MEASUREMENT OF SURFACE MACROTEXTURE ON RUNWAYS OF AIRPORTS. TEXTUROMETERS LASER VERSUS TRADITIONAL METHODS OF MEASUREMENT.

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PRESENTED FOR THE
2014 FAA WORLDWIDE AIRPORT TECHNOLOGY TRANSFER CONFERENCE
Galloway, New Jersey, USA

AUGUST 2014

Abstract

Because of the impact that is produced on the safety of aircraft operations, surface macrotexture is a vital parameter in airport runways.

In the present document are described different measurement methods to determine this parameter. It is made a comparative analysis between traditional volumetric methods and, besides, between them and those texturometers which are using laser technology, including the three-dimensional one. For this purpose, there are presented the results of tests of two different pavement surface layers performed on airports runways.

Besides, we review other comparative studies and other optical methods for measuring pavements textures.

In the end of the article comes a section of conclusions advising the use of 3D texturometer laser, as a method of measuring the surface macrotexture and MPD (Mean Profile Depth). Besides there are used digital devices to obtain texture values which could be easily adapted to the Sand and Grease Patch tests.

1. Concepts and categories of surface texture.

A fundamental property of the pavement surface is texture. The texture allows that the pavement could evacuate water while it is raining and maintain contact between the tire and the pavement surface.

The slope of the pavement facilitates the evacuation of water from the surface. Nevertheless, when the slope is very small and the movement is performed at high speed, considerably increases the possibility of occurrence hydroplaning or aquaplaning, with the risk of accidents.

These conditions become more important in airport runways, due to the lower slopes that are required by the normative, so the existence of a good texture is critical for the aircrafts safety, independently of the fact that it can also have influence on the friction coefficient of the runway.

The AIPCR established in 1995 a classification of surface irregularities in four categories, based on their wavelength. The four categories are defined as the deviation from the road surface with respect to an ideal flat surface exactly at wavelengths ranging from 0 to 0.5 mm (micro-texture) , from 0.5 to 50 mm (macro-texture) , from 50 to 500 mm (mega-texture) , and from 0.5 to 50 m (regular) .

This article will be focused on the macrotexture, which at certain times will be called simply texture. Together with microtexture, is the parameter that influences the adhesion between tire and pavement, as well as hydroplaning or aquaplaning. Texture is always dependent on the particle size of the aggregates that form asphalt concrete or cement pavement.

In Figure 1 it is shown a scheme of the Micro and Macro- texture and its effect on the friction coefficient, as reported in “*Project Manual of Aerodrome International Civil Aviation Organization (ICAO)”.[1]*

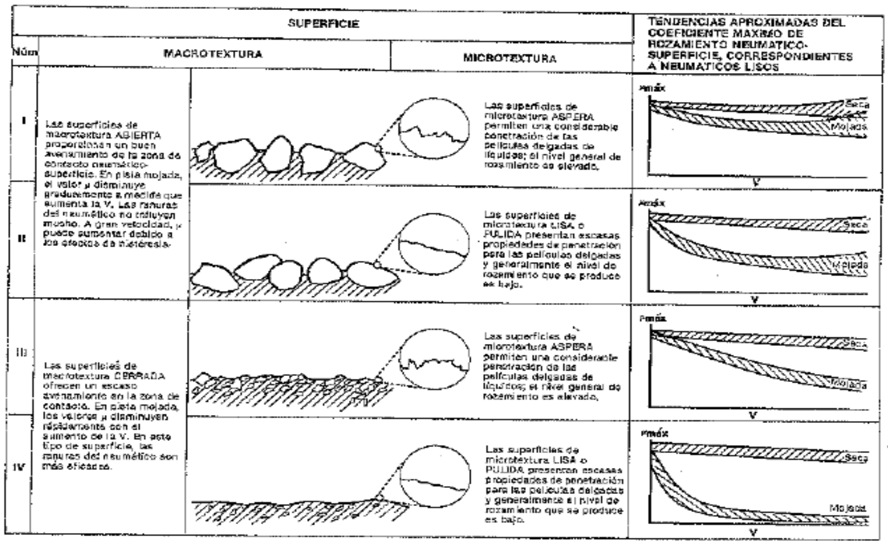


Figure 1. Microtexture and macrotexture, and their effect on the coefficient of friction. ICAO source.

Similarly like the coefficient of friction can give us an idea of whether the surface is smooth or rough, surface macrotexture would indicate where that area is course or fine (see picture 1).

Picture 1. Course and fine texture.

