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Study of the road surface properties that control the acoustic performance of a rubberised asphalt mixture

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ABSTRACT

Simultaneously with the fact that vehicle industry has been able to lower the noise emission from driving vehicles, tire/pavement noise has become the most significant source of traffic noise. In order to reduce it, low noise surfaces are seen as a practical solution. One of these types of surfaces may be elaborated with bituminous mixtures with crumb tire rubber added to the binder in high content by a wet process. However, the generation mechanisms involved in the tire/pavement sound and the reasons of the noise attenuation achieved with these mixtures are not so clear. This study analyses the different generation mechanisms that take place in the tire/pavement sound generation in these crumb tire rubber pavements. The surface properties of the in-service pavement, which are most important in controlling the acoustic performance (texture, acoustic absorption and dynamic stiffness or mechanical impedance), have been measured for the characterization of a test track constructed with and without crumb tire rubber. After results correlation of these surface characteristics in a pavement with crumb tire rubber added by a wet process, it seems that the parameters of roughness and texture could have a relevant role in the global tire/pavement sound emission, whereas dynamic stiffness influence is relatively minor.

1. Introduction

For passenger vehicles at constant speed, tire/pavement interaction sound contributes significantly to the traffic noise at vehicle speeds greater than 40 km/h, and their generation mechanisms are influenced by pavement surface characteristics, such as sound absorption, texture depth and surface stiffness. Many tire/pavement sound studies are focused on the road texture, however, for a complete road surface characterization with respect to noise emission, the sound absorption and the dynamic stiffness (or mechanical impedance) of the surface should also be measured [1–12].

Low-noise road surfaces are seen as a good option to abate traffic noise. These surfaces include porous asphalt that, in contrast to dense asphalt surfaces, can absorb sound energy [13,14]. Porous road surfaces effect is focused in sound absorption mechanisms; nevertheless, these surfaces are not the only solutions in order to mitigate tire/pavement noise. For example, gap graded pavements with crumb rubber are another option in this respect [15]. Using crumb rubber modified asphalt, the mechanical characteristics of the mixtures could be enhanced: crumb rubber increases pavement life and resistance to rutting and cracking [16]. Crumb rubber could be incorporated to the mixtures by dry and wet processes. In a dry process, crumb rubber is in the mixture replacing some of the solid fraction, as a part of the aggregates. On the other hand, in the wet process, it is added to bitumen before mixing it with the aggregates [17].

LA²IC has been contributing to the understanding of the acoustics and performance of asphalt pavements during the last few years [6,7,9–11,14,15,18]. Now, the aim of this study is to have a better understanding of the sound generation mechanisms of an in-service road pavement with crumb tire rubber, thus contributing to improve their acoustic design. To achieve this objective, characterization measurements of a gap graded mixture with crumb rubber added by wet process were carried out. The pavement characterization has been focused on the parameters that define the texture of the pavements: Mean Profile Depth (MPD) and International Roughness Index (IRI). The sound absorption and dynamic stiffness of the pavement surfaces were also assessed. All these parameters associated with the pavement surface are the most influential in the generation and propagation of tire/pavement noise. Results were correlated with sound generated by the tire/pavement interaction measured in the near field conditions.

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2. Methodology

2.1. Experimental test track

Three asphalt pavement sections located in Ciudad Real, Spain, are studied in this work. Two of them (experimental sections in Fig. 1) have a wearing course of a gap graded mixture (European denomination BBTM11A) containing crumb rubber added by wet process in a percentage of 20% by weight of bitumen (around 1.5% of the total weight of the mix); this is a high content for these types of road pavements. The last section (reference section) was constructed with the same gap graded mixture but without crumb rubber. The binder used for the experimental and reference test sections are respectively a high viscosity modified bitumen (BMAVC Spanish denomination) with crumb rubber and a conventional penetration grade bitumen. The characteristics of the binders employed for this research work are shown in Table 1. Crumb Rubber Modified Binder (CRMB) and conventional binder are quite different according to their characteristics. More detailed material properties of these pavements (grain size of the CRMB gap-graded mix, grain size of the crumb rubber used, etc.) are described elsewhere [15]. The measurement campaign for this work was performed after three years in service.

