ON MACROTEXTURE AS AN INDICATOR OF THE CONDITION OF THE ROAD SURFACE

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Abstract: *Many factors influence the friction coefficient on an asphalt road: microtexture and macrotexture, wear of the road surface, variation in precipitation, traffic intensity, aggregate properties and road geometry. Macrotexture is mainly created by the size of the aggregates used or the surface treatment of the roadway and is the major factor influencing drainage capacity. The macrotexture of the road surface provides the hysteresis component of friction and allows natural drainage of water. The macrotexture does not change in a short period of time and rubber deposits can partially cover the texture, thus reducing the drainage capacity, which can affect safety of operations. The paper deals with the analysis and interpretation of the values of the average depth of macrotexture measurements in order to characterize the condition of the road surface.*

Keywords: *macrotexture, measurements, friction coefficient*

1. Introduction

The surfaces of the bodies deviate in reality from the shape and dimensions of the nominal surfaces, presenting deviations. From a geometric point of view, the deviation can be characterized by two parameters, namely: the amplitude (defined as the deviation from the line describing the ideal profile) and the step (defined as the distance along the line describing the ideal profile between two intersections similar to the real profile or between two similar points on the profile), [Muscă,2019].

The surface texture is the characteristic that determines most tyre-road interactions, such as the modification of the friction coefficient values, the tire wear rate, the noise level, the vibrations generated by the tyre-road contact.

The texture of the road surface, according to [Henry,2000], was classified into three relative reference intervals depending on the wavelength λ of irregularities: microtexture $\lambda<0.5$ mm, macrotexture 0.5 mm$<\lambda<$50 mm and megatexture 50 mm$<\lambda<$500 mm.

Road roughness is an important issue for the assessment of road pavement condition. Road roughness evaluation can be carried out using a number of different approaches. Among these, the most common ones are based on the assessment of detrimental effects induced by irregularities on road surfaces, like the dynamic increment of loads transmitted to pavements, road users' comfort and noise generated due to road traffic [Loprencipe,2017]. The IRI or International Roughness Index is a parameter for a pavement's ride quality, it is a component in analyzing the decline in road conditions and a determinant used to describe the elongated profile to show and calculate the amount of rising and falling of a lengthwise profile of the total length examined [Orlean,2021].

The values of the friction coefficient on the road surface are affected by the characteristics of both microtexture and macrotexture.

2. Macrotexture

Macrotexture is the texture between the individual aggregates. This characteristic of the road surface can be appreciated with the naked eye. Over time, the structure of the road can also change by producing bumps that can favor the appearance of stationary accumulations of water after rainfall.

Macrotexture is a result of asphalt mixture properties, mostly the aggregate gradation, maximum aggregate size, binder and air voids content. Macrotexture is usually measured using different volumetric or optical devices, and the measuring results are expressed as texture depth or profile depth values. Several studies showed that macrotexture level can be correlated to pavement skid resistance performance, [Pranjic,2019].

3. Methods for determining the average depth of macrotexture

Macrotexture measurements are performed to obtain the data necessary to characterize and interpret the average texture depth, correlated with recommended drainage characteristics, which are related to skid resistance and the impact on operational safety. The average macrotexture depth is determined by direct measurements on the surface using dedicated equipment, while the microtexture is estimated indirectly using the measured friction coefficient values for interpretation. There are several methods that are commonly used to measure macrotexture and can be classified as static or dynamic measurements [Flintsch, 2003].

In *volumetric measurement methods*, also called *static*, the estimation of texture depth is considered as a result of a known volume of material used on the covered surface (to fill the voids in the surface) with the type of material used. These methods can be applied to isolated sectors of the measured surface, they are giving a smaller value for the MTD and, therefore, overestimating it, [Fiscao,2013].