Finally, regarding the measurement methods, while the microtexture is not measured directly, but through the coefficient of friction, macrotexture is measured directly by various methods. We will describe, in this article, the four main that are the following:

- Grease Patch method
- Sand Patch method
- 2D spot laser texturometer
- 3D laser texturometer

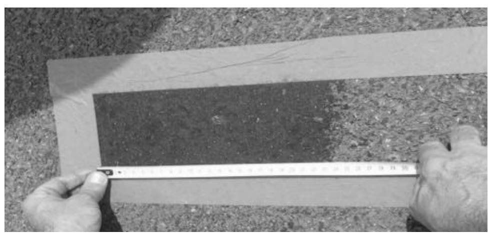
Traditional methods helps us to understand easily the physical meaning of the macrotexture measuring as the average height of penetration, either with grease or sand material (or glass beads, as discussed below) in the interstices of the pavement on the surface to be examined, as follows:

Texture index (h) = Volume of grease, sand or beads (V) mm^3 / Covered Area (S) mm^2

2. Grease Patch test method.

The test method that is normally used to determine the surface macrotexture at Spanish airports is a Grease Patch method, described in Appendix 2 *of "Manual of the ICAO Airport Services. Part 2 "[1],* and it is performed as follows:

A cylinder is filled with a volume of 15 cm^3 of any general purpose grease. Two parallel lines of adhesive tape are stuck on the surface of the runway with a spacing of 10 cm and then it is stuck a third strip line at a straight angles to the previous two, in one of the ends of them. Grease it is taken out of cylinder and it is extended with a spatula through the tested area (see Picture 2).



Picture 2. Grease Patch method procedure. Euroconsult source.

Consecutively, it is measured the distance reached by the grease along one of the parallel strips. If the grease in its free end does not form a straight line perpendicular to the line, it will be also measured along the other line, and it will be taken the average value of the two measurements.

3. Testing method of Sand Patch / Glass beads.

This test method is similar in principle and the implementation to the Grease Patch one, described above, with the difference of the material to be used and surface geometry to be covered.

Ultimately it is about covering a surface that could be easily measured, in this case a circle patch with a determine volume of material.

In Figure 3 shows a diagram of the test and the formula to determine the mean depth profile of the texture as the ratio between the volume of the spread material and the area of the formed circle patch.

It is implemented the European Standard EN 13036-1 *"Surface characteristics of roads and airports. Test methods. Part 1: Measurement of the pavement surface macrotexture using the volumetric method* "*[2]* and glass beads instead of sand.

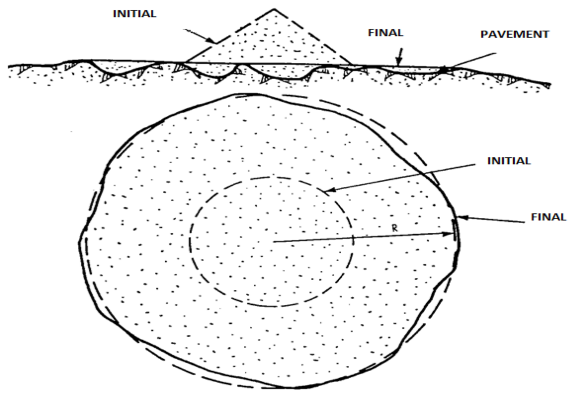


Figure 2. Scheme of Sand Patch test. EN 13036-1 source.

4. Comparison between the two traditional methods.

Experience with testing by traditional methods has shown different results depending on the used method.

From the performed tests, it appeared that the humidity and temperature significantly modified the values obtained by both methods (Sand Patch and Grease Patch).

In the case of sand, it was observed that the humidity compressed the sand and made difficult its extension and this means the creation of more small patches. In the case of grease, it was noticed apparent viscosity variation with temperature, which in future could lead to different, not real results.

Of the total number of tests performed, the following comments of the used materials were extracted:

• Glass is a material that is showing less sensitivity to such parameters as humidity and temperature.

• That the grease seems to vary depending on the temperature and possible changes in viscosity, thus the method of testing with Grease Patch should be used taking into account this factor.

• The sand shows sensitivity to changes in humidity.

Due to previous observations, given the disadvantages of sand and grease materials, glass beads are recommended for the purposes of international standardization of the material.

Furthermore, depending on type of pavement, it was observed that in most asphalt concretes, the grease test seems to be more affected when applied in finer asphalt surfaces.
In this respect, a study conducted by “*Aktas et al”* (TRB 2011 Annual Meeting) *[3]* discovered that the method of Sand Patch should be used in pavements with macrotexture thicker than 0.79 mm, both in hydraulic and asphalt concrete, and not allow its use on surfaces with low macrotexture.

The test plan carried out at airports was designed so that the two types of them will be performed at the same point, along longitudinal profiles located in width of the central part of the runway.

The airports were chosen from different climate thermal zones in accordance with the following: two of them with porous asphalt concrete and two others - LB3 slurry. The tests were performed in three different seasonal periods: autumn, spring and summer.

In Figures 4 to 7 are shown the examples of the results compared between the two methods (using in addition to sand material, glass beads), in the sections with 2.5 and 5 m distance from the axis of a LB3 slurry runway.

