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Effect of pavement temperature on the macrotexture of a semidense asphalt surface

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The temperature of the softening point of most bitumen is above 35 °C. Increasing the pavement temperature could change the texture surface of the pavement. The aim of this work is to analyze the influence of the surface temperature on the macrotexture of a semidense asphalt pavement located in an urban area and a semidense asphalt sample in laboratory. The superficial macrotexture profiles at different surface temperatures were measured with the LaserStaticPG-LA²IC and a texture scanner. The mean profile depth (MPD) and the texture spectra have been used for the macrotexture analysis. The analysis of the results shows that increasing pavement temperature does not necessarily leads to a variation in the MPD index but a change of texture level has been observed for temperature superior to 40 °C. Moreover this study has allowed observing the repeatability of the measurements realized with the new LaserStaticPG-LA²IC and ensure another technique of road texture auscultation associating MPD and texture spectrum analysis to be used.

1 Introduction

The Laboratory of Acoustics Applied to Civil Engineering (LA²IC) has proved [1] the influence of surface temperature on tire/road noise. Measurements carried out with the trailer TiresonicMk4-LA²IC following the CPX method showed an increased temperature resulted in a decrease of the tire/road noise level. The low frequency bands of the spectrum of sound emission were the most affected by the variation of the tire/road noise level on semidense asphalt. The low frequency tire/road noise level is related to impact and vibration, and thus linked with the superficial macrotexture. In another study, Anfosso [2] showed the coefficient of correction temperature changes with the type of asphalt pavement. Furthermore, the road surface colour has an effect on temperature pavement [3]. A black bitumen surface might easily become 10 °C warmer in sunshine than a bright cement concrete surface. Other authors have observed a change in pavement texture due to temperature [4]. It has been also hypothesized [5] that due to the increased flexibility of asphalt at higher temperatures, compressive pressure on a rigid aggregate may cause minor local depression into the underlying matrix, resulting in a decreased height of asperity presented by the aggregate.

This study analyzes the influence of pavement temperature on the macrotexture of a semidense asphalt surface. The measurements have been carried out through a summer morning on the same section studied previously by the LA²IC on an acoustical level [1].

2 Experimental setup

2.1 Test section and asphalt surface

The test section selected for this study is an urban track located in a residential area of Ciudad Real (Spain). The test track and the surface texture details are shown in Figure 1. The road surface is constructed with a semidense asphalt surface type S-12 (Spanish denomination). This type of mixture presents 6–12% air voids content, a maximum aggregate size of 20 mm and an average thickness of surface layer of 70 mm. More design specifications for this type of asphalt surface can be found in reference [6]. The road surface was laid 5 years before the texture measurements were performed.



Figure 1: Studied test track S12 and S12 details.

The macrotexture of the road surface is an important parameter related to tire/road noise; hence it has been determined in three different points (A, B and C) along the 200 m test track by a portable laser texture scanner produced by Greenwood, the denominated LaserStaticPG-LA²IC. The whole test section presents a rough texture surface with an average value of mean profile depth (MPD) of 1,360 μ m.

The ageing of the pavements due to weather effects and traffic conditions can cause changes in the surface properties that could have influence on the superficial texture assessment. For this reason, the different measurements have been performed during a summer morning thus minimizing the influence of other variables such as the state of conservation of the road surface. The minimum pavement temperature measured presents is 26 °C and the maximum temperature registered is 57 °C. Measurements have been repeated 3 times at each temperature, on the different three positions of the test section, in order to obtain parameter to characterize the surface.

2.2 Macrotexture measurements

Texture measurements on site have been carried out with the denominated LaserStaticPG-LA²IC which is composed by a laser frame that supports a scanner. The scanner is moved along the laser frame rail on a 63 cm distance (see Fig. 2). A magnetic band in the superior rail assures the number of registered data to be the same on a given distance; the laser registers data every 0.1 mm. This system is not speed dependent and the laser displacement is realized manually. Thus it allows realizing fast measurements.



