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STUDY OF SOUND ABSORPTION PROPERTIES OF MULTILAYER PANELS MADE FROM GROUND TYRE RUBBERS

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Abstract— Our paper is focused in characterizing multilayer acoustic panels made from recycled tyre rubbers (GTR's) in order to determine the sound absorption properties of these new materials for different applications such as sound barriers. This waste is currently used as modifier of asphalt, sport surfaces, molded and calendered products. Two types of products can be obtained from the waste of the tyres: fibers and rubbers. Multilayer panels of thickness 10 mm and 20 mm have been made for a three layer disposition: rubber-fiber-rubber. Then, the standing wave tube method has been used to determine the sound absorption in these materials. Rubbers are used in two different granulometries: 0,7 mm and 2,2-4 mm. The results show that multilayer panels made of 2,2-4 mm granulometry present a higher acoustic absorption in the studied frequency range (400-3500 Hz).

Keywords**—**sound absorption, ground tyre rubbers

I. INTRODUCTION

THE problem of the waste of tyres is increasing due to the growth in population. Because of that, countries have to implement policies for managing this waste. In the case of Spain, of the more than 625000 tonnes managed during the period 2006-2009, SIGNUS [1] allocated 63% to material recovery and 28% to energy recovery. Re-use accounted for 9%. Basically two types of products can be obtained from the waste of the tyres: fibers and rubbers. This waste is currently used as a modifier of asphalt, sport surfaces, molded and calendered products.

First of all, it is conducted a granulometric study of the waste to obtain two particle sizes: one size of 0,7 mm and the other 2,2-4 mm. The construction of multilayer panels (rubber-fiber-rubber) has been done sintering the three layers in three stages in a compression moulding machine. Varying the percentage of fiber and the granulometry in different proportions [2]-[5], the effect on the sound absorption properties is studied.

Then some samples are prepared and tested in the acoustic impedance tube in the frequency range from 400 Hz to 3500 Hz. It is a rigid-walled tube of constant circular cross section made of methacrylate with a sound source and two microphones. The standing wave tube method follows the standard ISO 10534-2 (Determination of sound absorption coefficient and acoustic impedance in impedance tubes. Part 2: Transfer-function method) [6], that is used for the determination of the sound absorption coefficient and acoustic impedance in porous and fibrous materials.

II. MATERIALS

A. Ground Tyre Rubbers (GTR)

The waste to be used in this study comes from crushing tyres of vehicles. Generally, this product is provided by sizes defined by the retention of particles in the sieve. Depending on whether it is a mechanic or cryogenic crushed, the surface of the particles vary and affect the adhesion process. For this reason it is needed a granulometric and morphological analysis of the particles to analyse the composition and volume of each one of the provided samples.

Another component of the tyres of vehicles is the fiber or "fluff". This product is supplied by volume. One of the most important factors of the fiber is the method used to obtain it. If it is a mechanical crushed, the fiber is more contaminated with rubber dust.

In this study, there are samples with 0,7 mm particle size and samples with 2,2 to 4 mm particle size.

B. Sintering Process

Sintering is a process used to make objects from powders based on atomic diffusion. It is a method of transformation through the application of pressure and temperature in an object; in this case a sheet of waste tyre. Conditions of sintering are 50 bar for compression in the case of the residue of 0,7 mm particle size, and 80 bar of compression for the particle size between 2,2 and 4 mm; in both cases the temperature is 200 °C, since at this temperature the best mechanical characteristics in the waste tyre are achieved.

III. EXPERIMENTAL TECHNIQUE

A. Samples

First of all, a granulometric study of the particles of rubber from tyres is carried out by the vibratory machine CISA ® SIEVE SHAKER model RP09 for a 300 g sample of residue.

Table 1 shows the series of sieves used for 0,7 mm and 2,2-4 mm particle sizes.

Table 1. Sieves.

Sample	Sieves (µm)							
< 0,7 mm	63	125	180	250	425	500	600	850
2.2 – 4 mm	63	850	1000	1250	2000	2360	4000	8000

Once the granulometric study has been conducted, another study for the compression ratio of the particles is carried out. A universal tension machine ELIB 30 (S.A.E. Ibertest Madrid) is used for this test. The force cell used in these tests is 50 kN and the scroll speed is 5 mm/min.

Fig. 1 shows the morphology of some panels: a) rubber panel, 0,7 mm granulometry, b) rubber panel, 2,2-4 mm granulometry c) fiber panel and d) compacted panel with rubber and fiber.

