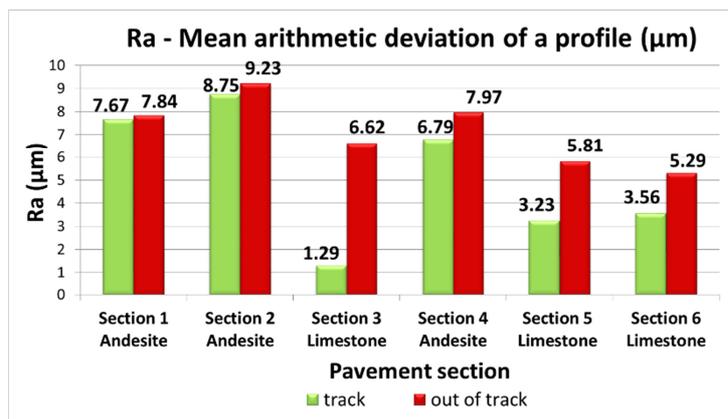
2.3. Data analysis and results

Each sample of the pavements section consisted of ten aggregate particles. Five aggregate particles represented the sample from the wheel track on the pavement surface and five aggregate particles taken from the core sample after the extraction represented the out of track sample. Six profiles were obtained for particular aggregate particle and statistical characteristics were calculated for the each one. Data in the Table 1 shows the obtained results, where the representative value of investigated microtexture characteristic for each sample was obtained by determination of mean value from thirty values calculated from individual profiles.

The results presented in the Table 1 have shown expressly differences between values determined on the aggregates represent track sample and aggregates represent out of track sample. For better interpretation, the values of Ra characteristics are presented in Figure 4. In all samples, the results have shown the degradation of microtexture values due to polishing of aggregate under loading from traffic in relation to the type of used aggregate. It is evident that the considerably lower values of statistical texture parameters were in the road sections, when the limestone was used. And thus it can be argue, that the obtained results confirmed an assumption that the filtration process allows distinguish microtexture levels also in related to type of used aggregate. Obtained results also point to importance of polishing properties of aggregates used in road surfaces.

Table 1. Resultant statistical texture characteristics and *BPN* values.

	Sample	Ra (μm)	σ^2 (μm)	Rq (μm)	Rsk (-)	Rku (-)	MPD (μm)	BPN (-)
Section 1 Andesite	track	7.67	97.34	9.61	0.209	2.87	4.41	55
	out of track	7.84	99.60	9.81	-0.086	2.98	4.69	
Section 2 Andesite	track	8.75	131.66	11.31	0.092	3.53	4.94	64
	out of track	9.23	139.76	11.66	-0.067	3.18	5.22	
Section 3 Limestone	track	1.29	13.00	1.71	-0.193	4.19	1.07	38
	out of track	6.62	73.76	8.47	-0.102	3.26	4.02	
Section 4 Andesite	track	6.79	76.75	4.07	0.057	3.34	4.26	50
	out of track	7.97	118.24	8.61	-0.067	4.10	4.61	
Section 5 Limestone	track	3.23	19.24	4.07	-0.064	2.96	2.07	42
	out of track	5.81	60.10	7.41	-0.084	3.30	3.83	
Section 6 Limestone	track	3.56	21.99	4.64	-0.185	3.91	2.14	37
	out of track	5.29	47.65	6.68	-0.001	3.26	3.39	

**Figure 4.** Resultant values of Ra characteristics for investigated aggregate samples.

3. Comparison of BPN evaluation with evaluation based on statistical characteristics

The BPN values obtained from measurements on pavements (in the wheel track) were compared with the values of the statistical characteristics obtained from measurements of profiles on the particular aggregate particles taken from the pavement surface (from the sliding path).

The linear regression was chosen, considering of location of values in point charts (Figure 5). The results of comparison are presented in the Table 2, by the coefficient of determination and coefficient of correlation.

Table 2. Characteristics of regression and correlation analysis – *BPN* and statistical texture characteristics.

	Ra	Rq	σ^2	MPD	Rsk	Rku
Coefficient of correlation r	0.905	0.896	0.917	0.906	0.842	0.348
Coefficient of determination R^2	0.819	0.803	0.841	0.820	0.710	0.121

Data in the Table 2 shows, that some correlation between the *BPN* values and statistical texture characteristics Ra , Rq , σ^2 , MPD was found. These results can be useful in order to explain the basic relation between friction and the surface profile proprieties of aggregates. Specifically, higher values of the BPN are related to higher profile heights exclusive of shape properties and vice versa. The

coefficient of determination $R^2=0.710$ between BPN and Rsk characteristics implies that BPN values is also associated with distribution of surface irregularities within profile because of the Rsk characteristics describes the texture by the distribution of peaks and valleys over and under the mean line and allows defining „positive” or „negative” texture. Thus, from the obtained results is obviously, the polishing process by the tires causes a reduction in the height of the peaks on the aggregate surface with a subsequent reduction of the BPN . The lowest correlation between BPN and Rku characteristics probably related to definition of this characteristics. Whereas statistical characteristics Ra , Rq , σ^2 , MPD and Rsk describes irregularities of investigated profile by mean values of profile heights the, Rku characteristics describes the texture indirectly by the probability density sharpness of the profile.