Dynamic measurements are usually continuous optical measurements, not on isolated areas as in the case of static ones, which use laser technology to detect surface texture characteristics, usually the values obtained being used to determine the average texture depth. Dynamic measurements are more practical for road surfaces, as they allow the collection of large amounts of data in a relatively short time. The measuring equipment, for example a laser beam or similar device, is installed on a vehicle.

Both static and dynamic measurement methods provide macrotexture characterization indicators, as measurement results: *Mean Profile Depth* (MPD, is a purely geometric indicator, as *per* ISO 13473-1:1997 and ASTM E1845-01) and the *Mean texture depth* (MTD is affected by dense granular flows as known as sand patch texture, as *per* ASTM E965-96 and EN 13036-1), [Praticò,2015].

The main disadvantage of laser scanner is their limitation on the size of scanned area.

This article deals with the results of measurements carried out on an airport runway using a Hawkeye 1000 laser measuring equipment.

4. On field macrotexture measurements

MPD values measured using a laser profilometer are not the same as MTD values measured using volumetric techniques (sand patch tests). However, MPD can be converted to EMTD (equivalent to MTD of the volumetric method) to characterize macrotexture, [Flintsch,2012], using the following equation:

$$\mathrm{EMTD} = 0.8\mathrm{MPD} + 0.2 \quad \text{units in mm} \qquad (1)$$

4.1 Equipment used in measurements

The HAWKEYE 1000 equipment, Fig. 1, is used for the continuous determination of the international roughness index (IRI)and the average macrotexture depth on all categories of roads with bituminous or cement concrete pavements.

The Hawkeye 1000 profilometer, [CNADNR,2012], uses concentrated laser beams that are reflected from the road surface and are detected by an array of photo-sensitive cells to determine the distance between the laser source and the road surface.

The method consists of using a modern technology for measuring flatness and roughness, an opto-electronic system for reading the reflection of the wave emitted by the laser sensor, the signal being transmitted to a complex electronic equipment that allows its processing and storage. As the laser sensor moves over the road surface, its high-frequency pulses allow the creation of a profile of the macrotexture of the road surface.

The equipment calculation program allows the transformation of the determined values, by measuring the depth of the macrotexture of the surface of the pavement using the volumetric sand patch technique according to SR EN 13036-1.

Figure 1: *Hawkeye measuring equipment mounted on a transporter car type*

4.2 Measuring distances and speed

The measurements were carried out along 4 lines to the left and 4 lines to the right of the centerline, from South zone to North. The measurement distances from the center line were 2 m, 4 m, 6 m, 8 m to the left and 2 m, 4 m, 6 m, 8 m to the right.

The measurement length was 1900 m, the starting area being the threshold of the runway from the South.

In Fig. 2 the measurement lines, measurement distances and the direction of travel used in the measurements are graphically presented, on the right side of the reference centerline.

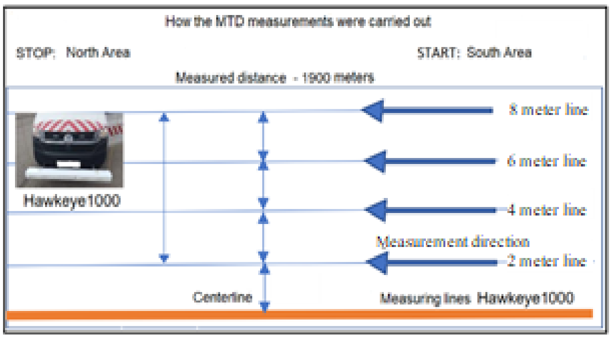

Figure 2 : *Measurement procedure using Hawkeye 1000*

Measurements were performed at a speed of 50 km/h on both sides of the centerline. All measurements were recorded and centralized for analysis and interpretation.

4.3 Measurement step

The step for performing macrotexture measurements was 100 m. An example of the results of the average macrotexture depth measurements is presented in Table 1 (extract).

In this study the acceptable macrotexture values for analysed road surface, according to [EASA,2023], were comparated with the reference value of 1 mm.