2.2. Dynamic stiffness

Dynamic stiffness could play an important role in the tire/pavement sound generation, especially for surfaces with the same texture profile but different aggregate and bitumen content, or in surfaces aged by compaction [3,10,18]. Dynamic stiffness measurements have been achieved by means of the Non-Resonant Method, directly on the upper face of the surfaces studied [10,18]. The dynamic stiffness (S) can be expressed in terms of complex numbers between the force (F) and the displacement (d) vectors of a tested surface:

$$S = \frac{F\ [\mathrm{N}]}{d\ [\mathrm{m}]} \tag{1}$$

The experimental set-up was composed of an impedance head that records the movement and force signals, a vibration exciter and an amplifier. Inset of Fig. 2 shows the impedance head and the exciter during a field measurement. A multianalyzer system was used to record the response and to produce the spectra of the dynamic stiffness. Sweep signals between 10 Hz and 7 kHz were used for the mixture excitation.

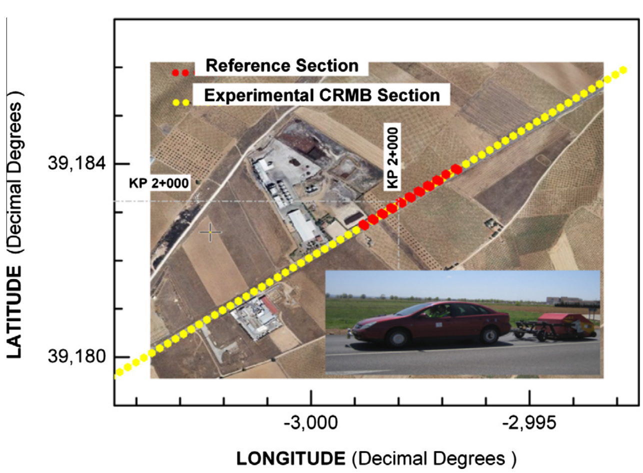

Fig. 1. Location with GPS coordinates of the test track section. Inset displays the equipment for the close proximity and longitudinal profile measurements of the road surface.

Table 1
Pavement's specifications.

	CRMB (experimental)	B 50/70 (reference)
Binder		
Penetration (0.1 mm, 25 °C) EN-1426	19	57
Ring and ball softening point (°C) EN-1427	80	51
Air void content		
	5.7%	6%

2.3. Sound absorption

The acoustic absorption coefficient (α) is defined by the relation between the incident acoustic energy (E_{inc}) and the absorbed acoustic energy (E_{abs}) by the bituminous mixture (without return).

$$\alpha = \frac{E_{abs}}{E_{inc}} \tag{2}$$

The acoustic absorption coefficient value depends on the one hand on the facility of the wave to enter the material pores and on the friction with the internal surface structure, which participates in the sound energy dissipation. Sound absorption coefficients of the mixtures studied have been evaluated by means of an impedance tube. Details of the measurement technique have been given elsewhere [6,11].

2.4. Pavement surface profile

The longitudinal profiles of the studied test sections (experimental and reference) were measured by means of the so-called LaserDynamicPG-LA^{2}IC; a high-speed profiling laser device which allows measuring profiles of the surface course. The characteristics of this equipment are described elsewhere [15].

To characterize the surface texture of the sections studied, different parameters were used. The Mean Profile Depth (MPD) [22] was used to characterize the pavement macrotexture, whereas the International Roughness Index (IRI) [22] was used to characterize the pavement megatexture and roughness. The macrotexture corresponds to texture wavelength range from 0.5 mm to 50 mm, whereas the megatexture and roughness corresponds to texture wavelength above 50 mm up to 500 mm. The MPD influences

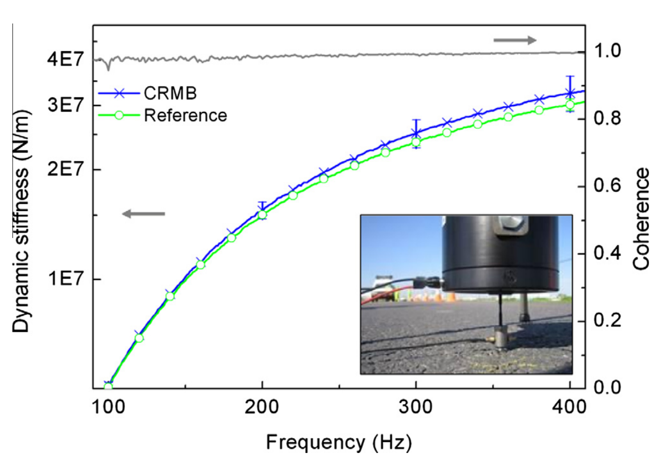

Fig. 2. Dynamic stiffness measured on the pavement without CRMB (reference) and with CRMB (experimental section). An example of the coherence function is also shown.