Acoustical Performance of Rubber Crumb Material

Paresh Shravage, PhD
Alfa Acoustics
Plot No-5, Swami Vivekanand Soc. Opp. Aher Garden,
Walhekar Wadi Rd, Chinchwad, Pune India-411033
Cell-9423208575
info@alfaacoustics.com

Abstract

The improvement in the quality of human life and the continuous growth in population in developing and developed societies, has resulted into several environmental and economical problems. One of the problem is related with ground tire waste mostly created by transport industry. The amount of waste tires is increasing due to the huge demand for tyres and their short lifetime. It is therefore necessary to improve or to develop certain process or applications for recycling waste tires. In order to contribute to the solution of the environmental problem created by the tire waste ways, a possibility of using tire rubber crumb as an acoustical materials was studied. The experimental sound absorption coefficient and sound transmission loss of rubber crumb material was measured in a two microphone impedance tube and in a reverberation chamber. Intrinsic parameters of rubber crumb material were also measured and used for simulation of absorption coefficient and sound transmission loss. The paper presents use of rubber crumb material as an alternative to current acoustic materials. The paper also compares the experimental results with theoretical predictions which can used in design of multilayers in later stage.

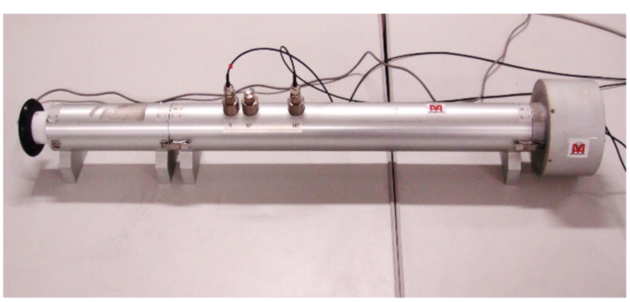
Keywords: Sound absorber; Recycler rubber; Acoustical properties; Impedance tube; Simulation

Introduction

In the modern world, humanity is facing environmental pollution problems. These problems are an outcome of continuous industrial developments, improvement in technologies and unconditional usage of natural resources. As a result of this, huge amount of waste has been created and becoming a serious problem for the society. Therefore, waste management is becoming one of the first priority in whole world. In transport industry also scrap tire waste is also one of the major challenge along with the traffic noise and air pollution. . In order to contribute to the solution of the environmental problem created by the tire waste, a possibility of using tire rubber crumb as an acoustical materials was studied. Recently, many researchers have proposed to use recycled rubber crumb from tire waste for acoustic absorption and insulation applications instead of using them for landfill or incineration of used tires. Within this context, the goal of the paper is to study acoustic absorption and insulation performance of rubber crumb material. The paper also discusses simulation methodology which can be used to design multilayer treatments for industrial noise control applications.

Acoustic Properties

Rubber crumb samples considered in this study were 5, 10, 15 and 20 mm in thickness with density 64 kg/m^3. Initially the small samples were tested for normal incidence sound absorption coefficient in a three microphone impedance tube as per ISO 10534-2 / ASTM E1050 and large samples were tested for random incidence sound absorption coefficient in a Reverberation room as per ASTM C423 / ISO 354 [1]. The sound transmission loss test was carried out in a reverberation room suite as per ISO 10140-2 [2]. The experimental test set up is given in figure 1 with typical test results in figure 2.