Interpretation of measured data was made as follows : if the measured value is greater or equal to 1 mm it is considered acceptable and if the values are below 1 mm do not meet the recommendations.

Direction 34→16 Area ≈ 2 meters right from centerline Km 0+000 - 1+900						
Distance (km)	MTD (ETD) Right (mm)	Acceptable condition for macrotexture (≥1.00)	MTD (ETD) Left (mm)	Acceptable condition for macrotexture (≥1.00)	Speed (km/h)	Events
0.100	0.92	<1.0	1.12	Acceptable	49.60	
0.200	1.09	Acceptable	1.17	Acceptable	49.10	
…..	…..	…..	…	…..	….	

Table 1: *Example of initial measurement data for MTD (ETD) values provided by the equipment software*

5. Data analysis and interpretation

Fig. 3 shows the distribution of average texture depth values, referring to the passes and measurements made on the road surface with the Hawkeye 1000 equipment (left and right mean the lateral reference to the centerline, the side on which the measurements were made).

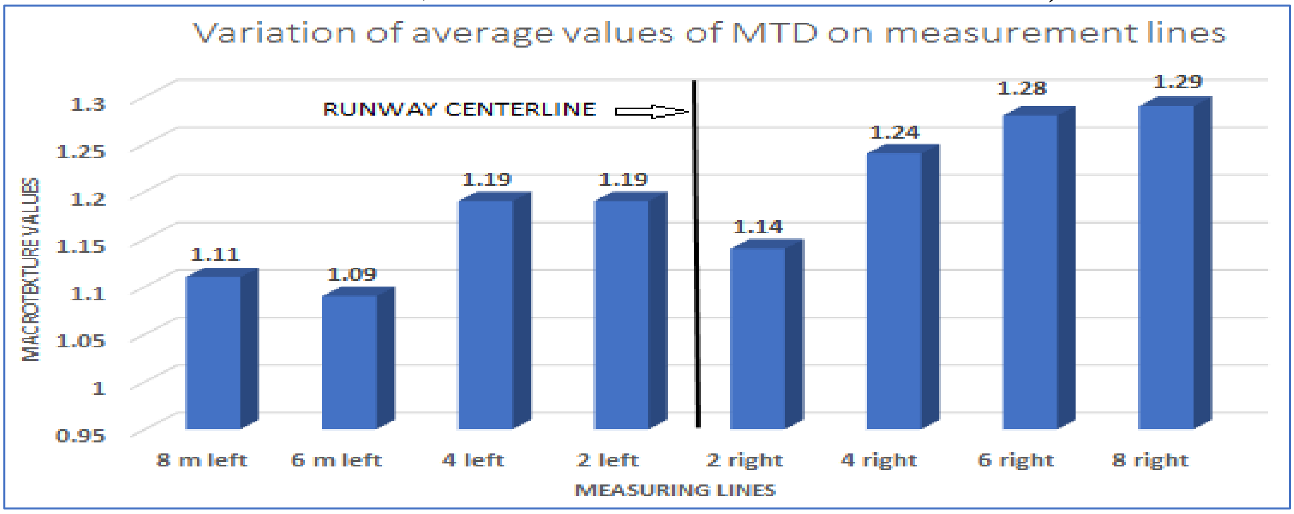

Figure 3: *Average values on measurement lines*

It is observed that on the lines 2 meters left and 2 meters right from the centerline the MTD values (1.19 mm and 1.14 mm) are lower than those obtained on 4 meters left and 4 meters right (1.19 mm and 1.24 mm). This is determined by the fact that aircraft landings take place predominantly on the width from 2 to 4 meters laterally from the runway centerline and thus rubber deposits in the surface gaps reduce the depth of the surface macrotexture. In the case of repeated landings, the tyre-road contact affects the surface microtexture, which leads to the polishing of the interface surface, thus decreasing the value of the average depth of the surface macrotexture.

