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Influence of texture spectra on CPX noise of SMA pavements

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This work presents an experimental study of the influence of road texture profiles on the close proximity (CPX) noise of road surface courses type Stone Mastic Asphalt (SMA), which were used for rehabilitation of a road section. Acoustical field characterization has been performed through the measurement of CPX noise spectra with TiresonicMk4-LA^{2}IC. Road profiles along the test sections have been measured with a static profiling laser device. These profiles have enabled us to obtain, by numerical calculations, results of the Mean Profile Depth (MPD) calculated over a certain profile distance (baseline), and the Texture Profile Level (L_T) as a function of wavelength. One of the aims of this study was to analyze the relationship between texture spectra and the noise emitted by the tire/pavement interaction. In addition, normal incidence sound absorption spectra of compacted SMA sample cores have been measured using the two-microphone impedance tube.

1 Introduction

In the 1960s Stone Mastic Asphalt (SMA) mixtures [1] were designed and put into use in Germany due its high wear resistance. Between 1990 and 2000 SMA mixtures became part of the technical regulations of some European countries [2]. Nowadays this type of mixture is widely used in Europe, however, in Spain it has only been used in specific cases as in the Formula One circuit in Valencia and in some airports.

The aim of this work is to analyze the relationship between texture spectra and the noise emitted by the tire/pavement interaction in an experimental track section extended on road CV-43, near Valencia (Spain). This section is composed of two bituminous mixtures of SMA type.

This work has been developed by the Laboratory of Acoustic Applied to Civil Engineering (LA^{2}IC). To carry out the research several measurement techniques of the LA^{2}IC have been used such as the TiresonicMk4-LA^{2}IC [3,4], the Two Microphone Impedance Measurement Tube and the LaserStaticPG-LA^{2}IC.

2 Characteristics of the test sections

The test area used to study the SMA mixtures is located on the road CV-43 between KP 1+000 and KP 2+200 (See Figure 1). The mixtures analyzed are: SMA 11 3c CF and SMA 16 3c CF. The first one has a length of 700 m while the second one has a length of 300 m. The sections are separated by an underpass, which has not been taken into account due to its differing characteristics. The characteristics of the mixtures studied are shown in the Table 1.

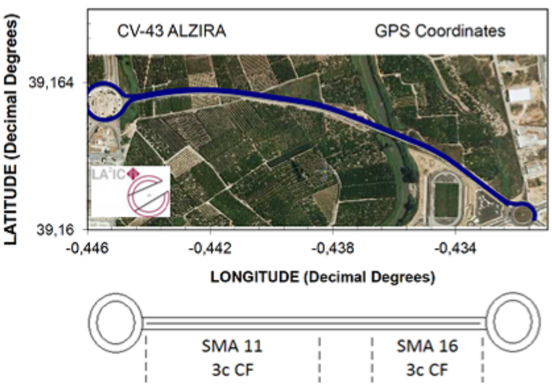

Figure 1. Plan of the test track of the road CV-43 (Valencia), showing the location (GPS coordinates) of the test sections, and a schematic drawing of the mixture's positions.

Table 1: Characteristics of the SMA mixtures.

Mixture	Apparent Density (kg/m^3)	Air void content (%)	Binder content (%)
SMA 16 3c CF	2389	4.8	5.6
SMA 11 3c CF	2350	6.4	5.0

Moreover specimens have been used in order to determine the acoustic absorption of each mixture. The specimens have been taken from the asphalt mixing plant during the construction of the CV-43 experimental road section. A detail of the road surface is shown in Figure 2.

Figure 2. Close up of road surface evaluated in Valencia (Spain).

3 Experimental Set-up

3.1 Tire/road noise measurements

The trailer TiresonicMk4-LA^{2}IC (developed at University of Castilla-La Mancha) was used for the acoustic characterization of the mixtures. The test vehicle and monitoring techniques are based on continuous tire/pavement close proximity road noise [5,6]. The trailer is made up of a semi-anechoic chamber, which isolates tire/pavement sound from the external traffic noise or wind noise. The mean value of the noise level generated in the interaction between tire and road is registered every 0.2 seconds. Close proximity noise emissions from the tire/pavement interaction, rolling at 50 km/h as the reference speed, were analyzed in third octave bands between 200 Hz and 10 kHz. A portable NI compact Rio control and acquisition system with a four channel module and GPS was used to constantly carry out geo-referenced acoustical measurements [7] (Figure 3). Measurements were performed at a constant temperature of 25 ºC during a summer night.

Figure 3. TiresonicMk4-LA^{2}IC showing the semi-anechoic chamber for the close proximity measurements of the acoustic pavement behaviour, and a schematic drawing of the microphone positions.