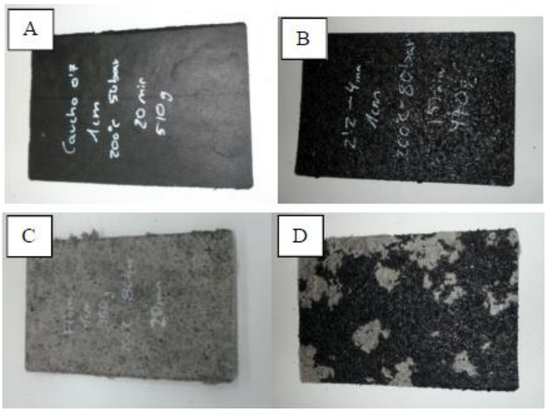

Fig. 1. Morphology of some panels.

Table 2 shows the thicknesses of every layer of the samples, both of 10 mm and 20 mm.

Table 2. Multilayer samples.

10 mm THICKNESS SAMPLE RUBBER-FIBER-RUBBER	20 mm THICKNESS SAMPLE RUBBER-FIBER-RUBBER
4 mm – 2 mm – 4 mm	8 mm – 4 mm – 8 mm
3 mm – 4 mm – 3 mm	6 mm – 8 mm – 6 mm
2 mm – 6 mm- 2 mm	4 mm – 12 mm- 4 mm

B. Acoustic Characterization

There are different methods for measuring the acoustic properties in materials. Some methods need the use of a reverberation chamber, such as the one described in the standard ISO 354:2003 [7]. Other methods determine the acoustic characteristics by means of a standing wave tube, such as the one described in the standard ISO 10534-2 (Determination of sound absorption coefficient and impedance in impedance tubes. Part 2: Transfer-function method).

The method based on the standing wave tube for measuring the sound absorption coefficient in porous and fibrous materials is one of the most important techniques in the acoustic materials characterization [8]-[11]. According to the standard ISO 10534-2, the device for measuring the sound absorption coefficient is shown in Fig. 2.

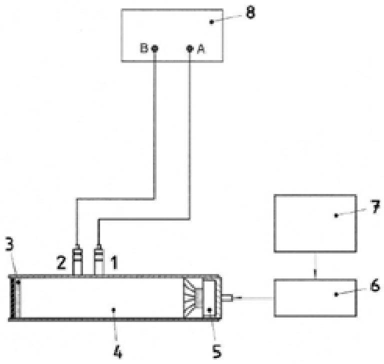

Fig. 2. Scheme of testing equipment from ISO 10534-2.

The components for this equipment are:

1) *Microphone 1.*
2) *Microphone 2.*
3) *Material sample.*
4) *Standing Wave Tube.*
5) *Source.*
6) *Amplifier.*
7) *Signal Generator.*
8) *Frequency Analysis System.*

Fig. 3 shows a photography of the acoustic impedance tube used for testing the samples.

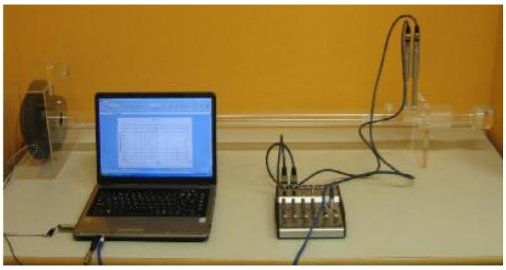

Fig. 3. Acoustic impedance tube.

The sound absorption coefficient is (equation 1):

$$\alpha = 1 - |r|^2 \quad (1)$$

r is the reflection coefficient. It is determined by means of the following equation (2):

$$r = \left((H_{12} - H_i)/(H_R - H_{12}) \right) \cdot e^{2 \cdot j \cdot k_0 \cdot x_1} \quad (2)$$

H_{12} is the complex transfer function.
H_i is the transfer function for the incident wave.
H_R is the transfer function for the reflected wave.
k_0 is the complex wave number.
x_1 is the distance from the sample to the last position of the microphone.

IV. RESULTS

The following figures show the graphs for the sound absorption coefficient for each one of the tested materials.

As it will be demonstrated later, there are no much differences when sintering the multilayer material in one or in three stages. So, the results are for a three stage sintering process.

In general, these new multilayer materials present low sound absorption properties. The main differences depend on the thickness of each layer, the granulometry of the rubber and the sintering process.

A. Sound Absorption for 4-2-4, 3-4-3, 2-6-2 multilayers. 0,7 mm granulometry

Fig. 4 shows the sound absorption coefficient for multilayers 4-2-4, 3-4-3, 2-6-2 and 0,7 mm granulometry, compressing the layers in three stages.

