DEVELOPMENT OF AN ECO-ACOUSTIC ABSORBER BASED ON LOCAL RE-CYCLED GRANULAR MATERIALS

Islam Ben Amara [*1], Raymond Panneton [†1], and Richard Gagne´ [‡1]
[1]Centre de recherche acoustique-signal-humain de l'Université de Sherbrooke, Sherbrooke, Québec, Canada

1 Introduction

Nowadays, noise pollution is causing significant socio-environmental problems, impacting both humans and the planet. It is crucial to address the detrimental effects of noise and find effective solutions. Traditional sound absorbers such as foams and mineral wools are commonly used indoors and outdoors to attenuate sound waves. However, the Earth is facing a severe shortage of raw materials due to high consumption and extraction rates. Consequently, massive amounts of materials are wasted. In response, Quebec government is working to establish new regulations to value various types of residual waste [1]. This presents an opportunity to explore sustainable alternatives that address both acoustic and material concerns. Previous research has shown that granular materials can be a suitable substitute for conventional applications. Several researchers have studied the acoustic performance of porous granular absorb-ers. Empirical and numerical approaches have been employed to predict the acoustical performance of these materials, identifying mechanical and structural parameters which can improve their acoustic response [2–4]. Additionally, the recycling of granular waste can contribute to sustainable development.

This study aims to investigate the potential of polydisperse granular recycled materials through experimental methods to enhance acoustic absorption across a broad range of frequencies. Furthermore, the antiresonant behaviors will be examined, based on combinations between transport properties, particle size, and the dosage of cementitious binders.

2 Recycled granular materials

The selection of granular materials is based on three primary criteria: sustainability, local availability, and affordability. Evaluation and determination of physical parameters, including particle size, shape, and diameter range, are also performed. Two types of granular waste, namely expanded glass beads and perlite, are characterized within a fixed diameter range of 250 µm to 2 mm. Acoustic and nonacoustic parameters are investigated through testing various recipes, including monodisperse, bidisperse, and polydisperse configurations. The main objective is to identify and analyze the acoustic absorption potential of these granular blends.

3 Experimental methods and results

3.1 Granulometry

Considering the improvement of acoustic absorption potential using granular wastes necessitates a comprehensive understanding of the material granulometry. The significant variation in particle sizes, coupled with the compaction level and the addition of a cementitious binder for consolidation purposes, can influence the dynamic porosity and, specifically, the open porosity crucial for attenuating acoustic waves. In the case of expanded glass beads, their granular size is already predetermined, ranging from 250 µm to 2 mm. However, for perlite, a granulometry test was conducted to analyze the distribution of particles, considering its low resistance and tendency to fracture when subjected to blending. Throughout the mixing process, the particle size of perlite gradually decreased within a timeframe of less than 5 minutes. To compare the particle size before and after the mixing phase, two portions were tested: the raw material and the crushed granules. The sieves utilized ranged from 0.08 to 10 mm. The results can be interpreted as follows: the grinding process predominantly affected the larger perlite beads, resulting in their fragmentation and the generation of a variety of smaller beads, primarily distributed within the 1.25 to 5 mm sieves. Concerning the smaller beads, a correlation was observed between the results obtained before and after the grinding process.

3.2 Porosity and resistivity

To characterize the samples, both monodisperse and polydisperse, measurements of open porosity and airflow resistivity are carried out. These two parameters are important as they are part of the transport properties essential for subsequent acoustic simulations. The experimental measurements were conducted using porosity and resistivity meters on cylindrical specimens of 44 mm diameter and 120 mm long.

Perlite

The perlite specimens have variable dosages of cement binder of 500 g/L, 600 g/L and 700 g/L, which enabled us to study the influence of the binder content on the properties of the granular soundabsorbent material. The binder dosage is defined as the sum of the masses of water and cement divided by the volume of the granular material in the dry state. The results of the measurements are given in Table 1. The results revealed that as binder content increases, the porosity decreas. Specifically, for a binder content of 700 g/L, the porosity is 49.5%. In contrast, for a lower binder content of 500 g/L, the porosity rises to 74%. Also, it appears from the measurements that the resistivity varies with the binder content. Specifically, blends with a higher proportion of binder exhibit the highest resistivity values.

