Evaluation of water superficial runoff in micro surfacing treatment pavement by Digital Image Processing in remote sensing software

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Abstract. The tire-pavement adherence is a major factor to minimize episodes of hydroplaning. Conventional texture assessment methodologies prove to be inefficient and unreliable, due to human intervention in the test. On the other hand, the development of new technologies has provided more agile assessments through techniques such as Digital Image Processing (DIP). In this sense, the present paper has the objective to analyze the superficial runoff of the rainwater with evaluation of the macrotexture of airport pavement through DIP. The field study was carried out at an aerodrome in the state of Ceará, Brazil, and sought correlations between the Sand Patch Test and the DIP methodology using remote sensing software (QGIS). With success rates of more than 70% according to the macrotexture classification.

Keywords: superficial runoff, macrotexture, digital image processing (DIP), software QGIS.

1 Introduction

In Brazil, the occurrence most reported (Santos, Almeida and Peixoto [1] for aeronautical accidents that occurred between 2008 and 2017 was the loss of control on the ground with 24.03% of accidents, and one of the causes of this type of occurrence is the accumulation of water on the runway. This accumulation promotes the occurrence of the phenomenon known as hydroplaning or aquaplaning, which is generated from the presence of contaminating fluid (usually water, ice, and rubber from aircraft tires) that interposes between the tire and the surface, resulting in the loss of aircraft contact with the runway.

A necessary characteristic to avoid hydroplaning is the pavement texture, which is responsible for the tire-pavement adherence and for the expulsion of rainwater. An effective tire-pavement interaction can be achieved through adequate texture and drainage. ANAC [2] regulates tests to control adherence parameters in Brazil. The manual approach is falling out of favor due to its subjectivity, time, and human resources.

Over the years, many researchers, Pidewerbesky et al. [3]; Araújo, Bessa and Castelo Branco, [4]; Puzzo et al., [5]; Mataei et al., [6] have studied deficiencies in traditional methods and advanced in the techniques of evaluation by digital image processing (DIP); however, most of them have restrictions with public access. Because DIP has a disadvantage when the tests and analyzes results needs a human resources and knowledge. Given the above, the general objective of this paper is to analyze the surface runoff of rainwater with an assessment of the macrotexture of different pavements on runways through digital image processing in a public remote sensing software.

2 Literature review

When the tire of an aircraft completely loses contact with the pavement surface due to the presence of water that interposes between the tire and the pavement, it may happen the phenomenon called hydroplaning [7]. Among other factors, macrotexture is linked to the phenomenon of adherence existing between the tire and the pavement, being associated with the drainage time of this same water layer [8]. The macrotexture is a function of the granulometry of the aggregates used in the asphalt mixture and can be classified as fine or coarse.

Many studies have demonstrated the relationship between tire-pavement contact on wet pavement and pavement surface texture characteristics. Ferreira [9], Rodrigues Filho [7], Aps [10], Silva [11], Rodrigues [12] and Leocádio and Frota [13] used conventional tests to highlight the importance of pavement texture characteristics in the safety of airfields and highways and to suggest that the pavement surface be monitored continuously.

With advances in technology and computational power, some systems capable of measuring texture parameters were introduced more quickly. Meanwhile, processes have been developed that capture and analyze images to obtain information from them. In paving, this procedure can be used to analyze texture, defects, among others features.

Many studies presented reveal the applicability of computerized methods in macrotexture analysis. However, the association of wet pavement with macrotexture is little evaluated by such techniques. Puzzo et al. [5] and Mataei et al. [6] were innovative in investigating the behavior of the texture in case of rain in road pavements with DIP. Gonçalves [14] examined asphalt pavements in runways. These studies concluded that it is possible to determine the drainage capacity from the macrotexture analysis, using DIP.

Another case of DIP is the utilization of images that collect geographic information, these images can be later used in a Geographic Information System (GIS) software. Therewith, different elements are presents on the surface through the values assigned to the pixels in each band of the electromagnetic spectrum. Pixels can take different shapes, such as dots or polygons, Silva [11]. QGIS 2.18 with a grass is a GIS software that has tools that allow managing and manipulating the images without coordinates. Therefore, the software QGIS can be used to analyze pavements texture images.