3.2 Texture measurements

Static texture measurements on the road CV-43 were carried out with the so-called LaserStaticPG-LA^{2}IC, which is composed of a laser frame that supports a scanner. The scanner is moved along the laser frame on a 63 cm rail (Figure 4). A magnetic band in the superior rail assures the number of registered data points is constant along a given distance; the laser registers data every 0.1 mm. The system is not speed dependent and the laser displacement is realized manually.

Figure 4. LaserStaticPG-LA^{2}IC used for the profile measurements of the pavement surfaces.

3.3 Noise absorption measurements

A 4206 Bruel & Kjaer (B & K) impedance tube was employed in order to evaluate the acoustic characteristics of core samples [8]. The impedance tube consists in a 100 mm inner diameter tube with a loudspeaker mounted at one end. The impedance tube used is suitable over an extended frequency range (50 Hz-1.6 kHz). Broadband, stationary random sound waves, which propagated as plane waves, were generated from the noise source of a B & K multi-analyzer Pulse system type 3560 B-T06 with a power amplifier type B & K 2716C.

The asphaltic mixes tested in the impedance tube were taken from the asphalt mixing plant before being laid over the road CV-43. Subsequently, these mixtures were compacted. The samples were covered laterally with a thin film of Teflon to eliminate the air gap between the specimens and the tube. The specimens are shown in Figure 5.

Figure 5. Samples studied. SMA 11 3c CF (Left) and SMA 16 3c CF (Right).

4 Analysis of results and discussion

4.1 Close proximity sound

A study was carried out to evaluate the acoustical behavior of SMA mixtures on the road CV-43 (Figure 1). The aim was to study the influence of road texture profiles on the close proximity (CPX) noise of road surface courses of type Stone Mastic Asphalt (SMA).

Figure 6 shows the values of the L_{CPtr} (dB(A)), registered at the reference speed with the TiresonicMk4-LA^{2}IC and with a tire Pirelli P6000. The test section has been measured four times with similar results, ensuring data-reproducibility.

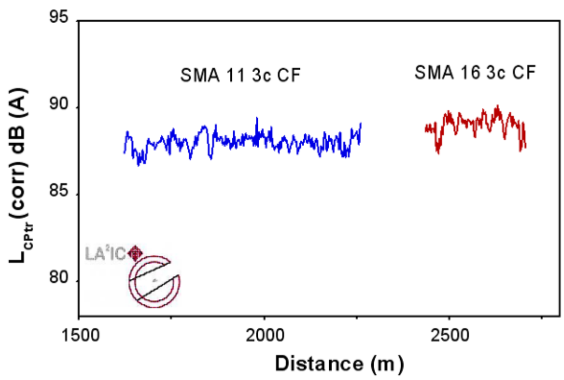

Figure 6. Speed corrected sound level L_{CPtr} measured in close proximity to the tire/pavement contact patch, rolling at 50 km/h for SMA 16 (blue line) and SMA 11 (red line).

The mean values of the close proximity tire/road noise level L_{CPtr}, corrected for temperature at 50 km/h, are 88.4 dB(A) for the mixture SMA 11 and 89.2 dB(A) for the mixture SMA 16. It can be observed in Figure 6 that the sound emission generated by the SMA 16 is slightly higher than the one generated by the SMA 11.

Figure 7 details the sound emission showing the sound spectra for both SMA test section. The section with a larger size of aggregate generates more noise for frequency up to 630 Hz. A low frequency range is linked with the generation of noise by impact and vibration, whereas the higher frequency range (> 1000 Hz) is related to aerodynamics effects (absorption, horn effect…) [9]. The effect of the larger aggregate size could explain the higher SMA16 noise level above 630 Hz.

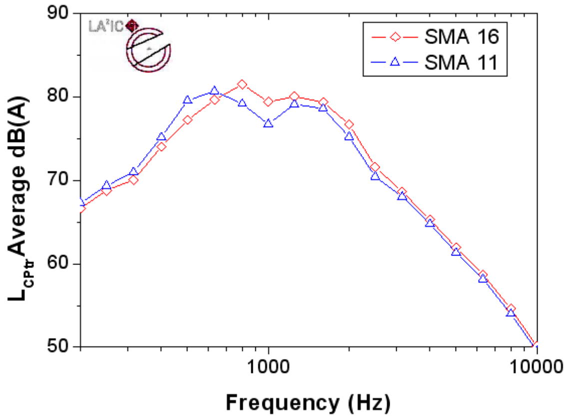

Figure 7. Sound level spectra L_{CPtr} measured in close proximity to the tire/pavement contact patch, rolling at 50 km/h with the reference tire Pirelli P6000.