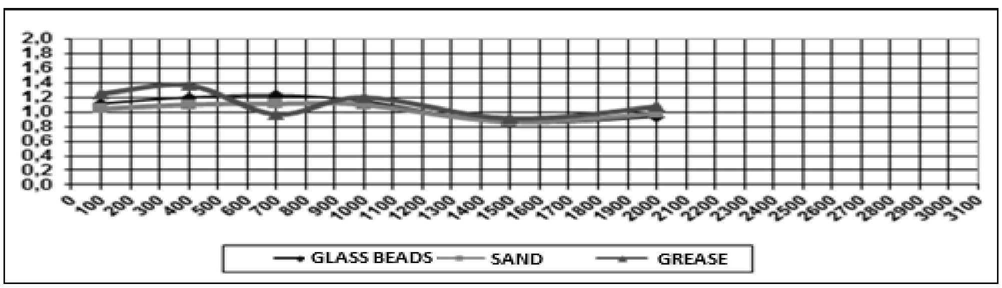


Figure 3 Comparison between traditional methods on the runway with slurry surface type LB3 with 2.5 m distance to the left of the axis

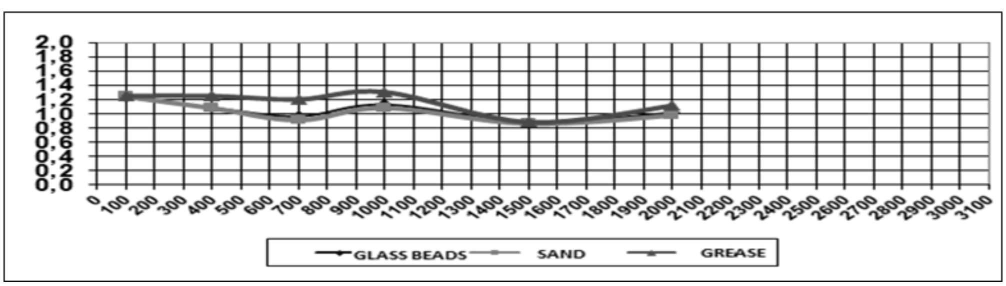


Figure 4. Comparison between traditional methods on the runway with slurry surface type LB3 with 2.5 m distance to the right of the axis

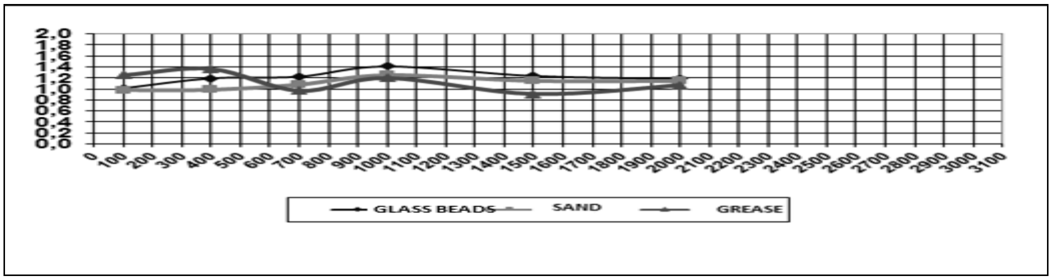


Figure 5 Comparison. Between traditional methods on the runway with slurry type surface type LB3 with 5 m distance to the left of the axis.

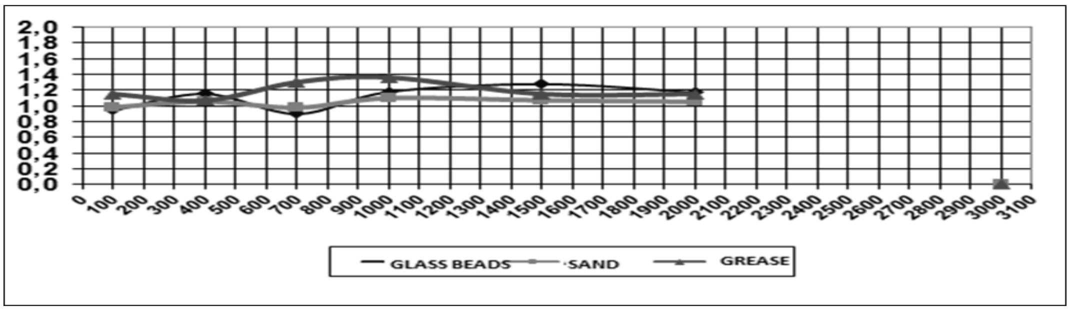


Figure 6. Comparison between traditional methods on the runway with slurry surface type LB3 with 5 m distance to the right of the axis

In the bar graphics in Figure 7 the above tests are summarized in their average values taken form figures 3-6. It is measured from both distances of the axis, on the runway with slurry surface type LB3.

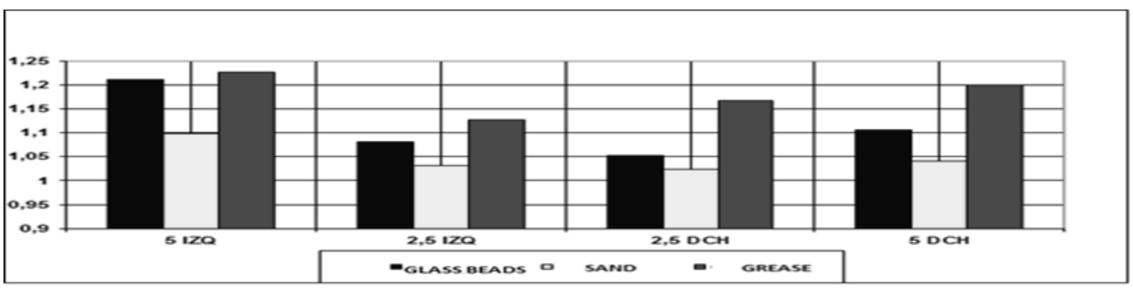


Figure 7. Comparison between medium values of the traditional methods on the runway with slurry surface type LB3.