Another factor affecting the average depth of the macrotexture is the use of de-icing agents on the road surface. If the drainage of liquid de-icing agents is not adequate, patches or deposits of liquid can form and affect the surface structure.

The environment, in particular dust deposits, or any other detachments from the surface structure, can generate particles that can lead to the covering of voids in the surface.

Another aspect that emerges from the measurements is that although the 6 and 8 meter left lines are not predominantly used for landings, they have a fairly low average value of 1.09 and 1.11 mm, compared to the 4 meter left and right lines that are frequently used by aircraft, which have average values of 1.24 and 1.19 mm. It is observed that for the 6 m left line, Fig. 4, 26.32% of the values are below the 1 mm threshold, compared to those for the 4 m left line, Fig. 5, where 5.26% are below the 1 mm threshold.

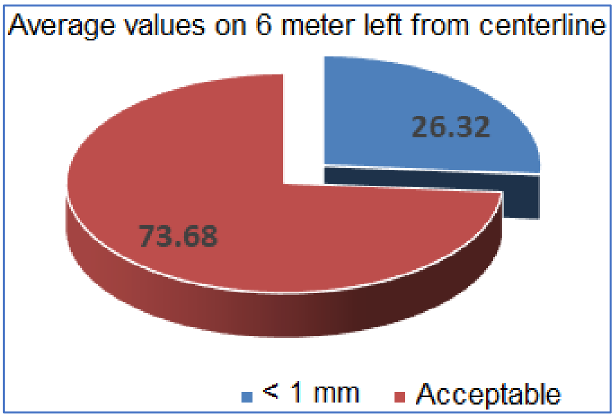

Figure 4: *Percentile values of acceptability on the line 6 meters left of the axis*

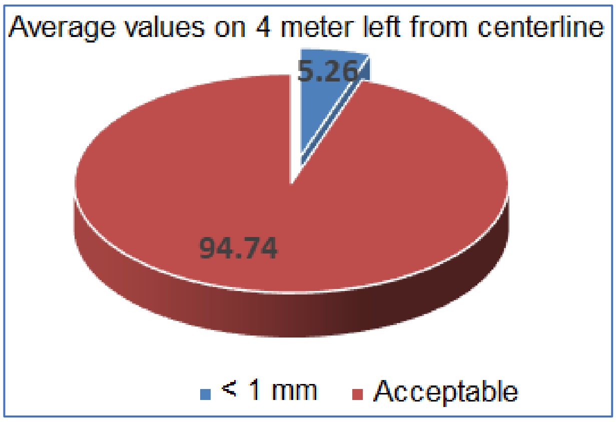

Figure 5: *Percentile values of acceptability on the line 4 meters left of the axis*

Following the field analysis of the areas wich correspond to the 6 and 8 meter lines, Fig. 6, and 4 meters, Fig. 7, left of the centerline, it was observed that the 6 and 8 meter lines correspond to the areas where road surface de-icing fluid predominantly collects, which means a low macrotexture, as it no longer allows for proper drainage of the fluid towards the side of the runway to the water collection pits.

Figure 6: *Macrotexture lines 6 and 8 meters left*

Figure 7: *Macrotexture line 4 meters left*

An aspect to consider is also the influence of the runway slope, because if it is inadequate, it contributes negatively to the drainage on the surface and allows the accumulation of de-icing fluid on the runway and the formation of stationary accumulations of fluid.

In Fig. 8 it can be seen that the prevailing average values of the MTD at the road surface are in the range of 1.08 – 1.22 mm.