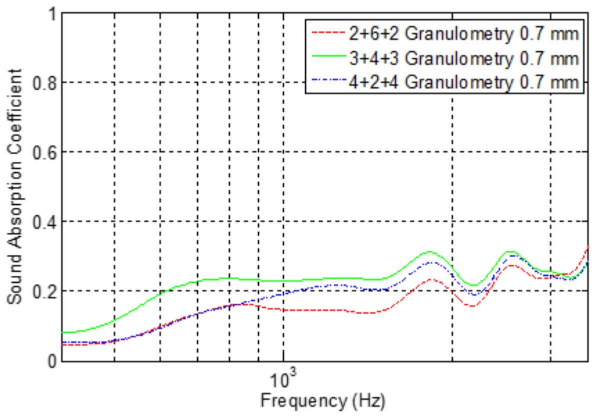

Fig. 4. Sound absorption for multilayers 4-2-4, 3-4-3, 2-6-2 (0,7 mm)

B. Sound Absorption for 4-2-4, 3-4-3, 2-6-2 multilayers. 2,2-4 mm granulometry

Fig. 5 shows the sound absorption coefficient for multilayers 4-2-4, 3-4-3, 2-6-2 and 2,2-4 mm granulometry, compressing the layers in three stages.

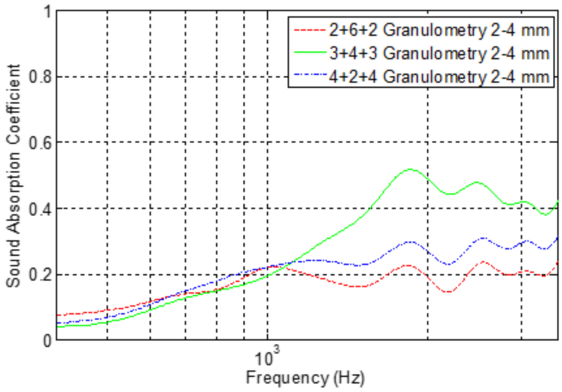

Fig. 5. Sound absorption for multilayers 4-2-4, 3-4-3, 2-6-2 (2,2-4 mm)

C. Sound Absorption for 8-4-8, 6-8-6, 4-12-4 multilayers. 0,7 mm granulometry

Fig. 6 shows the sound absorption coefficient for multilayers 8-4-8, 6-8-6, 4-12-4 and 0,7 mm granulometry, compressing the layers in three stages.

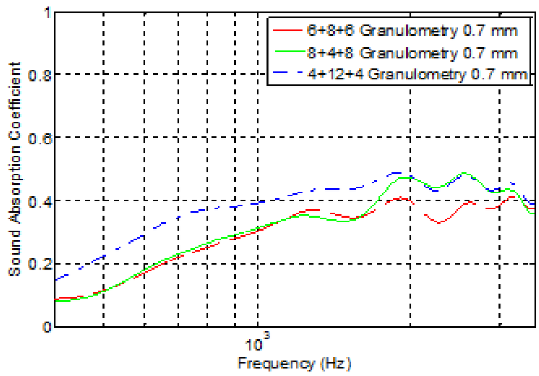

Fig. 6. Sound absorption for multilayers 8-4-8, 6-8-6, 4-12-4 (0,7 mm).

D. Sound Absorption for 8-4-8, 6-8-6, 4-12-4 multilayers. 2,2-4 mm granulometry

Fig. 7 shows the sound absorption coefficient for multilayers 8-4-8, 6-8-6, 4-12-4 and 2,2-4 mm granulometry, compressing the layers in three stages.

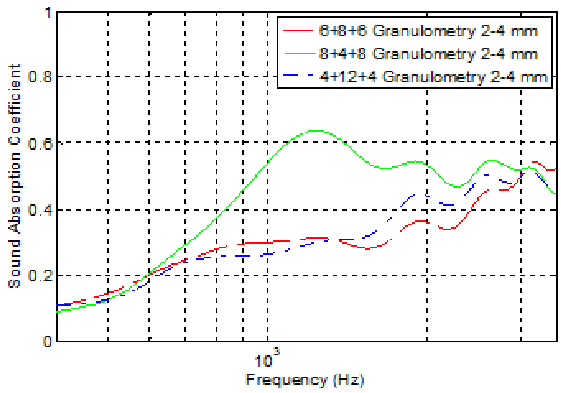

Fig. 7. Sound absorption for multilayers 8-4-8, 6-8-6, 4-12-4 (2,2 - 4 mm).

The best sound absorption properties have been found in multilayers of 20 mm thickness. In this sense, it is worth saying that the disposition 8-4-8 is the best sound absorber, as it is presented in Fig. 8.

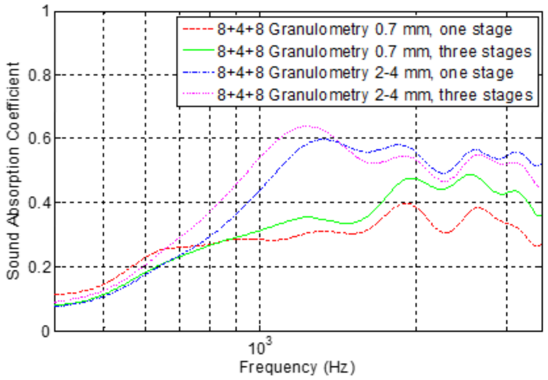

Fig. 8: Sound absorption for multilayers 8-4-8.