In Figures 8 to 11 examples of the tests performed with the three materials, with 2.5 to 5 m distance from the axis of a runway with hot porous asphalt concrete road surface.

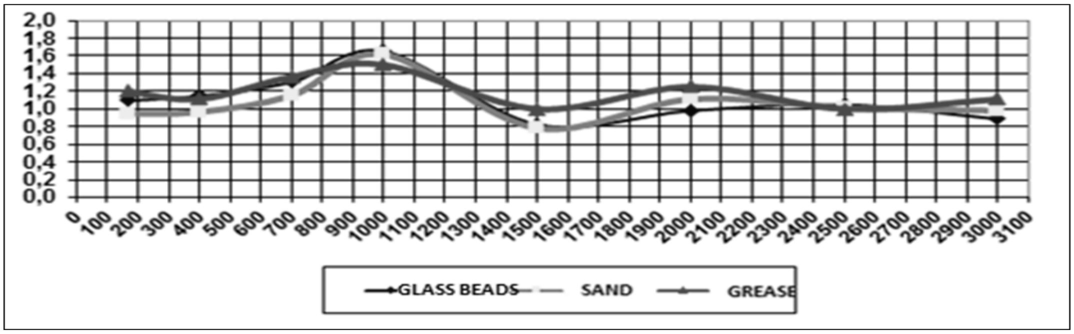


Figure 8. Comparison between traditional methods on the runway with porous asphalt concrete with 2.5 m distance to the left of the axis.

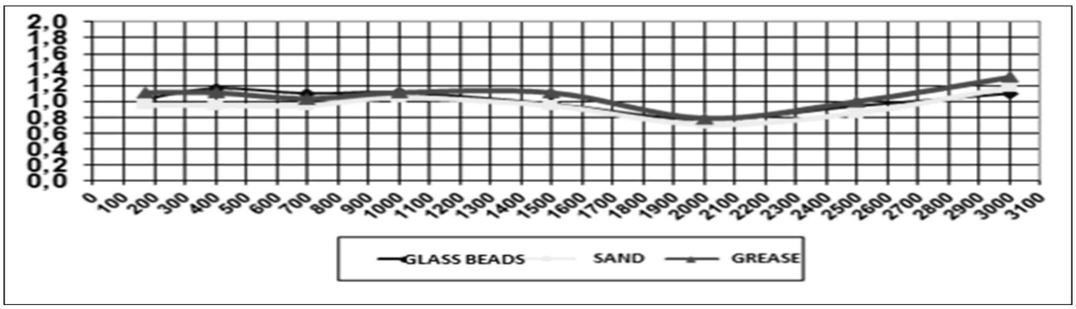


Figure 9. Comparison between traditional methods on runway with porous asphalt concrete with 2.5 m distance to the right of the axis

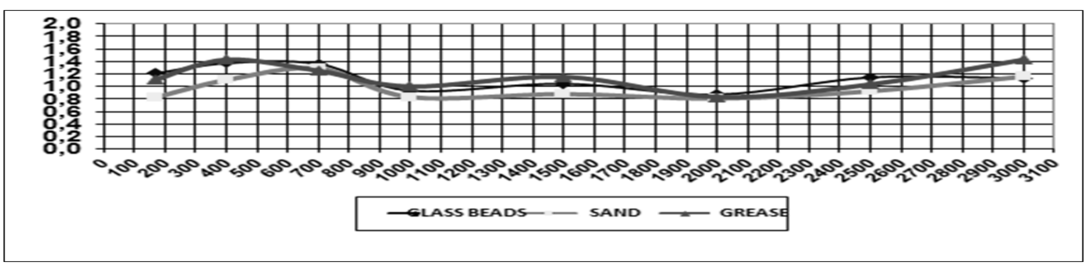


Figure 10. Comparison between traditional methods on the runway with porous asphalt concrete with 5 m distance to the left of the axis

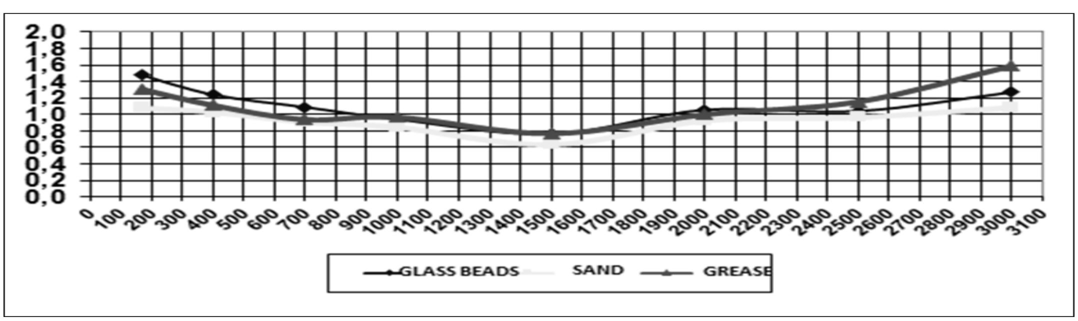


Figure 11. Comparison between traditional methods on the runway with porous asphalt concrete with 5 m distance to the right of the axis.

