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IN-SITU EVALUATION OF TYRE/ROAD NOISE OF A PAVEMENT BASED ON FOOTWEAR WASTE

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ABSTRACT

The noise emission generated by road traffic is one of the main noise sources in urban and interurban environments. A variety of noise sources are found in a driving vehicle, where tyre/road noise becomes a relevant one, even in the case of electric vehicles. Nowadays, much work is focused on the development of road surfaces with sound-absorbing properties, such as work based on the development of poroelastic road surfaces (PERS), that may contribute to the improvement of road noise levels. In that sense, the present article presents a preliminary study exploring the sound-absorbing capabilities of a pavement made using the polymeric fraction of post-consumer shoe waste. The tests have been carried out in-situ on a prototype paved area using an acoustic camera, and the results are compared with those obtained when circulating on a dense asphalt.

Keywords: *Recycled material, tyre/road noise, shoe waste*

1. INTRODUCTION

In the last years, the automotive industry invested significant resources in reducing vehicle outside noise, giving as a result the currently quiet vehicles. Since mechanical noise source has been significantly reduced in all speed conditions, Tyre/road noise has become vehicle's main noise source [1]. The use of a road surface made of 'Poroelastic Asphalt Mixtures material' is presented as a solution capable of reducing the levels emitted by tyre/road interaction [2]. Successful proposals for these materials based on recycled tyre rubber [3], other materials from recycled vehicles [4], as well as general waste material [5] can be found in the literature.

On the other hand, end-of-life management of footwear represents one of the main environmental challenges for the textile and footwear industry. According to the European Recycling Industries' Confederation [6], more than 95% of post-consumer footwear in Europe ends up in landfills or incinerated, due to its compositional complexity and the lack of specific collection and treatment infrastructures. This problem is aggravated by the increasing volume of production: in Spain, more than 83 million pairs of shoes were manufactured in 2023 [7]. The literature shows how materials from used footwear and manufacturing processes can be utilised for different applications using different methods [8]. EVA material is widely used to manufacture soles and midsoles for footwear. It is estimated that EVA accounts for around 14% of the waste generated from used footwear [9]. Chemical treatments can be used to produce absorbent materials for the removal of pollutants in water [10, 11]. This material has also been studied as a filler in cement mixtures [9] and asphalts [12]. Fibres obtained from recycled leather have been used as reinforcement in rubber matrices [13], with some studies finding that the inclusion of leather chips improves mechanical properties such as tensile strength, elongation at break and increases the crosslink density of rubber blends [14]. Leather has also been used as a reinforcement for polymers such as ABS [15]. The influence on the mechanical properties of asphalt has been studied with the inclusion of leather and rubber

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from footwear [16] as well as the addition of polyurethane, which can be added from used footwear [17].

With the aim of offering a sustainable solution in line with the Ecodesign Regulation for Sustainable Products (ESPR) and the EU Circular Economy Strategy, INESCOP*[1] has developed a technology for the mechanical recycling of post-consumer footwear, capable of recovering materials currently considered waste, without the need for prior separation of components.

The process allows for the recovery of differentiated fractions such as ferrous and non-ferrous metals, textile fibres, foams, leather and, especially, high density polymers, which can account for up to 60% of the total weight of the footwear, mainly from soles. Mechanical recycling in a single pass makes it possible to obtain a mixture of high-density polymers (SBR, SBS, PU, TPU and PVC), free of impurities, which, although they present limitations for direct reintegration into footwear, are ideal for technical applications with high added value, such as safety flooring for playgrounds, continuous flooring for bicycle lanes or urban paths, drainage surfaces and filtering flooring for green areas, impact absorption systems in sports facilities and urban furniture.

The aim of this research is to establish previous evidence on the acoustic applications of this material by using as pavements for road traffic and transit routes.

2. METHODOLOGY

2.1 Method of manufacturing the material and its characteristics

The material can be installed as a prefabricated tile or in situ as a continuous paving. In this study, it has been applied manually on an experimental surface, through the following stages:

1. Collection of post-consumer footwear. Complete footwear, without previous classification, from social and waste management entities.

2. Shredding and physical separation. Mechanical fragmentation without distinction of components, followed by separation by density, sieving and magnetic extraction to isolate the polymer fraction (initial granulometry: 5-6 mm).

3. Polymer conditioning. Secondary crushing (up to 2-3 mm), encapsulation and pigmentation for reducing porosity, improving internal cohesion, and uniformity of colour and aesthetic finish.

4. Primer application. Preparation of the base with adhesive primer, ensuring surface cleanliness.

5. Cold bonding. Bonding with two-component polyurethane resins in glueblender system. Maximum resin proportion: 12 % by weight. Possibility of adding mineral fillers for structural reinforcement.

6. Application and curing. Manual spreading with a trowel on a clean and even surface, curing at room temperature (20-25 °C, RH 40-60 %) for 24-48 hours.

As a result of this process and from a flat sample, the properties listed in table 1 have been evaluated.