3 Methods

The field research was conducted at the Catuleve Aerodrome, in the city of Aquiraz, in Ceará State, Brazil. This aerodrome is private and has a runway of 720 meters, 18 meters wide and designation of runway thresholds 13 and 31. The runway was initially constructed of Hot Mix Asphalt, built in 2010, and in 2018, underwent reconstruction, in which part of the runway was rehabilitated with Micro surfacing over a length of 300 meters, starting from the 13-runway threshold. The macrotexture and runoff conditions were evaluated along the micro surfacing pavement.

The test procedure, used to conduct the sand patch test (SPT), follows the ABNT [8]. In summary, a known volume of glass microspheres was poured on the pavement in the same location where the images were taken. Specifically, the microspheres fill the grooves on the surface of the asphalt, they are spread on the surface trying to form a circular shape of evenly distributed spheres using a spreader tool. In total, 18 points were evaluated.

The evaluation of runoff by pixel counting method (PCM) proposed in this study is divided into two main phases. Firstly, a photographic survey was carried out based on the technique of Mataei et al. [6], which consisted of the use of a 12-megapixel GoPro HERO7 digital camera. To capture the videos of water runoff, it was necessary to saturate the pavement with 0.5 liters of colored water and washable white paint to better visualize the runoff. The camera was always placed parallel and 20 cm from the surface, capturing 40 seconds of drainage. The procedure was carried out in the morning, between 7:00 am and 11:00 am, to reduce the interference of the sun's rays in the photographs. Secondly, the data are processed and analyzed. The threshold was calculated by an algorithm Otsu method. In the software QGIS 2.18 with grass were used image processing toolboxes to count of white pixels present in the photos. As the images follow the RGB color model (red, green, and blue), in which each pixel of the image is represented by three integer values of intensity from 0 to 255, which correspond to the colors, the Equation 1 was used to leave it in the monochromatic pattern, that is, in gray tones, using the Raster Calculator tool.

$$IM=0{,}299\times R+0{,}587\times G+0{,}114\times B \quad (1)$$

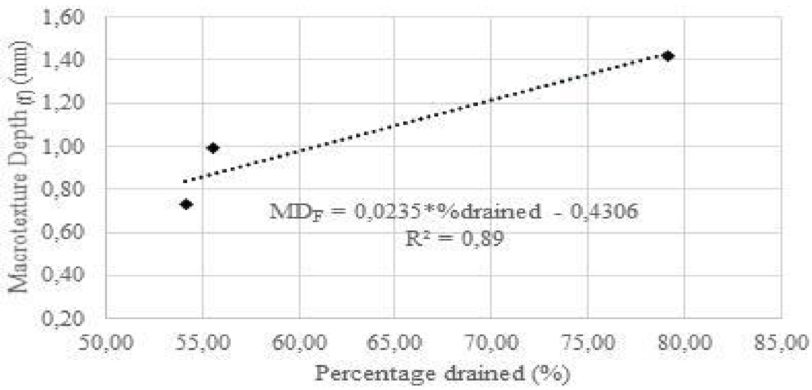
With the binarized image, the average of the gray levels (0-255) of all the pixels below each threshold was calculated, that is, only the pixels with values of 1 in the segmented images, through the Slicer toolbox. To choose an appropriate automated threshold, the Otsu method was applied. Once the threshold intervals were defined, it was possible to count the number of white pixels in the images using the Statistics Raster Pixel Count by Class Break tool.

4 Results and discussion

To create the pixel counting model, the photos were uploaded into a commercial computer remote sensing software. In this study, a free software – QGIS 2.18 with grass – was used. Using the procedure previously described, it is possible to obtain the runoff percentage and the sand patch test value with the correlation equation between the variables. This model is enough to capture the main macrotexture depth of the segments classified as open graded.

The pixel counting method is defined as the number of white pixels that decreases while the liquid flows after 40 seconds. This method applies a threshold on monochromatic photos to segregate white and black pixels. With a threshold of 0.61, the white pixels decrease 59.51%.

