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Measuring skid resistance of hot mix asphalt using the aggregate image measurement system (AIMS)

Victor M.C. Araujo [a], Iuri S. Bessa [b], Verônica T.F. Castelo Branco [a,*]

[a] Universidade Federal do Ceará (UFC), Laboratório de Mecânica dos Pavimentos (LMP), Campus do Pici S/N, Building 703, 60440-554 Fortaleza, CE, Brazil
[b] Universidade de São Paulo (USP), Laboratório de Tecnologia de Pavimentação (LTP), Av. Almeida Prado, Travessa 2, No. 83, 05508-070, Cidade Universitária, São Paulo, SP, Brazil

HIGHLIGHTS

- Different aggregates were evaluated using digital image processing.
- Different HMAs composed by those aggregates were also investigated.
- Aggregates were analyzed in respect to its angularity and surface texture.
- Mixtures were analyzed in respect to texture characteristics.
- Correlations between DIP and conventional HMA texture are not as good as expected.

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ABSTRACT

Pavements need to have adequate structural, geometric and signaling conditions, in order to prevent accidents and to ensure safer transportation. In Brazil, asphalt pavement projects require proper volumetric and structural parameters, where as functional aspects, such as tire–pavement friction, are not always considered in the asphalt mixtures design. One of the most important factors in the tire–pavement friction is the asphalt mixes texture. In this context, the main objective of the present study is to evaluate a method for characterization of asphalt mixtures texture properties using digital image processing (DIP) techniques, demonstrating how these results can be correlated to the results of conventional tests and to the aggregate particles' shape properties, such as angularity and surface texture. For this purpose, three hot mix asphalt (HMA) with different aggregate gradations and composed by aggregates with different shape properties were analyzed. Two HMA used in road pavements were produced, one with aggregate particles in their original form, and the other one with polished aggregate particles. The third mix was a HMA used in airport pavements, produced with non-polished aggregate particles. Besides these three mixes evaluated in the laboratory, four HMA used in the field were analyzed in order to compare the results obtained from the DIP, and the ones obtained using conventional texture and skid resistance tests. The results showed that the correlations between the HMA texture properties obtained using DIP and those obtained through conventional tests are not as good as expected. Moreover, the results indicated that the HMA particle size distribution directly affects its texture characteristics. Regarding the aggregate particles shape properties, it was found that small variations in these properties do not provide major variations in the results of HMA texture obtained by the DIP technique.

1. Introduction

Traffic accidents can be a combination of many factors, including drivers' imprudence and pavements conditions. Accident rate can be reduced if safety improvements are provided by analyzing parameters that affect pavement friction. A main safety criterion for asphalt pavements is the tire–pavement interaction. It is expected that the pavement surface provides safe and comfortable conditions to its users, and this is directly related to adequate surface texture characteristics, which contributes to skid resistance and to surface drainage. The evaluation of hot mix asphalt (HMA) surface texture generally includes the study of micro and macrotexture characteristics. Microtexture is usually related to the aggregate particles characteristics, while macrotexture is related

* Corresponding author.
E-mail addresses: victor.mosca@insttale.com.br (V.M.C. Araujo), iuri@usp.br (I.S. Bessa), veronica@det.ufc.br (V.T.F. Castelo Branco).

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to the aggregate particles arrangement and the interaction with the asphalt binder and the air voids.

The evaluation of texture properties in asphalt pavement surfaces often performed with the sand patch test, the British Pendulum test, and the drainage test. These tests are normally performed in the field after the pavement construction. Several researchers have been trying to develop different methods for the analysis of asphalt pavements surface in respect to its skid resistance, including the use of digital image processing (DIP) techniques. The evaluation of aggregates resistance to polishing and the correlation of this property with the surface texture of asphalt mixes have been proposed and validated [1].

The main objective of this study is to validate a more practical test method used to evaluate aggregates and HMAs in relation to their surface texture characteristics. This paper also aimed to correlate aggregate particles texture to its correspondent HMA macrotexture. A comparison between the results obtained by conventional tests and the aggregate image measurement system (AIMS) for measuring texture is also presented.

2. Skid resistance and surface texture characterization

2.1. Skid resistance

According to Asi [2], skid resistance can be considered as the measure of the resistance of a pavement surface to vehicles sliding and skidding, and it is directly related to the forces developed due to the tire–pavement interaction. An adequate skid resistance might lead to a decrease in the number of highway accidents. Rough pavement surface textures tend to promote better friction between the vehicles tires and the pavement surface.