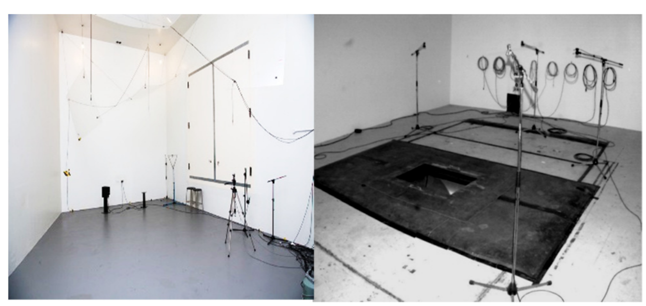


Fig 1 (a): Normal Incidence Impedance Tube (b): Reverberation Chamber Suite

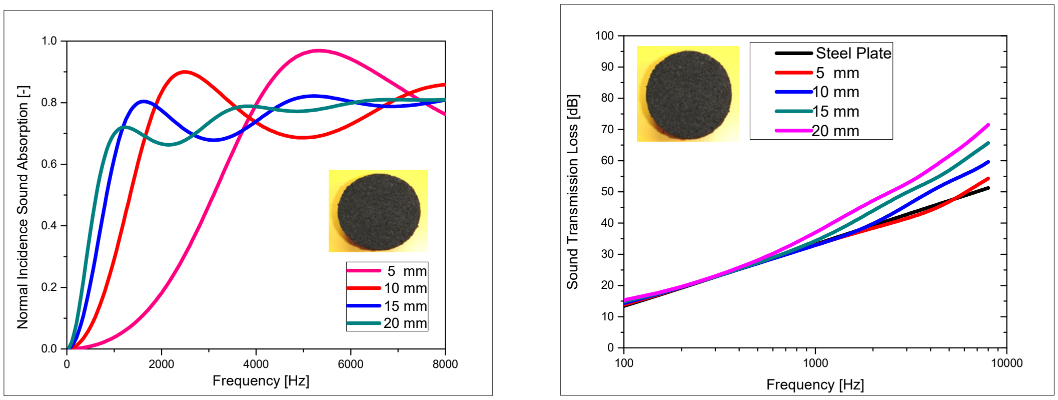


Figure 2. Experimental results for sound absorption coefficient and Transmission loss measurements

Non-acoustic Properties:

The performance of sound absorbing materials can be predicted with prior measurement of five intrinsic physical parameters like porosity, flow resistivity, tortuosity, viscous and thermal characteristic lengths and three mechanical parameters like Young's modulus, Poisson ratio and loss factor. Tortuosity and characteristic lengths are inverted using optimization technique based on Inverse Algorithm. This technique requires prior measurement of sound absorption coefficient with surface impedance using two microphone impedance tube along with measured porosity and flow resistivity to fit a mathematical model. The global solution of this optimization gives tortuosity and characteristic lengths. For this purpose, Johnson-Champoux-Allard model is used which considers frame of porous material as a rigid, motionless frame. Hence porous material can be replaced on a macroscopic scale by an equivalent fluid of effective density $\rho(\omega)$ and effective bulk modulus $K(\omega)$. The motionless frame condition can occur either because of high density or elasticity modulus, or because of particular boundary conditions imposed during the test. The dynamic density $\rho(\omega)$ and bulk modulus $K(\omega)$ for Allard model [4] are given by following equations.

$$\rho(\omega) = \rho_0 \alpha_\infty \left[1 + \frac{\sigma \phi}{j \omega \rho_0 \alpha_\infty} \sqrt{\frac{4 j \alpha_\infty^{\;2} \eta \omega}{\sigma^2 \Lambda^2 \phi^2}} \right] \tag{1}$$

$$K(\omega) = \gamma P_0 \left[\gamma - (\gamma - 1) \Big/ 1 + \frac{8\eta}{j \Lambda' N_{pr} \omega \rho_0} \sqrt{1 + j \rho_0 \frac{\omega N_{pr} \Lambda'}{16 \eta}} \right]^{-1} \tag{2}$$

Where, ρ_0 is density of fluid, P_0 is atmospheric pressure, γ is specific heat ratio N_{pr} is Prandtl number, η is coefficient of viscosity of air and ω is circular frequency.