The bar graphics of Figure 13 represents the average values of above performed tests (figures 9-12) with two different distances from the axis, on a porous asphalt concrete.

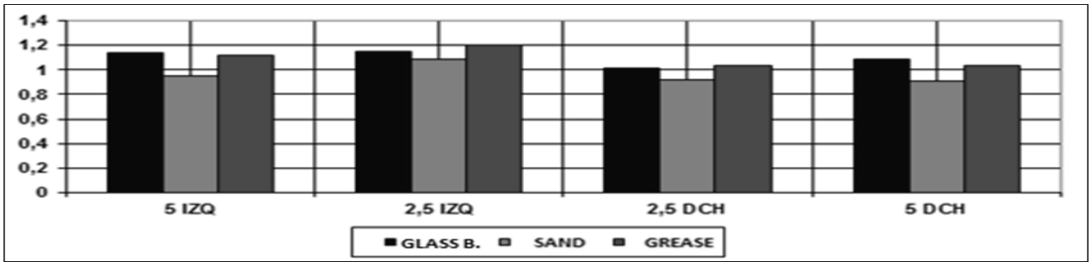


Figure 12. Comparison between average values of the traditional methods in runways with porous asphalt concrete.

Finally, analyzing the two traditional methods, the test of Grease Patch is much easier to perform and it requires only to spread the material evenly in only one direction, while the Sand Patch test, requires a uniform extension in all directions.
Furthermore, the glass beads offer more security against changing weather conditions, so it would be interesting to perform the test of Sand Patch with not this material, but with glass beads, since it seems that it would give more accurate results.

5. Texturometer Laser 2D and 3D. Description of the equipment and test method.

The laser technology applied in pavement engineering has led in recent years to a major advance in obtaining of reliable and descriptive results of high performance and at high travel speed, offering different characteristic parameters of the pavement surface.

In the field that we are working, since long ago, it is possible to obtain the values of depth texture in continuous longitudinal profiles by means spot laser sensors.

The spot laser sensor (see picture 3) performs non-contact 2 dimensional measurement of the distance between a reference level and the pavement surface by means of triangulation along one longitudinal line.

Picture 3. Sensor laser of 2D spot texturometer

The above mentioned laser sensor, mounted on a vehicle, is capable of measuring continuously the pavement texture to the traveling speed of the vehicle, which can achieve, in the measurement process, the 100 km / h. The components of 2D spot laser texturometer which measures along the line and obtain 2D profiles, are:

- Light source laser IR of controlled intensity.
- Camera with focusing lens and photo detector of high resolution.
- Lens system located behind the laser aperture.
- Lens system located in the sensing camera.
- Unit of signal processing.

In comparison with above mentioned equipment, there are available the three-dimensional laser profilers that use high power laser line projectors, custom filters and a camera as the detector. The shape of the pavement is acquired as the inspection vehicle travels along the runway using a signal from an odometer to synchronize the sensor acquisition.

Picture 4. 3D Texture measurement. Pavemetrics source.

The data from the 3D images are represented by the height of texture on an x-y plane, and continuous pavement surface is divided into many discrete images of 4096 pixels from the left or right mounted camera sensor in the measuring vehicle, thus showing the left and right side of each race.

Should be considered the warning expressed in the work "*Development and Field Evaluation of a Texture Measurement System Based on Continuous Profiles from 3D Scanning System"* (Huang et al, 2013 TRB Annual Meeting) [4], in the sense of applying a very small exposure time for each sample tested with the 3D system, to achieve bigger precision in the texture data collected, independently of the speed of the vehicle in which the system will be mounted.

The developed systems have noted that a certain percentage of captured 3D points do not correspond to the reality of the pavement surface, due to imperfections of the laser optics to distinguish jumps due bumps or local photometric properties of the surface. With these conditions, the obtained zeroes must be removed and replaced and should be corrected those, unusually high values, in comparison with the average ones.

From the direct measurements of the profile can be obtained various parameters, the most common being the MPD (Mean Profile Depth), mean depth profile in 2D systems, which is calculated according to the UNE-EN ISO 13473-1 *"Characterization of texture pavements using surface profiles. Part 1: Determination of Mean Profile Depth ".* [5]

This standard describes a test method for determining the mean depth of the macrotexture of the floor surface, which consists in obtaining the curve of a surface profile and to calculate the depth of the texture from the profile. The technique is designed to provide mean depth profile of the pavement macro-texture only and it is considered insensitive to pavement microtexture and irregularities as it is described in its own method regulation "Purpose and scope".