This graph shows the results for the 4 mm – 8 mm – 4 mm (rubber – fiber – rubber) with 0,7 mm granulometry and 2,2 – 4 mm granulometry. Moreover, it is observed, as mentioned before, that there are no much differences when sintering the new material in one or in three stages.

V. CONCLUSIONS

As it would be predicted, the sound absorption coefficient is higher in the 20 mm samples. It is demonstrated in previous studies [12] that rubbers and fibers are not good sound absorbers when working independently with small thicknesses. In this sense, it is intended to evaluate the sound absorption properties of these materials when they are combined in a three multilayer disposition: rubber-fiber-rubber.

In general, the multilayers with 2,2-4 mm granulometry present a higher absorption coefficient than those with 0,7 mm granulometry.

From the obtained results, this study is considered a first step for future lines of research:

- It would be interesting to study the influence of the sintering process in other acoustic characteristic factors such as tortuosity and porosity. These factors are important in order to evaluate the acoustic behaviour of the materials and allow to find a model for optimizing the relation between the sound absorption coefficient and the mechanical properties.
- The trend in materials is the use of recycled products and natural fibers [13]-[15]. For multilayer panels it would be possible to use textile fibers, coconut fibers, kenaf, etc.
- Determining parameters such as damping and loss factor can be useful in order to find applications for isolating rooms and industrial equipment. In this sense there are some interesting previous works from Hongisto [16], Diaz-Cereceda [17] and Uris [18].

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REFERENCES

[1] SIGNUS. End of life tyre prevention plan; 2010-2013. <http://www.signus.es/Portals/0/Plan_Empresarial_extracto_Ingl.pdf (30/04/2012)>
[2] A. Miravete et al. *Materiales compuestos I y II*. INO Reproducciones, Zaragoza, 2000.
[3] W. Tsai, A. Miravete. *Diseño y Análisis de Materiales Compuestos*. Reverté, Barcelona, 1988.
[4] D. Hull. *Materiales Compuestos*. Reverté, Barcelona, 2003.
[5] F. Giles Carter and E. Donald. *Materials Science & Engineering*. CRC Press, First Edition, 1991.
[6] Standard ISO 10534-2: Determination of sound absorption coefficient and impedance in impedance tubes. Part 2: Transfer-function method.1998.
[7] Standard ISO 354:3003. Acoustics. Mesurement of sound absorption in a reverberation room.
[8] Attenborough K. *On the Acoustic slow wave in air filled granular media.* J. Acoust. Soc. Am., 1987; 81, 93-102.
[9] Beranek L. *Noise and vibration control engineering.* John Wiley & Sons; 1992.
[10] I.P. Dunn, W.A Davern. *Calculation of Acoustic Impedance of Multilayer Absorbers".* Applied Acoustics, 19, 321-334, 1986.
[11] B.H. Song, J.S. Bolton. *A transfer-matrix approach for estimating the characteristic impedance and wave numbers of limp and rigid porous materials.* J. Acoust. Soc. Am., 107 (3), 1131-1152, 2000.
[12] E. Juliá *et alter*. *Determining Acoustic Properties of New Multilayer Panels Made from Ground Tire Rubbers (GTR).* ISMA Conference. Leuven 2012 (Belgium).
[13] Asdrubali, F., "Survey on the Acoustical Properties of New Sustainable Materials for Noise Control," Proceedings of Euronoise, 2006, Tampere Finland.
[14] Kazragis A, Gailius A, Jukneviciute A., "Thermal and Acoustical Insulating Materials Containing Mineral and Polymeric Binders with Celluloses Fillers". Material Sciences 2002, 8 No. 2, p. 193-195.
[15] Ramis J et alt, ¨New absorbent material acoustic based on Kenaff fibre¨. Materiales de Construcción 2010, 60, p. 133-143. (doi: 10.3989/mc.201050809)
[16] Hongisto V, ¨Sound insulation of doublé panels-comparison of existing prediction models¨. Acta Acustica united with Acustica 2006, 92, p. 61-78.
[17] Diaz-Cereceda C, Poblet-Puig J, Rodriguez-Ferran A. ¨The finite layer method for modelling the sound transmission through double walls¨. Journal of sound and Vibration 2012, 331, p. 4884-4900. (doi: 10.1016/j.jsv.2012.06.001)
[18] Uris A et alt. ¨Sound insulation of double frame partitions with an internal gypsum board layer¨. Applied Acoustics 2006, 67, p. 918-925. (doi: 10.1016/j.apacoust.2005.11.006)