In the initial part of the analysis, the assessment was based on arithmetic mean values of the mean values of the macrotexture depth of the SPT (MDF) and percentage drained. A linear regression between PCM and SPT were calculated to evaluate if the drain evaluation is useful for practice. The linear regression (R^2) is equal to 0.89 which indicates the efficiency of the above-presented model. The results are presented in Fig. 2.

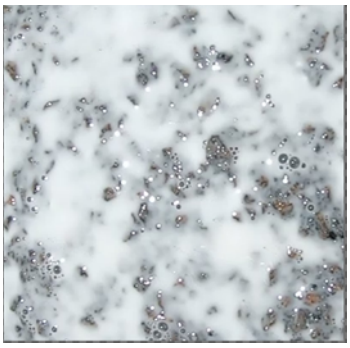
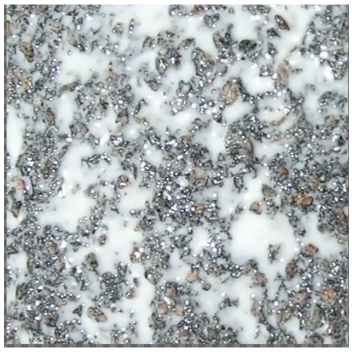
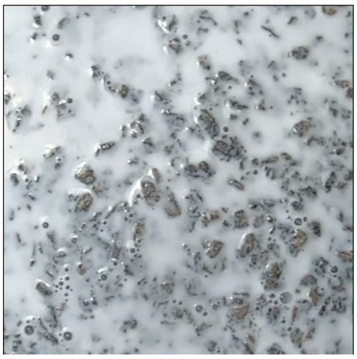
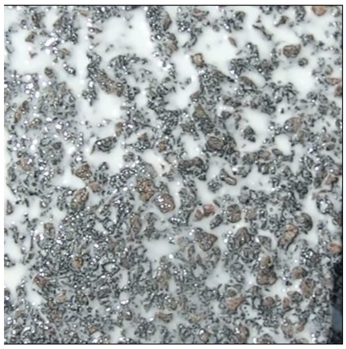


The line of equality equation was applied and then, calculated a model macrotexture depth (MD_M). The model can predict the macrotexture classification in most cases. However, the model could not be satisfactory in open macrotextures. The results are presented in Table 1.

Table 1. Relations between field analyses and model analyses

Percentage drained (%)	MD_F (mm)	Macrotexture classification (field)	MD_M (mm)	Macrotexture classification (model)
54.14	0.73	Mean	0.84	Open
55.54	0.99	Open	0.87	Open
79.12	1.42	Very open	1.43	Very open

In a representative analysis of the DIP, a random point was selected to show the liquid flowing in the micro surfacing pavement. This point has a macrotexture classification as open and texture depth of 0.95 mm. In micro surfacing, it is possible to see the aggregates even when the saturation starts. In the image after saturation, there is accumulation of liquid, but the drained percentage is about 57.6% from the beginning. The open macrotexture helps in faster drainage. Therefore, the liquid cannot saturate the texture pavement at the first moment. The situation is presented in Fig. 2.

Initial Image	Final Image
	
	

5 Conclusions

This work demonstrates the possibilities of a methodology based on the image processing using a remote sensing software to provide pavement texture models for asphalt pavements. The comparison of the Pixel Counting Method (PCM) values calculated using the QGIS software, analyzing water runoff and texture depth, and the values obtained from the sand patch test was performed. The proposed PCM calculated water runoff flows in micro surfacing treatment pavement with an image-based procedure instead of the measured with the sand patch method. As shown, the two indices assume remarkably similar values: the coefficient of determination is 0.89.

The PCM was performed but needs more studies in different macrotexture classification. Therefore, the model could have higher correlations and could do a range classification for a capacity of drainage. Moreover, it is possible to evaluate the macrotexture parameters also from the drainage pavement.

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Authorship statement. The authors hereby confirm that they are the sole liable persons responsible for the authorship of this work, and that all material that has been herein included as part of the present paper is either the property (and authorship) of the authors or has the permission of the owners to be included here.

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