From figure 1 & 2 the characteristic impedance Z_c and the complex wave number k_c of the porous specimen are calculated as given by Eq. (3).

$$Z_c = (\rho(\omega)K(\omega))^{1/2} \qquad k_c = j\omega.[\rho(\omega)/K(\omega)]^{1/2} \tag{3}$$

For a porous sample of thickness d, backed by rigid wall specific acoustic surface impedance is given by Eq. (4).

$$Z_S = -j\frac{Z_C}{\rho_0.c_0}\cot(k_C\ d)/\phi \tag{4}$$

Now to get inverse parameters, experimental surface properties are used to fit the mathematical model of a porous material, so that global optimization will yield intrinsic parameters of rubber crumb as given in Eq. (5).

$$\chi\{\phi,\sigma,\alpha_\infty,\Lambda,\Lambda'\} = \left|Z_{Exp} - Z_S\right|^2 \tag{5}$$

The global minimum of Eq. (5) gives intrinsic parameters which can be validated using experimental results of impedance tube. In this study only five physical intrinsic parameters were considered for simulation as mechanical parameters does not affect acoustic behavior of sound absorbing materials.

Results and Discussions

The physical intrinsic properties of rubber crumb samples measured using specialized test rigs and evaluated from inverse software are given in table 1.

Table 1: Measured physical parameters of cellular rubber

Material Samples	**Porosity [-]**	**Flow Resistivity [Ns/m^4]**	**Tortuosity [-]**	**VCL [µm]**	**TCL [µm]**
Cellular Rubber	0.86	150388	3.97	29	29

These parameters were used for simulation of normal incidence sound absorption coefficient. The results are compared in figure 3, which shows that intrinsic parameters evaluated using inverse characterization are actual intrinsic parameters of rubber crumb and they can be used to predict random incidence sound absorption coefficient. Normal incidence sound transmission loss was also simulated using intrinsic physical parameters by transfer matrix method and is also compared with measured sound transmission loss in a three microphone impedance tube in figure 3. The experimental sound absorption correlates well with simulation results while some deviation is observed in sound transmission loss at high frequencies which is due to elastic behavior of sample frame. As the limp model is considered for simulation, it cannot predict the elastic behavior of the frame.

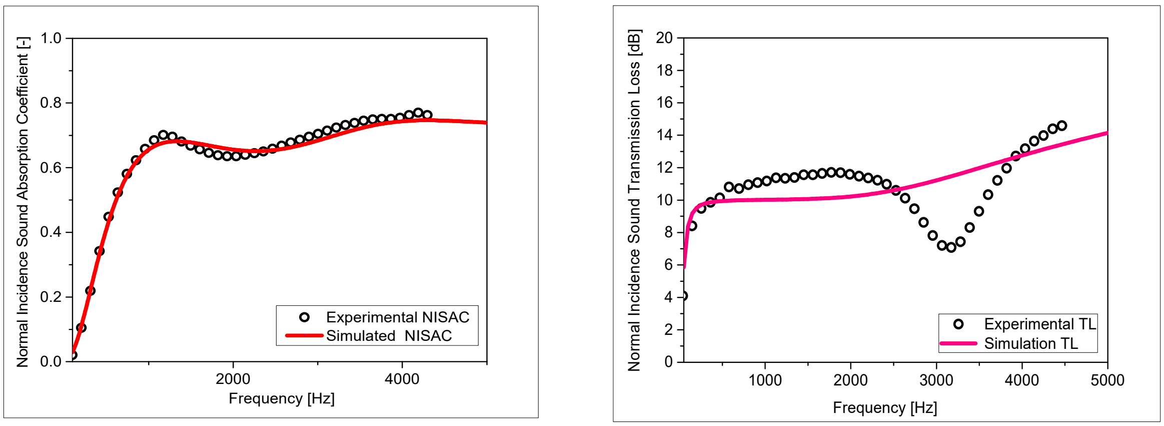


Figure 3. Comparison of normal incidence sound absorption and transmission loss with Simulation

Once these intrinsic physical parameters are validated for normal incidence sound absorption, they can be used to predict random incidence sound absorption and sound transmission loss of cellular rubber. Figure 4 shows comparison of experimental sound absorption and sound transmission loss with simulated results and it is observed that simulation results matches well with the experimental results.