4.2 Superficial macrotextures

The measurements of superficial macrotexture have been realized with the LaserStaticPG-LA^{2}IC on three points of each test section (see Figure 1). Measurements have been repeated 3 times. From the texture profile, the Mean Profile Depth (MPD) index has been calculated in accordance with the standard procedure [10a]. Figure 8 shows the average variation of the MPD index along the 63 cm measured profile.

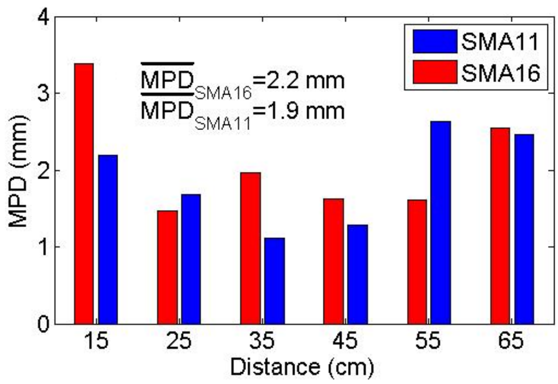

Figure 8. MPD variation of the SMA11 and SMA 16 mixtures.

Although the MPD of the SMA16 is not always higher than the SMA11 MPD, globally the SMA16 presents a higher texture level than the SMA11.

The texture spectra have been calculated following the standard method [10b]. Figure 9 shows the texture spectra of sections with SMA 11 and SMA 16 mixtures. It can be observed that the section with higher texture level is the SMA 16 with larger aggregate size. For wavelength below 7 mm the texture level of both sections is rather similar.

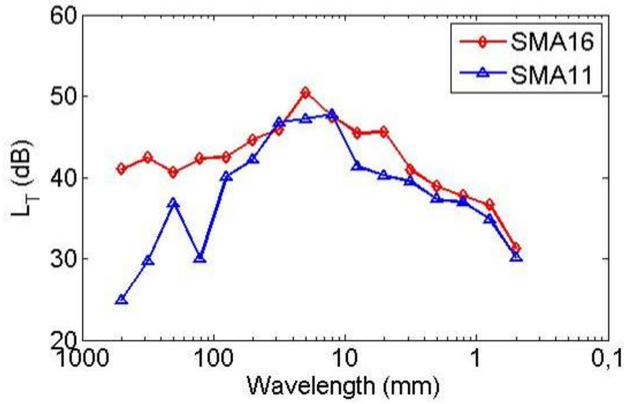

Figure 9. Texture spectra L_T measured with the LaserStaticPG-LA^{2}IC

4.3 Acoustic absorption

The acoustic absorption has been measured on sample cores compacted from the asphalt mixtures taken from the asphalt mixing plant before road laying. Figure 10 shows the sound spectra of the samples studied: one with 11mm maximum aggregate size and the other with 16 mm maximum aggregate size.

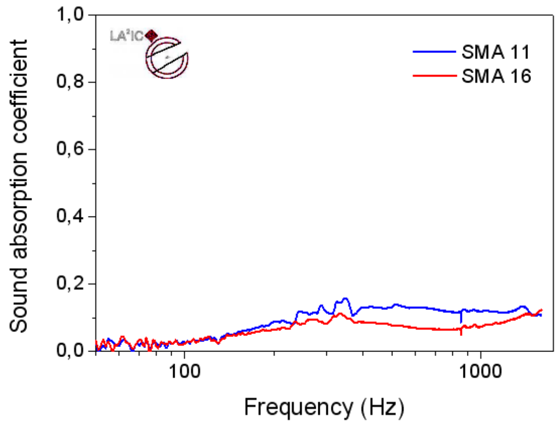

Figure 10. Comparison of normal incidence acoustic absorption spectra of core samples from asphalt mixture types SMA 11 and SMA 16.

The SMA 11 with a slightly higher air void content presents the better acoustic absorption coefficient above 300 Hz. On the whole the sound absorption coefficient is low for both test sections, with no significant differences between the two spectra.

5 Conclusions

The aim of this work was to study the influence of road texture profiles on the close proximity (CPX) noise of road surface courses of the Stone Mastic Asphalt (SMA) type. The acoustic auscultation shows that the SMA16 with larger maximum size of aggregate generates more tire/road noise. The higher emission is principally generated for frequencies higher than 630 Hz. With regard to surface macrotexture, the SMA16 globally presents the higher texture. It seems that noise emission and the mechanisms involved depend on the macrotexture of the surface in this case.

Acknowledgments

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[10] ISO 13473-4 Characterization of pavement texture by use of surface profiles.

a. Part 1: Determination of Mean Profile Depth.

b. Part 4: Spectral analysis surface profile.