Dynamic stiffness assessment of rubberized bituminous mixtures

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Abstract

The different properties of pavements influence the generation of rolling noise produced by the interaction between tire and pavement. Currently, many researchers are working on the achievement of silent pavements.

One of the variables that may be relevant in reducing noise generation is, in addition to the pavements texture, the dynamic stiffness. This property of pavements is closely related to the composition of the wearing courses. In this project, different Stone Mastic Asphalt (SMA) mixtures, with a different content of crumb rubber, have been studied.

The scope of this research is to evaluate the variation that occurs in dynamic stiffness as a consequence of the different content of crumb rubber. Results show that there could be a relation between the composition of the pavements and the dynamic stiffness. For certain frequencies, it is observed that, as the crumb rubber content increases, the dynamic stiffness decreases. This fact would translate into a decrease in rolling noise, which would improve the living conditions of the society close to the tracks, which suffers the undesirable effects of the acoustic pollution.

1. Introduction

The noise generated by the rolling is an issue that causes concern in the road environment. In order to mitigate it, different strategies can be considered focused on the study of the mechanisms of noise generation itself.

Dynamic stiffness is one of the factors that contribute to the greater or lesser generation of noise. In recent decades, experimentation has begun with the use of certain special components in asphalt mixtures, such as polymers or crumb rubber, which could have the ability to reduce noise levels. This study will focus on the dynamic stiffness of different reference mixtures with different crumb rubber content. The use of this recycled material, being more flexible, could reduce the stiffness of the pavement and, consequently, the noise generated by the interaction between the tire and the pavement would be lower.
No less relevant in relation to noise reduction is texture. Those pavements with small aggregation sizes will have a smoother texture and, consequently, will produce less noise against impacts and vibrations.
However, the above variables, even though they are the main ones in this study, are not the only ones that have an influence on rolling noise. Other influencing factors to be mentioned are the state of aggregation of the mixtures, the temperature, the bituminous mixture itself or the absorption.

2. Mixtures studied

In this work, asphalt mixtures of the SMA 8 (Stone Mastic Asphalt) type have been studied. Different samples of SMA, attending to their different content in crumb rubber, were tested.

The different reference mixtures were tested by packages of four samples with the same dimensions and characteristics. Five different types of mixtures have been studied, whose content in crumb rubber is detailed in Table 1.

Mixture	% of Crumb Rubber
Reference 1	0.3
Reference 2	0.5
Reference 3	1
Reference 4	1.5
Reference 5	2

Table 1 - Crumb rubber content of the reference mixtures.

The aim of this study is to analyze the existing relation, if any, between the dynamic stiffness of the test mixtures and the different content of crumb rubber.

Likewise, and in a complementary way for the surface characterization of these mixtures, the texture of each of them has been analyzed.

3. Methodology

The characterization carried out on the SMA mixtures has consisted of conducting dynamic stiffness and texture tests using the following pavement surface characterization equipment: the vibration exciter, for measuring the dynamic stiffness; and a laser profilometer, for the texture, respectively.

3.1. Experimental set up of the dynamic stiffness

The dynamic stiffness measurements have been carried out in the laboratory, on samples and in accordance with the Non-Resonant method.

The experimental methodology used to measure the dynamic stiffness is composed of a vibration exciter, commonly called "shaker", and an impedance head that is in contact with the upper face of the mixture, on which the measurements are made. The contact between the head and the sample is made by means of a 14 mm circular plate fixed to the surface.

This device measures the applied force and the displacement produced on the sample surface. The force and motion signals are recorded by a multi-analyzer equipment and, by means of the Fast Fourier Transform (FFT), the dynamic stiffness spectra are reproduced. Said measure of dynamic stiffness will indicate the ability of the mixture to resist movement when a certain force is applied to it.

To carry out the dynamic stiffness tests, the samples have been placed on a concrete floor and, in order to avoid undesirable vibrations during the tests, they have been placed on a thin layer of plaster.

Figure 1 - Arrangement of the series of samples to be tested.

