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STUDY OF SOME INFLUENCES ON THE ACOUSTIC BEHAVIOUR OF DISINTEGRATED SAMPLES OF USED CIGARETTES

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ABSTRACT

Used cigarette butts are one of the most common types of waste in today's environment. However, there are not many proposals for its recycling, if we take into account the amount of waste generated annually.

Our research group has been working in recent years on the recycling of these wastes to give them an acoustic use. Thus, cigarette butts' samples are prepared by disaggregating the filter of used cigarettes, which, as shown in previous studies, presents promising properties as acoustic absorber. However, due to the heterogeneity of the filters and the disaggregation process, these samples tend to lack consistency and lose their shape when handled. Thus, the use of binders is advised in case of severe disaggregation.

This study examines the use of binders on cigarette butts' prepared samples for acoustic applications. Thus, some natural binders has been applied to enhance the structural strength of the samples and their effect onto the acoustic samples performance is analyzed.

The results indicate that samples treated with low binder concentrations retained their acoustic absorption properties while achieving a stronger and more durable structure.

Keywords: *acoustic absorption, impedance tube, binders, cigarette butts*

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1. INTRODUCTION

Cigarette butts are among the most prevalent forms of waste worldwide, raising significant environmental concerns due to their composition and the volume generated. It is estimated that approximately 4.55 trillion cigarettes are consumed annually [1], resulting in an equivalent number of discarded filters.

These filters are primarily composed of cellulose acetate, a non-biodegradable bioplastic that can take years to decompose in the environment. Moreover, cigarette butts contain various toxic compounds, including nicotine and heavy metals, which can leach into soil and water systems, contaminating ecosystems [2]. Despite the well-documented environmental impact of cigarette butts, few recycling solutions have been proposed to mitigate this problem [3].

Cellulose acetate, due to its fibrous and porous structure, has shown favorable acoustic properties. Recent studies have characterized and modeled the sound absorption behavior of cellulose acetate fibers from used cigarette filters, suggesting that this material could serve as a viable alternative to conventional acoustic absorbents in building materials [4,5]. This approach not only contributes to reducing the environmental impact of cigarette butt waste but also offers a sustainable solution for the development of construction materials.

The results obtained to date have been promising, indicating that samples fabricated from these residues can achieve sound absorption coefficients comparable to those of commercial products. However, one of the major challenges identified has been the lack of structural consistency in the samples, which hinders their handling and potential commercialization.

To solve this issue, the use of binders has been proposed to improve structural integrity although their acoustic performance could be compromised [6,7,8]. The use of natural binders shows similar behavior to synthetics, potentially reducing environmental impact, as demonstrated by the study of Mirski et al. [9]

As an initial approach, white glue diluted in water at different concentrations has been used. The aim of this study is to develop a material that not only retains an effective sound absorption capabilities but also meets the mechanical and commercial requirements for real walls.

2. METHODOLOGY

2.1 Equipment used

To determine the absorption coefficient of samples, normal incidence wave measurements were conducted using the transfer function method, as established in ISO 10534-2 [11].

The equipment used for measuring the acoustic properties of the samples includes a Brüel & Kjaer 4206 T impedance tube, a Brüel & Kjaer PULSE multi-analyzer system with four channels (model 3560 C), a Brüel & Kjaer power amplifier (model 2716 C), Brüel & Kjaer ¼-inch microphones (model 4187), and Brüel & Kjaer Material Testing software for PULSE (model 7758).

The impedance tube features two sample holders with diameters of 100 mm and 29 mm, covering frequency ranges of 50–1600 Hz and 500–6400 Hz, respectively. However, for this study, only the 29 mm sample holder was used, limiting the results to the 500–6400 Hz frequency range.

Figure 1 presents a schematic of the experimental setup, while Figure 2 shows a photograph of the impedance tube with the 29 mm sample holder.

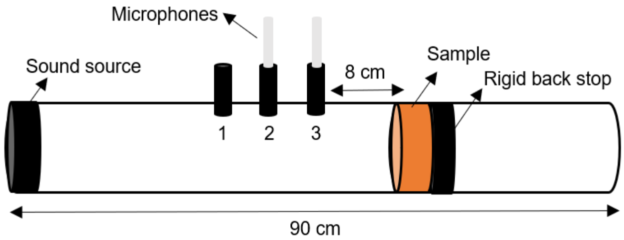


Figure 1. Diagram of sample placement for acoustic absorption measurements.

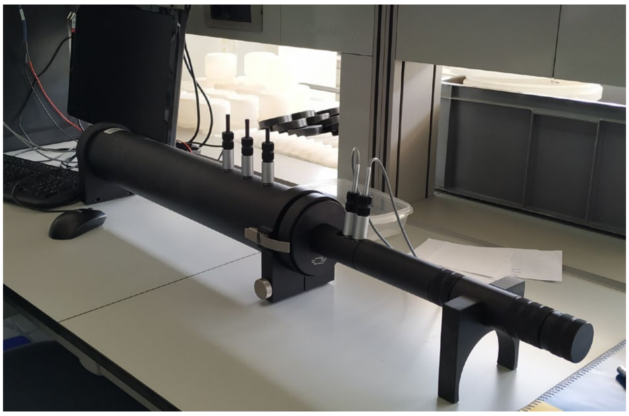


Figure 2. Impedance tube with the 29 mm diameter sample holder.

2.2 Materials

For this study, 30 samples composed of disaggregated cigarette butts were analyzed with the 29 mm diameter holder. Characteristics of the sample set are shown in Table 1.

Table 1. Characteristics of sample set.

