Acoustic Properties of Rubber Crumbs

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Abstract: In order to contribute to the solution of the environmental problem created by the tire wasteways, it has been studied in a systematic way, the possibilities of using rubber crumbs of waste tires as acoustic absorbent materials. Experimental absorption coefficients of rubber granulates has been tested in Kundt's tube and in reverberation room. Absorption coefficient values so obtained are compared with computational values afforded through mathematical prediction models that use the previously measured intrinsical parameters of the porous material. The good broadband acoustic absorption of the material, encourages its use as an alternative to the current absorbent acoustic screens, employed for the protection against traffic noise.

INTRODUCTION

Among the serious problems inherent to our modern society, those of the pollution and recycling has a first grade of priority. Under acoustical aspects, the traffic noise and the waste tires pollution are a growing problem. In this paper, an alternative to diminish both problems are presented, consisting in the reutilization rubber waste in the form of recycled material as an absorbent in the production of sound barriers along highways to reduce noise to neighboring residential areas. In this case, the acoustical design of a new material should be made in such a way, that its absorption characteristics should be broadband and adequate to the energy band spectrum of the pollutant source.

THEORETICAL ASPECTS

In the general case of common porous materials (as rubber crumbs), the key question is to find an expression for the characteristic acoustic impedance, that is function of the frequency dependent dynamic density, \( \rho(\omega) \) and the bulk modulus, \( K(\omega) \) of the material under study. If the material can be considered as a rigid frame whose porous are filled with a known fluid, the effective density of the fluid (air) can be expressed, following the simplification established by Johnson [1]:

\[
\rho(\omega) = T \rho_0 \left[ 1 + \frac{\sigma \Omega}{\rho_0 T} G_j(\omega) \right]
\]

with \( G_j(\omega) = c \sqrt{1 + \frac{\lambda^2}{16}} \); \( j = \sqrt{-1} \); and \( \lambda = c \sqrt{\frac{8 T \rho_0 \omega}{\sigma \Omega}} \)

where \( T \) is the macroscopic tortuosity of the material, \( \omega = 2\pi f \) (\( f \) = incident wave frequency), \( \rho_0 \) air density, \( \Omega \) porosity, \( \sigma \) air flow resistivity, and being \( c \) an adjustment parameter related to viscous losses in the pores.

The bulk modulus, \( K \), can be calculated introducing Johnson's simplification in the expression of Zwikker - Kosten [2]:

\[
K(\omega) = \rho_0 \left\{ \gamma - (\gamma - 1) / \left[1 + \frac{c' \sigma \Omega}{j N_{pv} \rho_0 T} G_j(N_{pv},\omega) \right] \right\}^{-1}
\]

with: \( G_j(N_{pv},\omega) = \sqrt{1 + \frac{j N_{pv} \left( \frac{\lambda}{\lambda_c c'} \right)^{2}}{\alpha_{cc'}}} \)

being \( N_{pv} \) the Prandtl number and \( c' \) another shape parameter related to the thermal gradients in the pores. In general \( c = 1/c' \), and \( 0.3 < c < 3 \).

It is well known [3] that the relationship between the surface impedance of a layer of porous material with a thickness \( d \), for normal incidence sound waves, considering rigid backing, is:

\[
Z(\omega) = -j Z_c(\omega) \cot(kd), \text{ being } k \text{ the wave number in the material, } k = \sqrt{\frac{\rho(\omega)}{K(\omega)}} \text{ and } Z_c = \sqrt{\rho(\omega) \cdot K(\omega)}
\]

RESULTS AND CONCLUSIONS

The acoustic absorption behaviour of a sample depends on the intrinsic characteristics of the pore sizes and on the thickness of the layer. The tested samples correspond to rubber crumbs obtained from waste tires (without metallic and textile residues) with granulometries that lie in the range of 1.4 to 7 mm.

It has been studied and experimented the following types of rubber crumbs:
being $\phi$ the size of the rubber crumbs in mm. The samples $s_2$ and $s_7$ include any size of grains (from powder to the limiting size of the mesh), and it has been found a content about 70% of samples $s_3$ and $s_4$ respectively.

For a given sample thickness, the absorption coefficient increases when the diameter of the grains decreases. In this way, figure 1 shows, for a layer of 10 cm, the absorption curves in function of the frequency for rubber crumbs samples: $s_1$ (+), $s_4$ (D), and $s_7$ (O), measured in Kundt’s tube. Analogous results have been found for other thickness of the studied samples.

For the different types of rubber crumb samples studied ($s_1$-$s_7$), the intrinsic parameters ($Q, T, \sigma$) have been measured. It has been checked that when the grain size diminishes, $\sigma$ and $T$ increases, decreasing $Q$. As an example, it is worth to compare the values obtained for two types of samples with different grain sizes. In this way, for the crumb $s_1$, the following values has been measured: $\sigma$=11000 Rayls/m MKS, $T=3$ and $Q=44.3$ %, whereas for the rubber crumb $s_6$ the measured values were: $\sigma$=1200 Rayls/m MKS, $T=1.4$ and $Q=54.4$ %.

<table>
<thead>
<tr>
<th>sample</th>
<th>s1</th>
<th>s2</th>
<th>s3</th>
<th>s4</th>
<th>s5</th>
<th>s6</th>
<th>s7</th>
</tr>
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<tr>
<td>size ($\phi$)</td>
<td>$\phi=1.4$</td>
<td>$\phi&lt;3.5$</td>
<td>$1&lt;\phi&lt;3$</td>
<td>$3&lt;\phi&lt;5$</td>
<td>$\phi=3.5$</td>
<td>$5&lt;\phi&lt;7$</td>
<td>$\phi&lt;7$</td>
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In figure 2 the calculated absorption coefficients (dotted line) for the test sample $s_2$ ($Q=54.1$, $\sigma=3000$, $T=1.4$, $c=2.5$, $c'=0.4$) and the corresponding ones (continuous line *) obtained by means of the Kundt's tube method has been represented, for a 10 cm of the layer thickness. In the same figure it has been included the absorption results measured in a reverberation room (continuous line o).

The reverberant room test can be considered the best one to know the actual behaviour in situ of the material and it only should be carried out when the designed material can be considered definitively ultimate. The measurement is not cumbersome with the appropriate installations and instrumentation facilities, but the preparation of the samples are tiresome due to the big size of them (e.g. a total weight of 600 kg. were necessary to prepare a sample of 12x0.09 m$^3$ of rubber crumb). In the figure it can be observed a smoother curve for the results obtained in the reverberation room, due to the spatial averaging of the incident acoustic field.

It has been checked that rubber crumbs specially sorted and prepared can be a good acoustic material with a broadband absorption spectrum. The developed algorithms constitute a good tool in order to design a new absorption granular material, adequate to the noise spectrum of a pollutant source.

The use of this kind of materials in noise barriers on emplacements exposed to climate atmospheric agents (specially rain) is advantageous compared to the classical ones (glass or rockwool fibres), because its performances are not degraded with the impregnated water, and not collapsed by dust.

For all these reasons, it is encouraged its use outdoors, being an excellent alternative to the current absorbent screens used for the protection against traffic noise, contributing at the same time to eliminate scrap tires.

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REFERENCES