The signal generated by the vibration exciter in the measurements has been a random signal. With this method, the dynamic stiffness spectra of each individual sample between 1 Hz and 6 kHz have been represented. Within this interval of frequencies, the values of dynamic stiffness have been selected, from the mean spectrum resulting from each type of mixture to be studied, for the discrete frequencies of 400 Hz. Considering these values, it will be observed if there is any trend between series with different crumb rubber content, in relation to dynamic stiffness.

An example of the dynamic stiffness spectra of the reference series 2 specimens is shown below (Figure 2), along with the mean spectrum resulting from them. The shape of the resulting spectra in the rest of the series is similar, only varying the range of values of the dynamic stiffness spectrum.

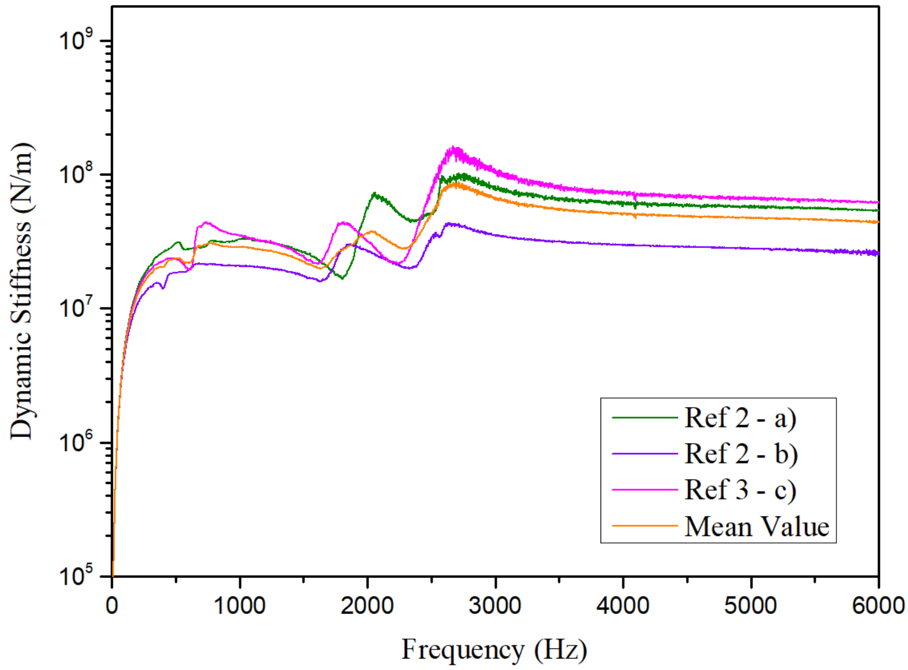

Figure 2 - Stiffness spectrum of the samples of reference two and mean stiffness spectrum.

It should be noted that, with the methodology used, an area where resonance occurs, between 1500 and 2500 Hz, stands out in the spectrum. This phenomenon is due to the configuration of the measurement system and therefore, when comparing the different mixtures, we will avoid doing so with the values of dynamic stiffness measured in the range of these frequencies.

3.2. Experimental set up of the texture

The texture measurements have been carried out through a laser profilometer.

The scanner is a separate unit that scans the surface of the material. To do this, it performs multiple two-dimensional scans, in order to represent a three-dimensional image of the surface. This equipment can scan pavement surfaces up to 75mm x 100 mm with a maximum cross-sectional resolution of up to 1200 lines. From the recorded surface profile, the mean profile depth (MPD-Mean Profile Depth) has been calculated.

The MPD is calculated from the texture profiles obtained with the laser profilometer.

In the tests carried out on the SMA mixtures, an area of 60 x 60 mm was scanned under the scanner, with a transverse resolution of 100 lines.

4. Experimental results and discussion

Measurements have been carried out to evaluate the differences existing with the addition of crumb rubber in dynamic stiffness.
With the dynamic stiffness measurements, a dynamic stiffness spectrum is obtained for each tested sample and, from them, the average spectrum with which we will work to compare the different reference series is calculated. In the Figure 3, the mean spectrum of the reference series under study can be observed.