[*] islam.ben.amara@usherbrooke.ca
[†] raymond.panneton@usherbrooke.ca
[‡] richard.gagne@usherbrooke.ca

Table 1: Porosity and resistivity of perlite samples

Binder (g/L)	Porosity (%)	Density (kg/m³)	Resistivity (Pa·s/m²)
500	74	509	2 423 ± 52
600	64	676	3 557 ± 71
700	50	967	17 720 ± 354

Table 2: Porosity and resistivity of expanded glass beads at binder dosage of 500 g/L and different mixtures of small (0.25-0.5 mm) and large (1-2 mm) beads.

Mixture (small vs large)	Porosity (%)	Density (kg/m³)	Resistivity (Pa·s/m²)
100 – 0%	56	652	112 403 ± 2 250
70 – 30%	47	654	58 413 ± 1 077
50 – 50%	54	613	53 673 ± 1 070
30 – 70%	55	594	19 473 ± 759
0 – 100%	52	663	37 940 ± 390

Expanded glass beads

The experimental methodology employed for the expanded glass beads samples followed a similar approach. Five blends, with the same binder dosage of 500 g/L, were prepared by varying the mixture of beads to create bimodal samples. Small beads (0.25–0.5 mm in diameter) and large beads (1-2 mm in diameter) were used. Additionally, monodispersed specimens were examined to facilitate a comparative analysis of their performance with that of the bimodal samples. The results of the measurements are given in Table 2. The porosity values exhibit a relatively consistent behavior across the blends, except for a slight decrease observed in the 70 30% bimodal mixture. Regarding the resistivity results, the influence of polydisperse properties is noticeable. Despite the consistent binder quantity maintained across all blends, the impact of particle size becomes apparent. Specifically, as the particle diameter increases, the resistivity proportionally decreases going down from 112 403 for the 100 0% mixture to 19 473 for the 30 70% bidispersed mixture. Regarding the resistivity results presented in Table 2, the influence of polydisperse properties is noticeable. Despite the consistent binder quantity maintained across all blends (500 g/L), the impact of particle size becomes apparent. Specifically, as the averaged particle diameter increases, the resistivity proportionally decreases.

3.3 Sound absorption coefficient

According to the ASTM E1050-12 standard, the sound absorption coefficients of the samples were measured using a 44.4 mm impedance tube. The chosen materials, perlite and expanded glass beads, are tested using cylindrical samples (44 mm diameter, 120 mm long). To ensure airtightness, a layer of" cellophane wrap" is applied on the contour of the samples. Measurements are taken on both sides of the specimens to assess symmetry of the samples in the frequency range 100-4500 Hz. The results are given in Figures 1 and 2. One can note that samples containing a significant proportion of larger particles exhibit oscillating curves and resonant dips, particularly at lower frequencies. These observations highlight the link between acoustic absorption, particle size, and mixture. This knowledge will be useful in our future work with the aim of optimizing the sound absorption of an acoustic absorber made from recycled granules.

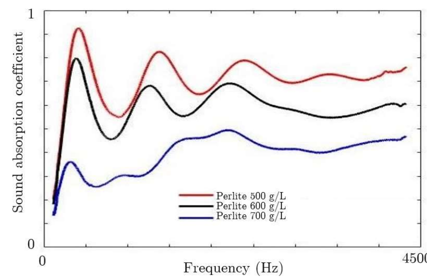

Figure 1: Absorption coefficient of granular perlite samples.

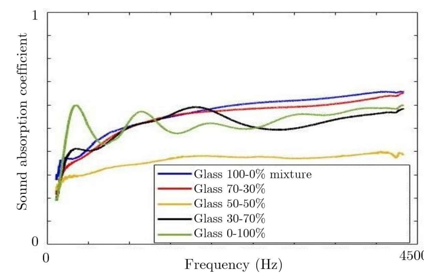

Figure 2: Absorption coefficient of expanded glass bead samples.

4 Conclusion

Revalorizing local granular wastes is a conscious and efficient approach to improve acoustics while considering environmental and economic factors. By optimizing both acoustic and non-acoustic parameters, granular absorbents have shown promising results in terms of sound absorption, comparable to conventional materials. However, it is essential to address constraints like binder quantities, polydiversity in particule diameters, and compaction to ensure the efficiency and durability of these acoustic materials.

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