In Figure 14, taken from the method regulation can be seen graphics with the mean depth profile (MPD) over a given distance (baseline).

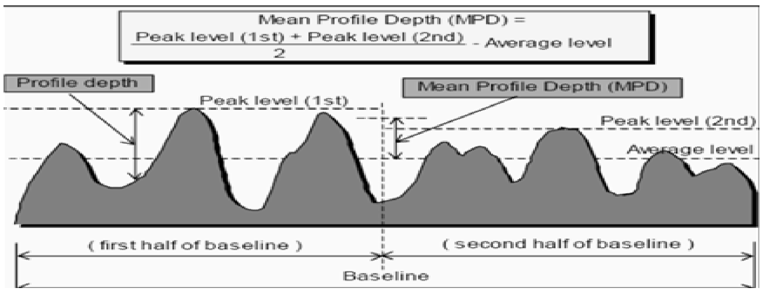


Figure 13. Mean Profile Depth (MPD). EN ISO 13473-1 source. [5]

The Media Depth Profile, MPD, is used to estimate the media depth texture, MTD (which is obtained by the method of Sand Patch or Grease Patch) by a transformation equation, obtaining the Estimated Texture depth (ETD), which coincides with the values obtained by traditional methods.

This transformation equation is: ETD = 0.2 + 0.8 MPD

All values are expressed in millimeters.
However, the results of the interesting study by Parra and Yanguas (Civil Engineering, Jan-Feb-Mar 2013) "Correlations between macrotexture measurements taken with the volumetric method and with different laser texturometers"[6] indicate that the clouds of points that relate MPD with the BAT, do not fit linear regression lines. On the other hand, best fits were obtained using exponential regressions:

$$MTD = ETD = a \times e^{b \times MPD}$$

With this equation, coefficient of determination R2 has increased over that obtained in the linear correlations, and the value of the errors decreased.

However, in sections tested with texture values thicker than 1 mm, there were given more elevated dispersions than in others sections with the similar characteristics. From this the authors deduct that the spot laser texturometers have difficulty in the correct measuring of finer surfaces. The study concludes that the correlation equation of the UNE-EN ISO 13473-1:2006, should be revised.

Acquiring sufficiently dense 3D data over the entire runway surface width it is possible not only measure standard MPD but also to evaluate texture using a digital model of the Sand Patch method. This allows the possibility to measure texture as a Sand Patch test would (MTD) over a full lane of 4 m.

6. Comparison of laser method with traditional methods.

The measurement of macrotexture surfaces of Spanish airports runways has been traditionally done by the method of the Grease Patch or Sand Patch, that have been discussed in previous sections.

Being specific test methods, they have the disadvantage of giving values that may give not exact characteristics of the surface condition of the runway, so the discovery of a method of continuous recording using a device that performs high-speed measurements should be considered a target.

However, there is a reluctance to adopt any new method that has not been proven and duly correlated with traditional methods, which have been considered reliable or at least have been used as a reference, until now.

It seems necessary, therefore, to establish a comparison between the measurements obtained with both methods, and try to find an acceptable correlation between the values obtained with each of them, which allowed validating the new ones, in order to be used as a preference after that.

Should be seen, however, the possibility of that comparative study that proves the inappropriateness of establishing a correlation between the two types of methods.

Consider also that since the classical tests have problems due to their subjectivity and other disadvantages that make them unreliable, it is inappropriate to think that the tests that we do using the more precise technologies would give the same results.

The most appropriate method of continuous testing that current technology could provide is the laser texturometer either 2D or 3D.

In the case of 2D texturometer is very unlikely that there is a correlation with the standard tests, because the measuring is performed on one surface - in the case of the Grease Patch or Sand Patch, and in one line or one profile - in the case texturometer.

6.1. Comparative tests with 2D texturometer.

However, the results of comparative tests are carried out in two airports in a thermal region of Spain with average summer temperature and dry rainfall season in autumn. Besides, they have similar ambient and pavement temperatures.

In Figures 15 and 18 are presented the graphics with collected values of measurements along the runway, each 10 meters using the texturometer. The results are shown in millimeters. Also there are shown the specific values obtained from Grease Patch test.

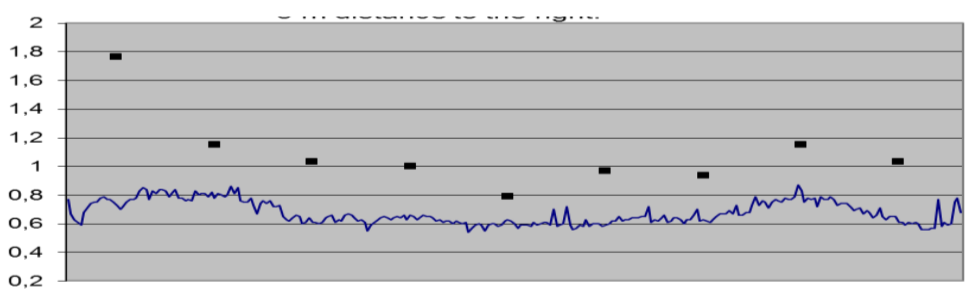


Figure 14. Comparison of texture between points of Grease Patch and 2D laser surface layer profile of LB3 slurry with to 3 m distance to the right of the runway axis.