Figure 2: LaserStaticPG-LA²IC.

From the measured profile, the parameter mean profile depth (MPD) that characterizes the superficial macrotexture of the road can be calculated, following the steps indicated in the first part of the international standard ISO 13473 [7.a].

Also, the texture spectra can be calculated as the fourth part of the standard recommends [7.b]. The texture spectrum informs of the texture level in decibel as a function of the wavelength (or spatial frequency). The profile texture level $L_{tx,m}$ of the fractional octave band m is described by the following Eq. (1):

$$L_{tx,m} = 10 \log \left(\frac{Z_{pm}}{a_{ref}^2} \right) \text{ in dB} \quad (1)$$

With Z_{pm} the power spectral density within the fractional band m , obtain from the result of the Fourier transform of the filtered profile amplitude and a_{ref} as the reference value of the surface profile amplitude ($=10^{-6}$ m).

2.3 Temperature measurements

The evaluation of the pavement temperature was carried out immediately after each measurements of superficial texture profile. The measurements of temperature were taken with a DVM77 infrared thermometer of Velleman Components that allows a measuring range of -30 to 270 °C with an accuracy of 2 °C. Surface temperature measurements were taken at different points along the test section to obtain an average value. The pavement temperature in the section can be different in each reference point, depending on the temperature dissipation made by a light wind; a variation of 3 °C is possible.

3 Results and discussion.

3.1 Repeatability study

A repeatability study has been realized on 3 different reference points A, B and C of the test section. Three followed measurements have been registered, at the same reference point, with the same temperature and the same operator (see Fig. 3).

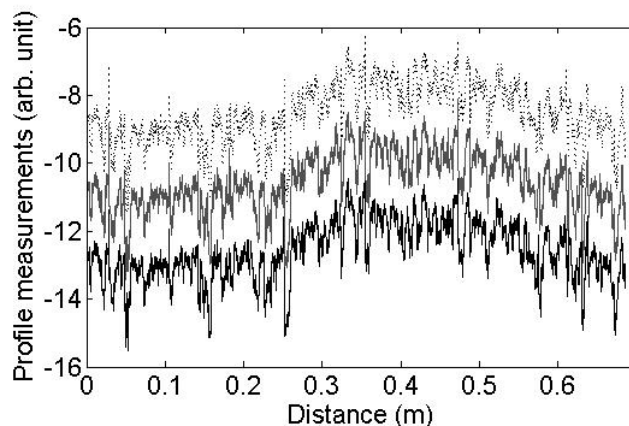


Figure 3: Three followed measurements at the same reference point, with the same temperature and the same operator.

The maximum standard deviation calculated between the three profile measurements is 0,988 mm which corresponds to 17 % of differences between 3 profiles measurements. It is important to note, that once the measured profile is processed through low pass and the profile slope is suppressed (8) to obtain the mean profile depth and the texture spectrum, the errors are reduced. A filtered profile compared to an original profile can be observed on Figure 4.

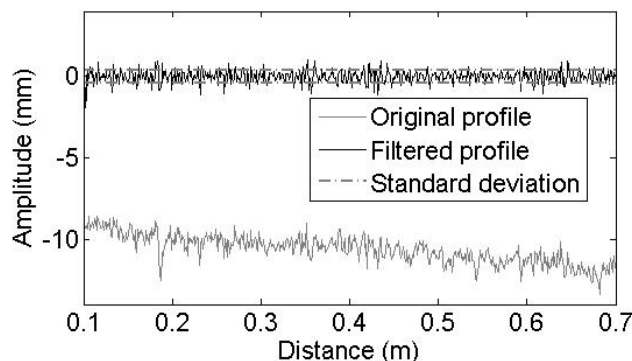


Figure 4: Comparison of an original profile with a filtered profile as a function of the distance.