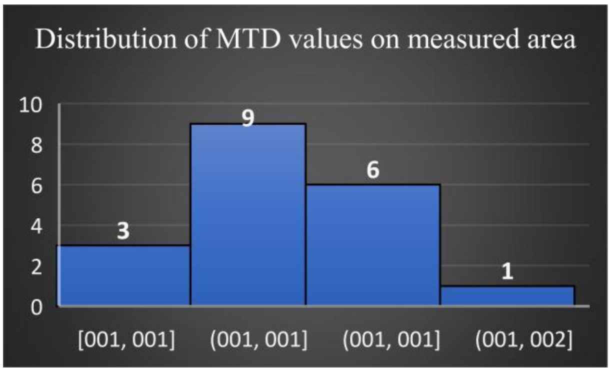

Figure 8: *Predominant MTD values distribution on measured surface*

The measurements were interpreted and compared with the reference values, [ASTM,2015]. According to ESDU 71026, the classification of runways according to the average depth of the macrotexture is: Class A: 0.10-0.14 mm, Class B: 0.15- 0.24 mm, Class C: 0.25-0.50 mm, Class D: 0.51-1.00 mm and Class E: 1.01- 2.54 mm.

If a correspondence is made with the reference values in the ESDU 71026 standard, it is observed that the measured surface condition falls into class E (MTD has values between 1.01 – 2.54 mm).

In the classification of macrotexture, regulated by [EASA,2023], it is observed that the threshold value between classes (for example for class D the MTD value is between 0.51- 1.00 mm) is 0.01 mm. The measured values of mean texture depth (MTD) have a discrete distribution, the reference value is very small, any small variation in the measuring equipment (in our case Hawkeye 1000), limitations of accuracy and resolution, must be evaluated according to the specific context, scope of application and required accuracy.

Because the classes mentioned above do not have clear specifications when and under what conditions they apply, to what type of surface, at what level of precipitation, measurement conditions, specific technical characteristics, the threshold of 0.01 mm may not be considered appropriate.

Moreover, in the case of certain runways this dynamic drainage capacity, established by the regulation, does not fully address the characteristics related to the variation of precipitation (rain, snow, etc.).

In Fig. 9 is presented a comparative analysis on two measurement lines on the same side of the reference centerline.

It is observed that on the 4 meter line the values are higher than those on the 2 meter line. The 4 meter line corresponds to the landing of Airbus 320 aircraft and the 2 meter line corresponds to ATR 45 aircraft. The conclusion from the field, as a result of visual observations, is that repeated landings of aircraft with a significantly higher weight lead to detachments of aggregate from the structure of the surface, thus the voids in the surface having a higher density and average depth.

The areas between 300-700 m and 1700-1400 m are where aircraft wheels predominantly make contact with the runway surface.

It is observed that lower values of MTD are recorded in these areas, which is obviously due to the rubber deposits in those areas.

