Assessment of Acoustic Properties of Different Recycled Polymer-Based Materials for Road Work Sound Barrier Walls Application

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1. INTRODUCTION

Due to their high sound absorption efficiency, rock and glass wools are largely used as sound absorber materials and particularly for the design of sound barrier panels. However, their fabrication is highly energy-consuming. Indeed, rock and glass used in the wool fabrication process required high temperatures (i.e. above 1,000°C), which are much higher than any polymer processing temperatures. In addition, centrifuges and burners, two energy-consuming equipments, are also required for fiber forming process [1]. Besides, the process is not over yet as wool has no mechanical strength. Accordingly, a thermoset resin, such as phenolic resin, is sprayed over fibers where it polymerizes and cross-links. Generally, the amount of resin used varies between 1 to 5% and 4 to 14% for rock and glass wools respectively [2]. It is important to highlight that cross-linking process is irreversible. Thus, if environmental concerns and sustainable development policies must be taking into account, the use of rock or glass wool as sound absorbent materials may be no longer adequate.

The objective of this paper is to investigate on environmentally-friendly alternatives for rock and glass wools in sound barrier walls applications. To achieve this goal, various recycled fibers-based materials were characterized and compared to evaluate their sound absorption potential. Eventually, best materials will be incorporated in an experimental on-scale sound barrier wall and tested.

2. MATERIALS AND EXPERIMENTS

2.1. Materials

To meet the objective of the study, the criteria to select materials are twofold. Indeed, chosen materials *i)* must be recycled and *ii)* exhibit acoustical performance. To satisfy both criteria and knowing that porosity is one of the key parameters for sound absorption efficiency, materials selection could be among recycled fiber-polymers category.

Table 1 depicts selected materials. For sake of simplicity selected materials were termed A, B, C and D respectively. The various entries of the table indicate the polymer fibers type, origin, and supplier's name.

Table 1. Description of selected materials

Material designation	Type of polymer fibers	origin	Supplier
A	Polyester	Post-industrial	Leigh textile (Montreal, Qc, Canada)
B	Blend	Residential carpet waste	
C	Cotton	Post -consummation clothes	
D	Cotton	recycled cotton-based insulation	Jasztex (Montreal, Qc, Canada)

2.2. Experiments

Around road-work construction sites, the most disturbing frequencies are between 500 and 2,000 Hz. Therefore, the materials should be acoustically efficient within this frequency range, and all measurements should be carried out, at least, on this frequency range.

Sound absorption coefficients were assessed in laboratory on small specimens and in-situ on an on-scale sound barrier wall.

Laboratory measurements

Absorption coefficient was measured by means of an impedance tube following the standard method ASTM E 1050-98. All tests were performed on 44.45 mm diameter samples with a thickness of 50 mm for materials A, B and C and 67 mm for material D. Under this configuration, the validity frequency range of measurements lies between 150 to 4,000Hz.

In-situ measurements

To obtain material absorption property and insertion loss, an experimental sound barrier wall was built (figure 1). This wall is characterized by three 4x4 m sections composed of 6 removable panels made of galvanized steel perforated on one side and filled with sound absorber.

Figure 1. Experimental on-scale sound barrier wall

Physical properties measurements

Generally to simulate the sound absorption coefficient *versus* frequency of selected materials using a model such asthe Johnson–Champoux-Allard (JCA) model [3], the knowledge of porosity (ϕ), density (ρ), airflow resistivity (σ), tortuosity (α_∞), viscous (Λ) and thermal characteristic lengths (Λ') is needed. Thus, porosity and density were determined using a pressure mass method described by the Salissous and Panneton [4] while the other parameters were measured following the method described by Attala and Panneton [5]. Table 2 presents the obtained parameters for the 4 selected materials (i.e. A, B, C and D).

Table 2. Measured physical properties of selected materials

Materials	ρ (kg/m³)	Φ (%)	σ (Ns/m⁴)	α∞ (-)	Λ (μm)	Λ' (μm)
A	85	99	18,428	1	87.6	721.6
B	100	84	20,277	1	72.3	466
C	45	95	18,184	1	58.8	875
D	26.5	95	3,730	1	164	490

3. RESULTS

Figure 2 shows the absorption coefficient as a function of frequency for the 4 selected materials. For sake of comparison, simulated absorption curves of rock and glass wools were also included. As can be seen, materials A, B and C have similar absorption coefficients over the whole range of frequency. More interestingly, those 3 materials seem to be better than rock or glass wool as they exhibit higher absorption coefficients. Only material D appears to be less efficient in spite of its larger thickness. This result can be ascribed to a lack of compaction as it has the lowest density among the 4 selected materials. Consequently one can, reasonably, expect that, if compactness of this material is increased, sound absorption coefficient of this material would be, at least, comparable to that of material C which is cotton-based material.

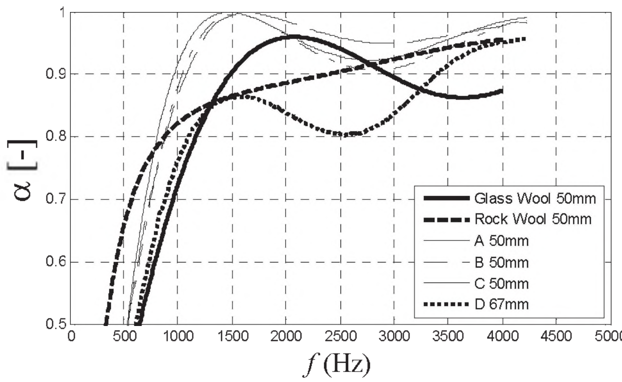

Figure 2. Comparison of measured absorption coefficients of selected materials and simulated absorptions of rock and glass wools.

Following these results, some selected materials will be tested on the experimental on-scale sound barrier wall. The acoustic characterization and modeling are presently underway and the results will be presented at the conference.

4. CONCLUDING REMARKS

In this paper sound absorption efficiency of 4 selected recycled polymer-based materials were investigated. It was shown that, in terms of sound absorption, the selected recycled fiber-polymers seem to be equal or better than rock or glass wool. Due to this encouraging result, acoustic characterization of the recycled material on an experimental on-scale sound barrier wall and modeling are presently in progress.

REFERENCES

[1] Lehamann J.-C. (2010), Formulation du verre et produits verriers, Techniques de l'ingénieur, J 2 296, p.13.

[2] Chevalier M. (1991), Phénoplastes ou phénols-formols, Technique de l'ingénieur, A 3 435, p.19.

[3] Allard J.F. and Champoux Y. (1992), New empirical equations for sound propagation in rigid frame fibrous materials, J. Acoust. Soc. Am. 91(6), 3346-3353.

[4] Salissous, Y. and Panneton, R. (2007). Pressure/mass method to measure open porosity of porous solids. J. Appl. Phys. 101, 124913.1-124913.7.

[5] Atalla, Y. and Panneton, R. (2005). Inverse acoustical characterization of open cell porous media using impedance tube measurements. Canadian Acoustics, volume 33, numéro 1, p. 11-24.

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