3.2 Mean Profile Depth

The Figure 5 presents the variation of the MPD parameter as a function of the temperature at the 3 reference points of measurements registered with the LaserStaticPG-LA²IC. It can be observed that the reference point A and C present similar MPD values. The MPD index of the reference point A varies with the MPD index of the reference point C, being MPD_A a little bit higher than MPD_C . It can be noticed that the reference point (B) that presents a different variation of the MPD parameter, is the reference point where measurement are the less repeatable.

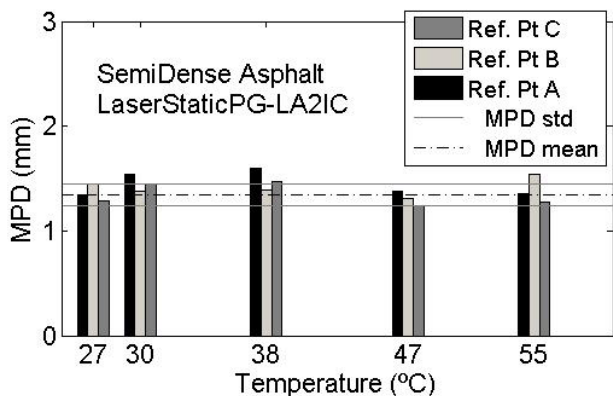


Figure 5: MPD variations as a function of the temperature at the 3 reference points of measurements.

The average mean profile depth of the pavement when the temperature reaches 27 °C is 1,360 mm. It seems the MPD slightly changes with the temperature but it does not follow a predictable evolution. The MPD increases with the temperature below 40 °C and above 40 °C the texture behaviour changes. The MPD changes stay in the standard deviation range. Figure 5 shows the changes of the MPD values with the temperature are reduced and can not be considered dependent from the temperature increase.

3.3 Spectral analysis

In this section the spectral analysis of the texture level (L_T dB) as a function of the wavelength in millimetre is presented (see Fig. 6-7-8). Figure 6 corresponds to the texture spectra calculated from the measurements profile of the reference point A. On figure 6, it can be observed that the texture spectra are very similar for spatial frequency superior to $0,05 \text{ mm}^{-1}$ (corresponding to wavelength inferior to 20 mm). For longer wavelengths, differences between texture spectra as a function of the temperature can be noticed. In this case, the low temperature spectra, between 26 °C and 38 °C, are very similar to each other. Up to 40 °C the texture spectra appears to be different and finally no pattern is identified to predict the texture level as a function of the temperature.

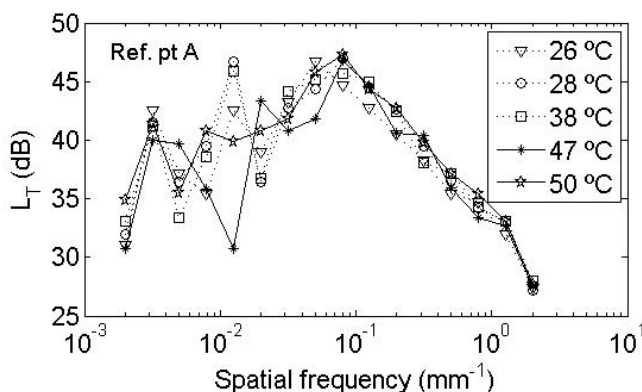


Figure 6: Texture spectrum variation as a function of the temperature in point A.

In the Figure 7, the texture spectrum related to the reference point B is presented. In the same way, below 10 mm (corresponding to a spatial frequency of $0,1 \text{ mm}^{-1}$), the

texture spectra are very similar, in opposition with the calculated spectra for longer wavelengths. For wavelength longer than 10 mm (below $0,1 \text{ mm}^{-1}$ as spatial frequency), it seems that for temperature lower than 40 °C, the texture spectra forms a group different from the texture spectra calculated for higher temperatures. Particularly, the texture spectrum calculated at 55 °C happens to have texture level very different from the other texture spectra at the same spatial frequency.