Several factors can affect pavement surface texture. According to FHWA [3], mix-related parameters such as asphalt binder and air voids contents, voids in the mineral aggregate, and filler to binder ratio highly influence the texture characteristics of an asphalt pavement surface. Aggregate particles characteristics also affect the texture of asphalt mixes. Properties related to aggregate angularity, soundness and resistance to abrasion, polishing and degradation have a major effect on the skid resistance. Change in the asphalt mixes gradation is another factor to be considered when trying to reach an appropriate surface texture value. In general, using a gradation that is not close to the maximum density line tends to increase the surface texture [4].

The international friction index (IFI) was developed as a unified standard value for measuring an asphalt pavement surface texture. This parameter is calculated with the use of at least one friction measurement and one macrotexture measurement [5].

2.2. Surface texture characterization

Many researchers have proposed new methods to characterize HMA surface texture by using faster and more reliable techniques. Sengoz et al. [6] compared results from the conventional sand patch test with the ones obtained through laser scanning analyses. The results provided a correlation between both tests with a R^2 of 0.97. Masad et al. [7] used AIMS combined with skid resistance measurements for field samples and proposed a model to predict IFI as a function of aggregate gradation and its texture characteristics. The Wehner Schulze (WS) test equipment was used by Friel et al. [8] to characterize different HMA, e.g., two stone matrix asphalt (SMA) mixes with different gradations and one hot rolled asphalt (HRA) mix. The same aggregates were used, but the results for friction coefficient for each mix was different, leading to the conclusion that the gradation and the mix type are important factors that influence skid resistance of asphalt pavements.

Wu et al. [9] performed several tests to develop a laboratory procedure for characterizing the skid resistance of different asphalt mixes. After the use of an accelerated polishing device, these authors measured HMA friction resistance and its surface texture through the dynamic friction test (DFT) and the circular texture meter (CTM), respectively. Mixes constituted only by sandstone aggregates led to better friction resistance in comparison to mixtures with limestone. In the other hand, surface texture results indicated that the type of mix evaluated had more influence than the aggregate type used in the mixes. The SMA and the open-graded friction course (OGFC) mixes presented better results in comparison to the HMA.

Rezaei [10] studied the influence of different aggregate sources regarding polishing resistance, by using them in different types of asphalt mixes. The evaluation was done with the use of the Los Angeles abrasion test, the British pendulum test, mean profile depth and AIMS. This author also analyzed the resistance of different types of asphalt mixes to polishing, through sand patch test, British pendulum, CTmeter and DFT tests. These mixes were constituted by the same aggregates studied before. After the results were obtained, the author proposed a model that was able to predict the loss of texture in asphalt mixes throughout their life service, according to their characteristics and the traffic loading.

Hadiwardoyo et al. [11] evaluated the impact of the temperature on the skid resistance of asphalt mixes. These authors produced five asphalt mixes constituted by different percentages of the Buton Natural Asphalt (BNA) additive: 20, 25, 30, 35, and 40%. BNA is an Indonesian material that can be made by refining bitumen rocks, and it can increase the amount of bitumen of asphalt cements (AC). For each mix, six 300 × 300 × 500 mm slab samples were produced, and each of these samples was divided into 15 sections. The sections were tested through the British pendulum test at different temperatures (30, 35, 40, 45, 50, and 55 °C). The results made it possible to develop a model that can predict skid resistance of asphalt mixes based on the pavement temperature and the binder penetration index.

3. Material and methods

3.1. Aggregates and asphalt mixes

This research was divided into two main parts: (i) characterization of aggregate particles and different types of mixes through image processing, and (ii) characterization of field mixes using conventional and image processing tests. For the laboratory study, a phonolitic type aggregate was selected. Two different HMA were designed and reproduced in the laboratory: one asphalt concrete used in highways and one used in airport pavements surface layers. A modified highway HMA, containing the aggregate particles after the Los Angeles abrasion, was also evaluated. Aggregate size distributions for laboratory mixes are shown in Fig. 1.

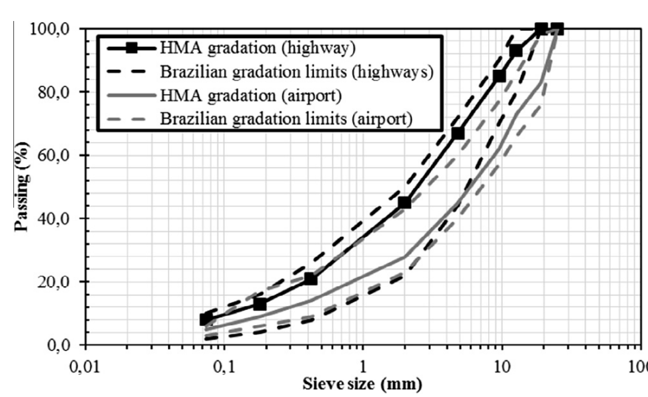

Fig. 1. HMA gradation: laboratory mixes.