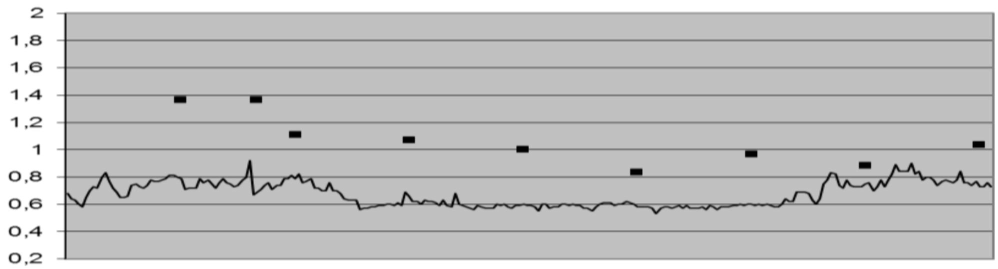


Figure 15. Comparison of texture between points of Grease Patch test and laser surface layer profile of LB3 slurry with 3 m distance to the left of the runway axis.

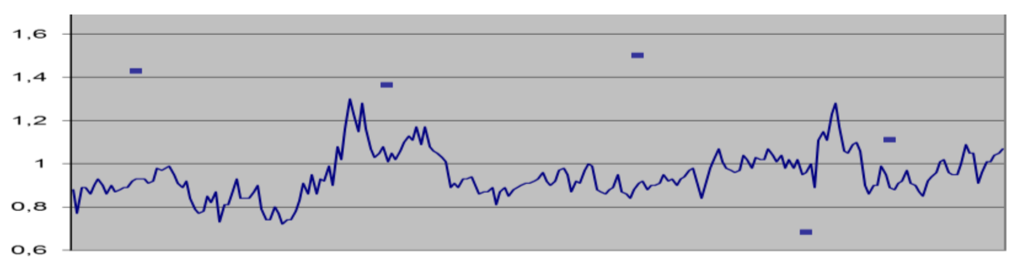


Figure 16. Comparison of texture between points of Grease Patch test and laser profile of porous asphalt concrete with distance of 3 m from the right of the runway axis.

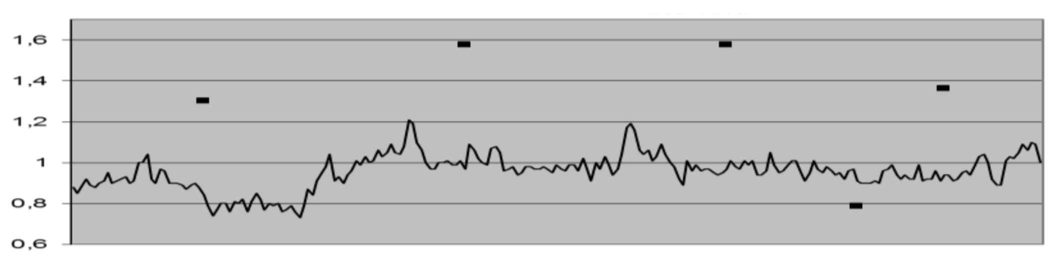


Figure 17. Comparison of texture between points of Grease Patch test and 2D laser profile with porous asphalt concrete with distance of 3 m to the left of the runway axis.

Analyzing the results obtained by both methods at different airports, of which, as an example, there are shown the two above-mentioned methods, it was concluded that, in general, although the texture values measured by the two methods are within a certain range, the obtained by the method of Grease Patch are usually higher than those given by the laser texturometer.

These tests were performed in a total of ten airports, six belonging to average summer temperature zones and four - for hot zones, and all of them within dry rainfall area. The tests were conducted in the period between the months of October and March.

Unlike the different measured object before mentioned, using the volumetric method or the two-dimensional laser texturometer, if using the 3D texturometer, the comparison would be made between the areas of both cases, so could be expected the more reliable results of the comparison study.

6.2. Comparative tests with 3D texturometer.

There were performed a comparative study at two airports, among them, two hot and dry Spanish regions, one was with LB3 slurry surface and the other of asphalt surface, in the months of March and June, respectively, of the same year.

There were used three above mentioned methods: Sand Patch (SP), Grease Patch (GP), and 3D Laser.

In order that the conditions in the three test would be the same, they were performed, consecutively, in the same day in each of the airports.

3D macrotexture was calculated via a digital sand patch model.

The results of each tested point are presented in the graphs of Figures 19 (for the runway with LB3) and 20 (for the porous asphalt concrete) indicating the method corresponding to each line.