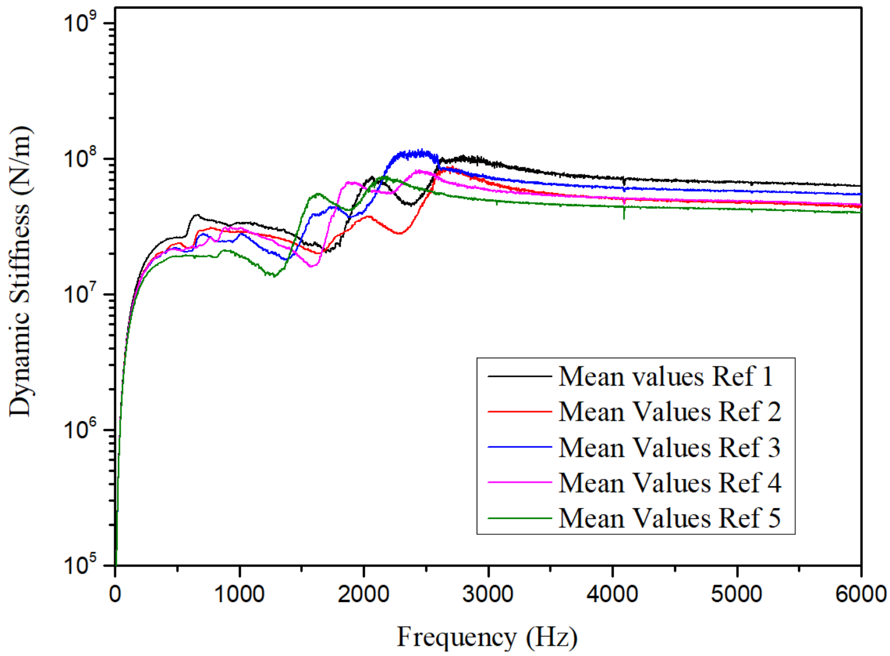

Figure 3 - Representation of the mean spectrum of the reference series.

From these mean spectra, the dynamic stiffness values have been selected for a frequency of 400 Hz. Knowing these dynamic stiffness values and their standard deviation, the results have been analyzed.

In accordance with other studies [1], the mean value of the dynamic stiffness at 400 Hz has been selected to compare the different bituminous mixtures. In addition, dynamic stiffness may influence tire/road noise in this frequency range.

On the other hand, using the present methodology, the results obtained for low frequencies (< 200 Hz) are not clear, since the standard deviation in the data is very high. The location of the frequency of 400 Hz is outside the resonance zone that characterizes the dynamic stiffness spectra, so we consider that it is the most appropriate value to characterize the behavior of the dynamic stiffness of the mixtures.

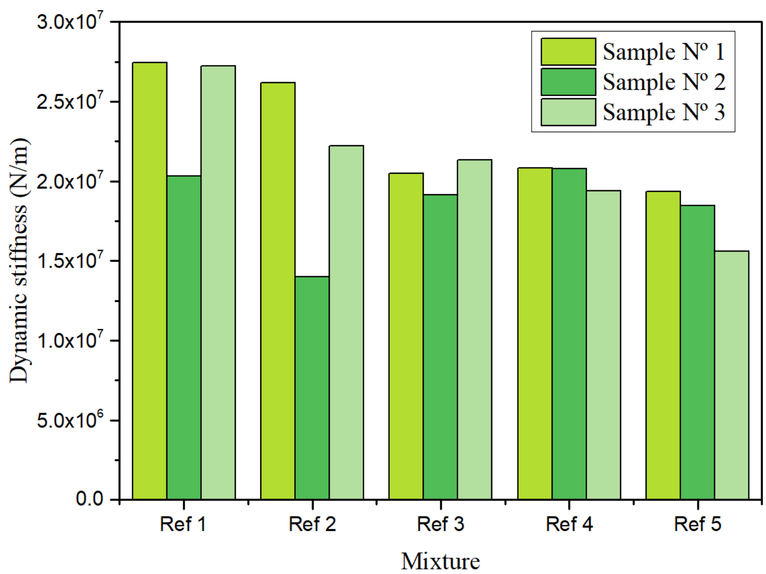

Figure 4 - Dynamic stiffness values obtained in the individual samples at 400 Hz.