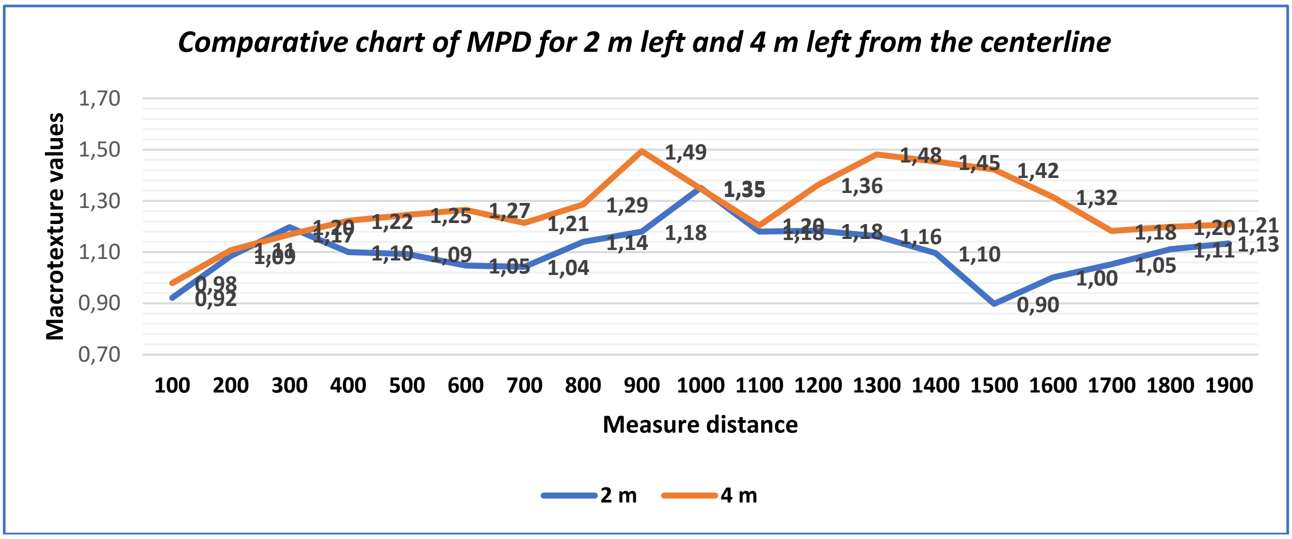

Figure 9: *Comparative chart MPD for 2 m left and 4 m left from the axis*

Taking a pass as a reference, Fig. 10, in the presented case being the 6 meter line left of the centerline, where MPD 1 (measurement on the left wheel of the equipment) and MPD 2 (measurement on the right wheel of the equipment), it can be observed that the shape, the profile of the measured surface has approximately the same shape, behavior.

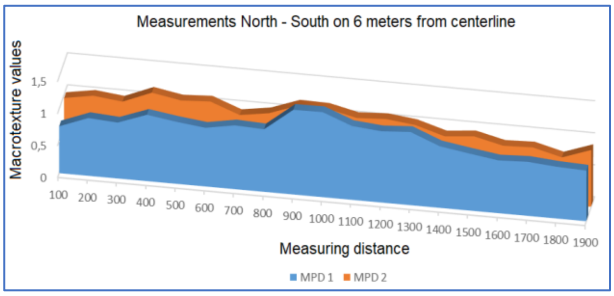

Figure 10 : *Measurements of MPD 1 și MPD2* on 6 meters from centerline

And in this surface interpretation of the measurements, it is observed that the frequently used areas, 300-700 m and 1700-1400 m, have lower values of the average macrotexture depth due to rubber deposits.

6. Conclusions

Macrotexture essentially ensures the drainage of water from the runway surface, a low macrotexture (in this study reaching values of 0.8 mm) can lead, in the case of a road surface that is subject to precipitation (rain), to a significant decrease in the tire-road friction coefficient.

Macrotexture is strongly influenced by rubber deposits detached from aircraft tires. These accumulates on voids in the surface and affect not only the macrotexture but also the microtexture of the surface, fig.7.

Surface de-icing procedures, runway de-icing fluid treatment procedures to melt contaminations (ice, snow, etc.) directly affect the macrotexture, fig. 4 and fig. 5, either through the chemical effect of the substances used, fig. 6, or through the mechanical effect of the brushes, or through the effect of the blades, turboblowers and brushes used to remove snow.

It was observed that the average depth of the macrotexture does not have a uniform distribution, fig. 8 , varying between reference values with peaks and values close to the lower limit of reference (in the case of this study the threshold is 1 mm).

Because the classification of macrotexture, regulated in [EASA,2023], assume that the threshold value between classes (classification that was developed, using sand or grease patch measuring techniques, and issued in 1971 by the Engineering Sciences Data Unit (ESDU)) is 0.01 mm, according to the study, is observed that due to discrete and uneven distribution, a reconsideration regarding the macrotexture threshold measurement references may be appropriate to be taken into account.

In the studied case, it is observed that dynamic measurements are more recommended than static ones (on isolated areas), thus providing significantly more amount of data and information, on larger surface zones, in a relatively short period of time, about the surface macrotexture for a better interpretation of surface characteristics.

In conclusion, for ensuring safe operation condition on road surface, macrotexture values must fulfill the recommended values, in our case, equal or grater than 1 mm.

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