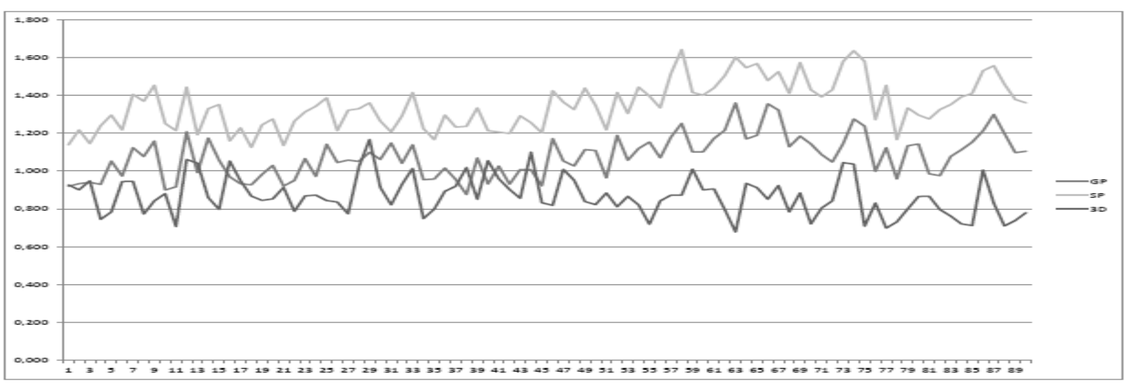


Figure 18. Comparison of specific texture values between Sand Patch (SP), Grease Patch (GP), and 3D laser on runway with LB3 slurry.

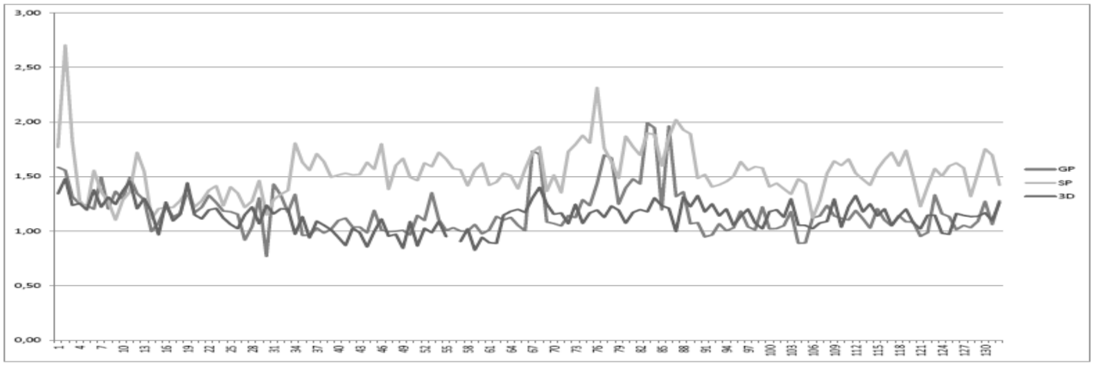


Figure 19. Comparison of specific texture values between Sand Patch (SP), Grease Patch (GP), and 3D Laser on runway with porous asphalt concrete.

From the tests carried out so far have been derived the following correlations due to different factors that must be considered:

- The traditional method with which it is compared : Texturometer 3D gives lower values than the Sand Patch (SP) and the Grease Patch (GP), but they are always closer to this, in other words, to the values obtained always follow this order: 3D < GP < SP .

- The type of surface tested: asphalts (BBTM or SMA type of those used in airports wheel tracks) or slurries as follows.

It was found better correlation between GP and 3D in asphalt rather than in slurry.
It was found better correlation between GP and SP in that slurry rather than in asphalt.

- Traffic: 3D texturometer values have more similarities with those of the Grease Patch in traffic areas of airports (up to 6 m from the runway axis and touchdown areas).

- It is observed, clearly, a lot of scattering in the 3D measurements of the transversal direction, between the center and the border of the wheel track of the airport.
It is seen that the values obtained by the Sand Patch are superior to those of the Grease Patch, probably because of the greater complexity of the extended material, discussed earlier

<u>7. Conclusions.</u>

• The laser system provides a continuous profile of the pavement and offers more representative results by using specific volumetric methods which allow to know the MPD (Mean Profile Depth).The MPD (Mean Profile Depth) is a concept that defines the surface texture.

• The high performance of the computers on which is mounted the laser system is another advantage over traditional methods, because they offer higher speed of processing data and lager area profiles in less period of time.

• However, the fact is that the method of Sand Patch or volumetric, in general, due to its spread use, is still used worldwide as a reference for other techniques, despite the evidence of its unreliability.

• As a result of this study it is proposed the adoption of laser texturometer, preferably 3D, as a method of measuring the surface macrotexture and MPD as a dimension of the parameter. It is still considered that the traditional methods could be useful in certain cases, but with importance of keeping in mind its limitations and putting special care in its execution, as well as taking into account the environmental and surface type in which they occur.

• Finally it is advised always to use in networks surveying, the laser with the same characteristics and to follow the same measuring procedure.

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6. Correlation macro-texture measures taken with the volumetric method and with different laser texturometers, Parra and Yanguas, Civil Engineering, Jan -Feb- Mar 2013.