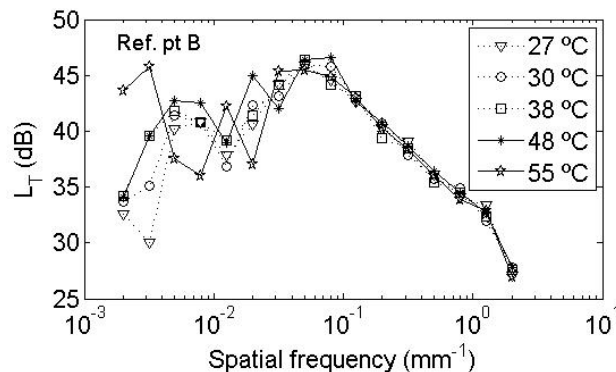


Figure 7: Texture spectrum variation as a function of the temperature in point B.

Figure 8 corresponds to the texture spectrum of the reference point C. Two groups can be observed: a group of low temperature (29-38 °C) with a different behaviour of the high temperature group (47-57 °C). The group of low temperature presents higher texture level (L_T) for spatial frequency $0,05$ y $0,2 \text{ mm}^{-1}$ (wavelength between 5 and 16 mm). And from 16 to 33 mm (spatial frequency between $0,03$ y $0,05 \text{ mm}^{-1}$), the group of low temperature presents lower texture level (around the aggregate size of this semidense asphalt).

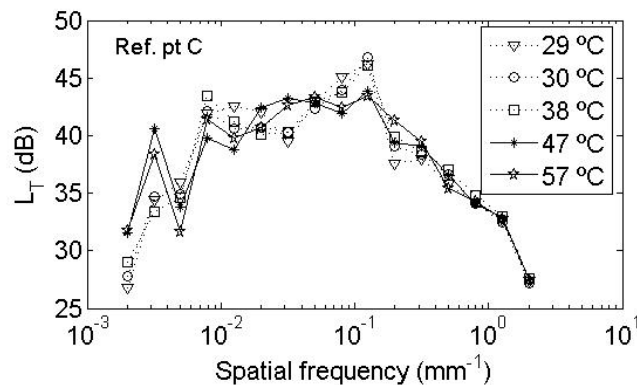


Figure 8: Texture spectrum variation as a function of the temperature in point C.

Hamet says [8] that tire/road noise level of frequency below 1 kHz is related to texture wavelength longer than 10 mm (below $0,1 \text{ mm}^{-1}$). These mechanisms of sound generation are linked mostly with impact and vibration. Thus an increased texture level results in an increase tire/road noise level. In the case of this study, it appears that the changes in the texture level appears for wavelengths longer than 10 mm for temperature superior to 40 °C, temperature which corresponds to the softening point of most bitumen. But the behaviour of the low temperature texture spectra in not the same in the three studied sections. The section B and the section C present similar texture behaviour to each other, different from the texture surface of the section A. The low temperature spectra present a

different behaviour from the high temperature texture spectra pavement in the case of a semi-dense compacted by 5 years of vehicle traffic.

4 Conclusions

In this study, the influence of the pavement temperature on the superficial texture has been assessed with the LaserStaticPG-LA²IC. First of all, the evaluation of the repeatability of the texture profile measurement has been studied, and the results ensure the use of this equipment for this work. In general, the evaluation of measurements carried out on the selected semidense asphalt pavement used as test track, shows that an increase of the surface temperature does not necessary lead to a variation of the macrotexture pavement. The mean profile depth does not seem to be temperature dependent; the MPD index remains constant while the temperature increases. Regarding the texture spectra, the pavement temperature seems to have more influence on longer wavelength above 10 -20 mm up to 40 °C. The little influence of the temperature could be due to the type of studied pavement, the colour and the age. In this sense, the macrotexture pavement of “dark” asphalt with high level of bitumen or with crumb rubber introduced in the bituminous mixture could change more drastically with the bitumen dilatation when the temperature increases. In order to complete the analyses of the influence studied and show the effect of the pavement temperature on the textural level, this test should be reproduced on different types of asphalt pavements, e.g. crumb rubber modified asphalts.

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