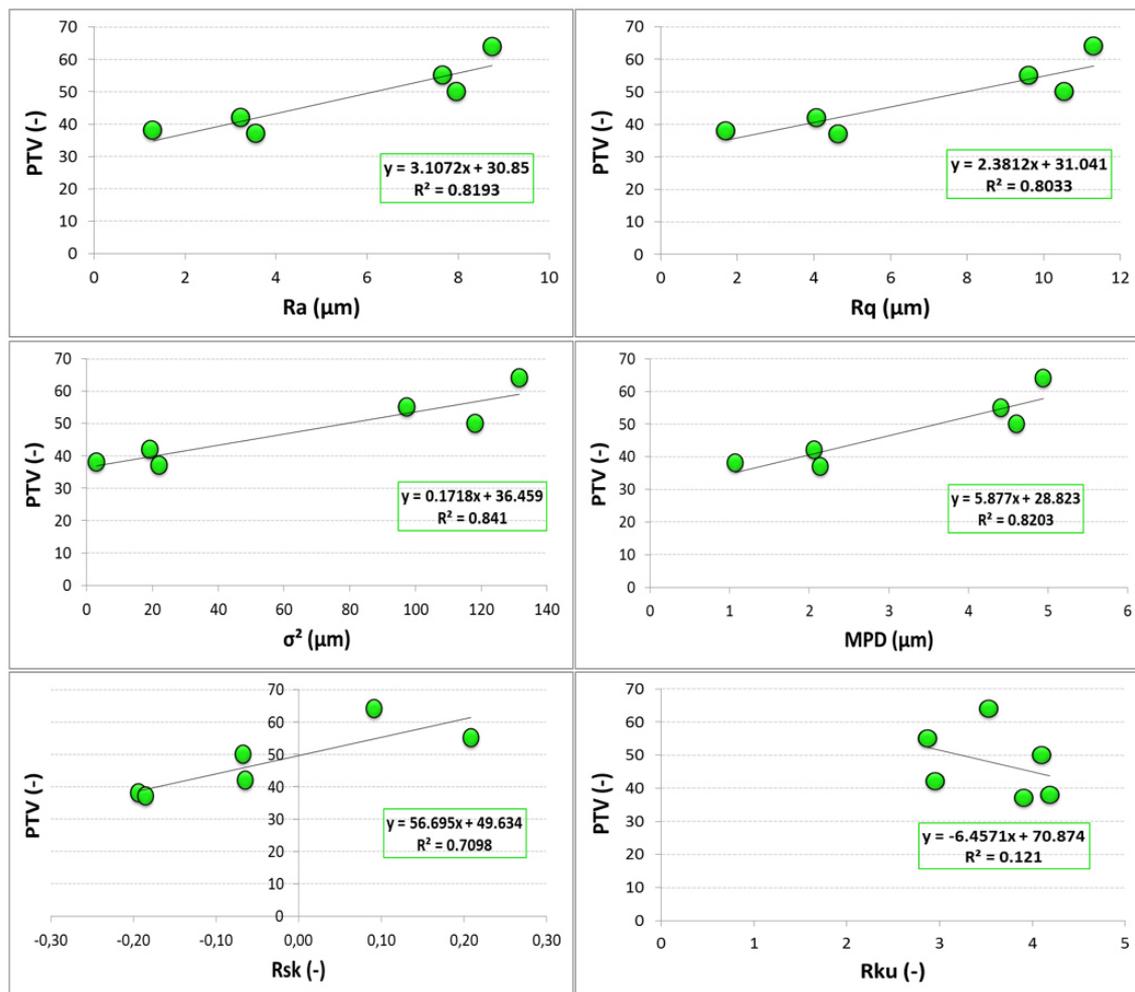


Figure 5. Relation of the BPN values with the values of statistical texture characteristics.

4. Conclusions

This paper in short presented results of microtexture measurement. The British pendulum tester measurements have been practiced on selected sections of roads with different asphalt surfaces. Individual grains of aggregates were taken from the surface of each section from the sliding path and also from the core sample after the extraction. The laboratory profilometry measurements have been practiced on these aggregate samples. Subsequently the surface microtexture was investigated based on commonly used texture characteristics and the filtration approach was applied in calculation process.

Based on the results obtained so far it can be argued that the application of filtration approach in the microtexture evaluation based on the profilometry measurements allows more accurate determination of microtexture characteristics and can provide the more representative results in the relation to *BPN* values. From this point of view presented research can provide a methodological recommendation and the implementation of the filtration approach in the further research can be useful for a better understanding of the material properties that affect the skid resistant coefficient of the pavement surface.

It is supposed that in the case of implementation of additional measurements even the more relevant correlation between *BPN* parameter and statistical texture characteristics can be expected. In the future research, it is also necessary to select measuring road sections with the available information's about type and composition of asphalt mixtures and the especially about service life and the intensity of traffic.

On the basis of this information's can be possible deal with the degradation of microtexture values in relation to traffic intensity, and mainly to the ability of aggregate to resist to polishing.

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