Table 1. Technical characterisation of the material

Property	Estimated value	Test method
Bulk density	0,75 – 0,85 g/cm³	UNE-EN ISO 845
Hardness (Shore A)	65 – 75	UNE-EN ISO 868
Tear strength	> 5 N/mm	UNE-EN ISO 34-1
Estimated composition	81% polymeric mix/7% mineral filler + 12% resin	

2.2 Acoustic testing methodology

The equipment used for the tests consists of a vehicle with a diesel engine (Ford Focus model), as well as an acoustic camera as measuring instrumentation. The acoustic camera is a microphone system that allows sound fields and acoustic parameters to be displayed in real time. The model used is the Array Ring48 AC Pro, with 48 microphones in a circular array arrangement. It has a video camera in the centre of the array which allows the sound field to be displayed superimposed on the filmed digital image.

The circulation tests were conducted at a speed of 15 km/h. When this speed was reached, the vehicle's engine was disconnected, driving with the transmission in neutral, simulating Coast-By test conditions. The tests were carried out in two different locations. At the facilities of the Miguel Hernández University of Elche on conventional asphalt and at the Inescop facilities on a surface obtained from the processing of footwear waste. Both locations had a road closed to traffic. During the tests, the acoustic camera was placed in line with the traffic lane, at a height of 1.2 m and

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at a distance of 4 m from the centre of the lane, see Figure 1.

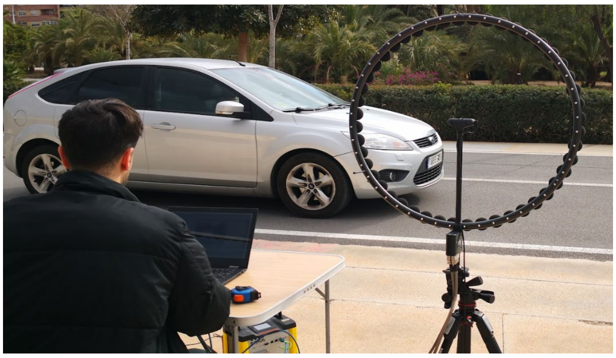

Figure 1. Testing Set-up.

Both acquisition and post-processing were performed using Noise Image software. After recording the acoustic time signal, a time window has to be selected for the software to generate the corresponding photograph by combining the information from all the microphones in the array. In this work, a time window of 0.125 s has been set. The acoustic photographs are generated to cover the contribution of the desired frequency range, such as the full audible spectrum or the 1000 Hz octave band.

3. RESULTS

The following are some of the sound pressure levels recorded by the acoustic camera in the whole frequency spectrum after the tests carried out using a conventional asphalt (Figure 2) and a surface composed of a layer of recycled material (Figure 3). The tests were developed by using the same vehicle circulating under the same operating conditions and speed.

Figure 2. Broad band SPL (dB), conventional surface

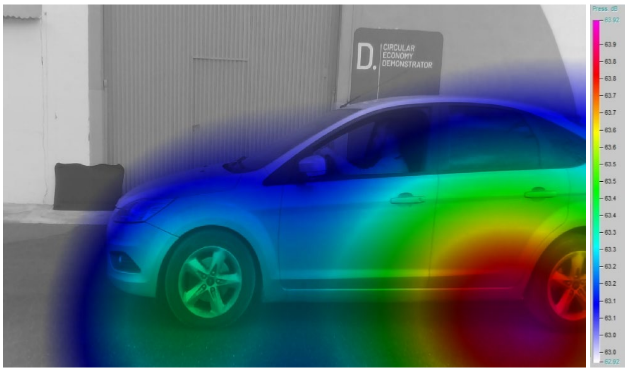

Figure 3. Broad band SPL (dB), footwear waste surface

Both figures locate the sound sources in the rolling of the front and rear tyres. An overall analysis of the results shows a difference in levels of more than 4 dB between the recordings taken with conventional asphalt and the material obtained from footwear waste.

Figure 4. 1 KHz band SPL (dB), conventional surface

Figure 5. 1 KHz band SPL (dB), footwear waste surface

In order to analyze the frequency behavior of the interaction between tyre and road, the results were analyzed for specific frequency values. Figures 4 and 5 show these results for the 1,000 Hz frequency band.

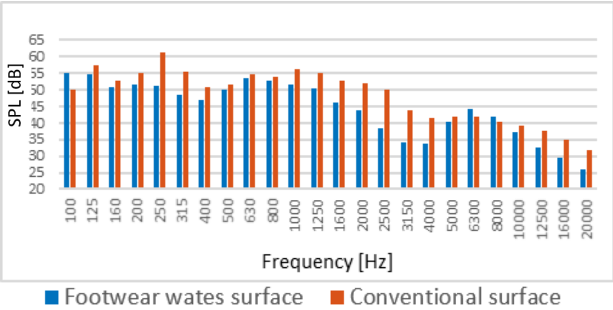

Figure 6. Frequency spectrum comparison

Finally, an overall analysis of the equivalent sound pressure levels at the center point of the microphone array in third octave bands was performed for both test conditions. As shown in the comparative results, Figure 6, the levels taken when the vehicle was driving on the proposed material are lower in the frequency bands between 200 and 400 Hz, and significantly lower in the band between 1,000 and 4,000 Hz.

4. CONCLUSIONS

The following conclusions can be drawn from the obtained results:

- The use of material obtained from shoe recycling shows indications of a sensitive reduction of the sound levels caused by the tyre/road interaction.
- A preliminary frequency analysis shows that the most significant reduction occurs in the frequency band characteristic of rolling noise.
- Further tests are being developed to advance the sound characterization process of these sustainable materials.

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