Taking into account the mean values resulting at the frequency of 400 Hz for the different reference mixtures, the graph of the following figure (Figure 5) is obtained, which shows the mean value cited and the standard deviation of the results obtained from the measurements in different samples.

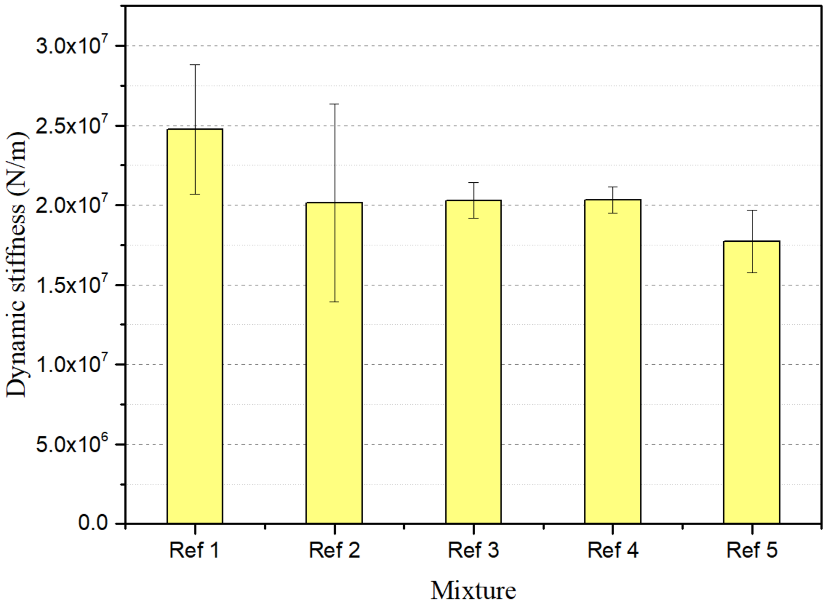

Figure 5 - Graphic of mean values of dynamic stiffness and standard deviation for the reference series at 400 Hz.

Dynamic stiffness (N/m x 10^7)					
400 Hz	Sample 1	Sample 2	Sample 3	Mean Value	Standard Deviation
Reference 1	2.74	2.03	2.72	2.48	4.05
Reference 2	2.62	1.40	2.22	2.01	6.19
Reference 3	2.04	1.91	2.13	2.03	1.10
Reference 4	2.08	2.08	1.93	2.03	0.80
Reference 5	1.93	1.84	1.56	1.77	1.97

Table 2 - Mean values of dynamic stiffness and standard deviation for the reference series at 400 Hz.

The results show a tendency to decrease the dynamic stiffness when the crumb rubber content is increased. This fact could represent a great advance in the achievement of the reduction of rolling noise, since this is related to the dynamic stiffness of the pavements.

There are multiple investigations about the use of recycled rubber in SMA mixtures, where de addition of crumb rubber has resulted in less noise [3][4].

5. Conclusions

Dynamic stiffness is one of the characteristics of pavements related to the amplification or reduction of rolling noise. Therefore, its study is important to characterize the noise generated by the contact between the tire and the road on different pavements.

This work has focused on studying the dynamic stiffness of different asphalt mixtures with different crumb rubber content. In view of the results, it could be that adding crumb rubber to bituminous mixtures may result in a decrease in dynamic stiffness values.

Taking into account the problems of safety and durability in our days, the key will be to find a balance between reducing rolling noise and maintaining sufficiently safe and durable pavements [2].

Ultimately, the controlled addition of crumb rubber in the manufacturing process can have positive effects on reducing rolling noise.

As a complement to the mitigation of noise levels, it is important to characterize the texture of the pavements. Depending on the state of aggregation of its components, they will contribute to a greater or lower extent to noise mitigation.

6. Acknowledgements

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