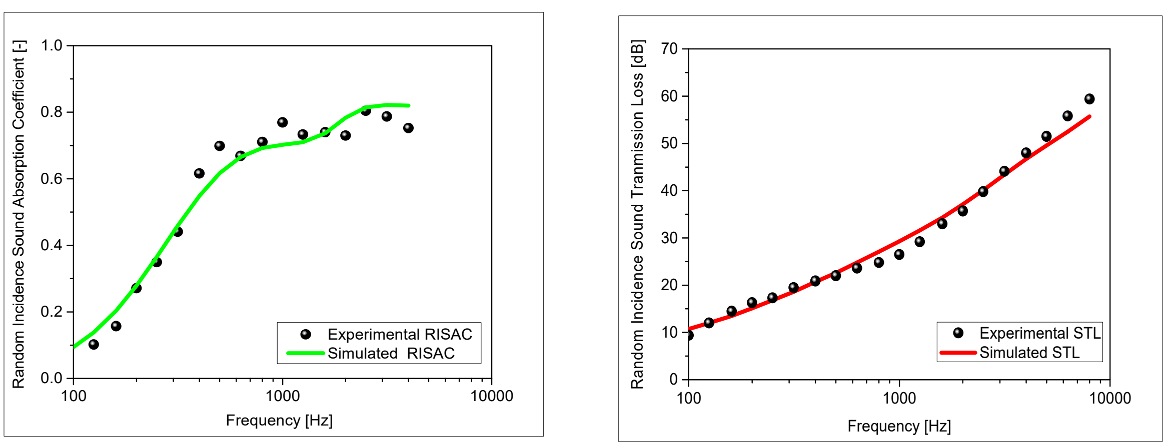


Figure 4. Comparison of random incidence sound absorption and transmission loss with Simulation

As the study shows, Cellular rubber is having good acoustic performance, it can be used for various industrial noise controls applications. Figure 5 shows, sound absorption and sound transmission loss of cellular rubber predicted for various thicknesses which can be used for design purpose in many applications.

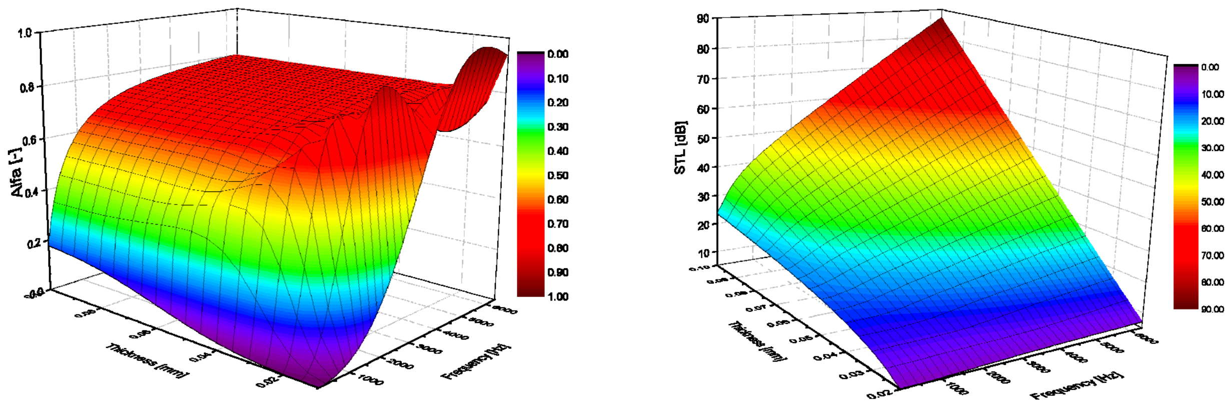


Figure 5. Normal incidence sound absorption and sound transmission loss for multiple thickness samples

Conclusion

From this study, it has been observed that cellular rubber is having good acoustic performance compared to regularly used foam / fibrous materials in the industry. So it can easily replace regularly used materials. Also as the materials is highly viscoelastic, it will have added advantage of reducing the vibration levels of the panels.

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