Sample number	Thickness	Density
30	21-25 mm	71- 84 kg/m³

The acoustic behavior of the samples has been measured both before and after applying the binder. The binder used has been white glue diluted in water at different ratios (10%, 20%, 40%, 60%, and 80% glue to water ratio). Each combination was applied to six different samples to assess the reproducibility of the results.

Figure 3 shows one of the samples before applying the binder.

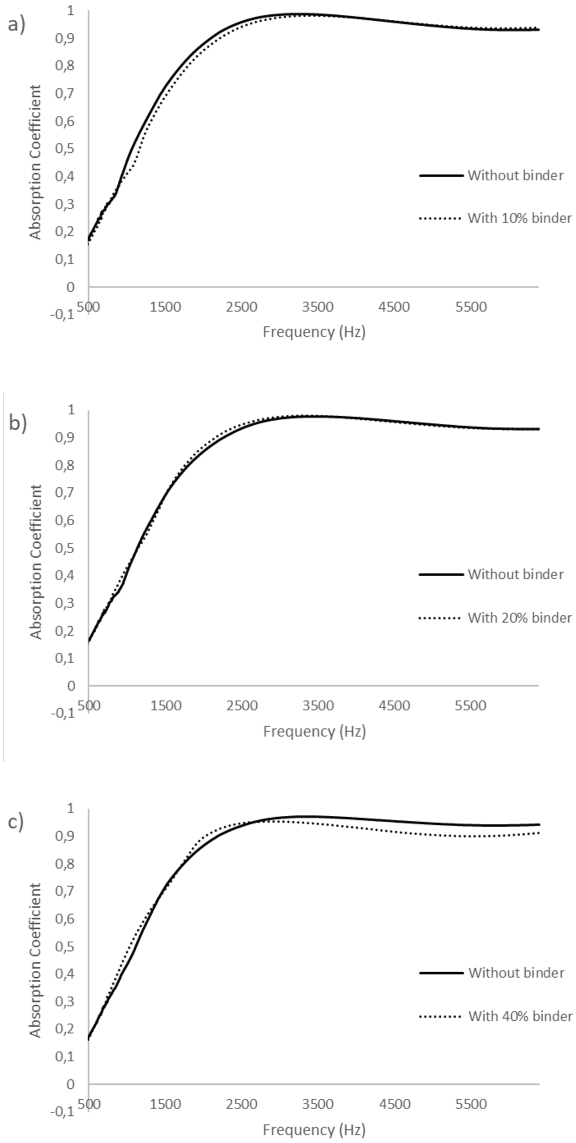
Figure 3. Initial sample before applying the binder.

3. RESULTS AND DISCUSSION

As mentioned earlier, 30 different samples were measured, all with similar characteristics. A different proportion of binder was applied to each six samples: 10%, 20%, 40%, 60%, and 80% white glue related to water. This approach allows us to evaluate how the binder application affects each sample (since measurements were taken before and after its application), how the amount of binder influences the acoustic behavior of the material, and whether these results are reproducible.

Figure 4 presents the average absorption coefficient values for sets of samples with the same binder concentration.

Figure 5 compares the behavior of the different sets, the green line represents the average value of all samples measured before the binder was applied, allowing for a comparison of the acoustic absorption before and after binder application.



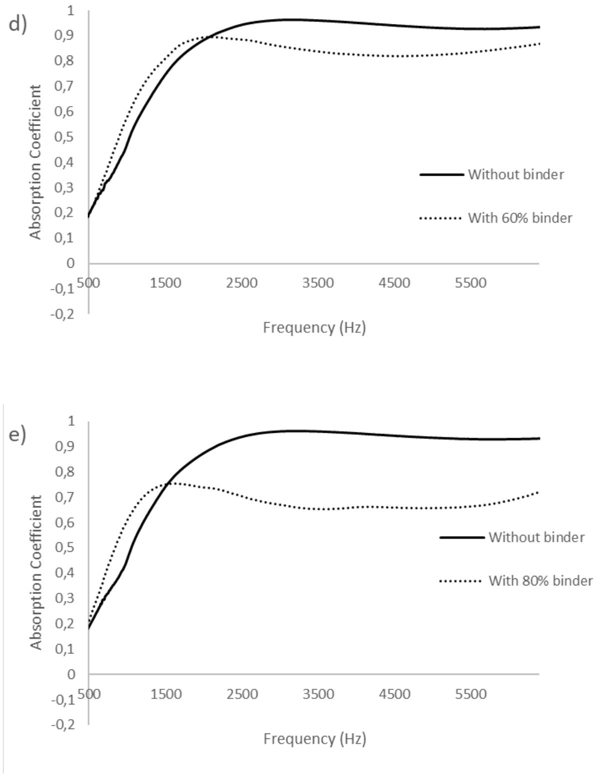


Figure 4. Comparison of samples with a without binder a) 10% b) 20% c) 40% d) 60% e) 80% glue respect water

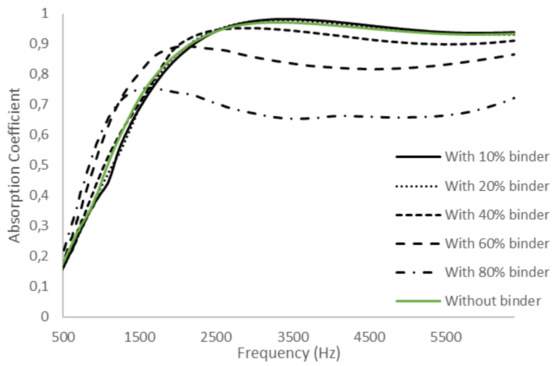


Figure 5. Average sound absorption coefficient before and after binder application

The results show that as the binder concentration in the solution increases, the difference in the measured absorption coefficient becomes more pronounced. Specifically, significantly lower values are observed for samples with solutions containing 60% (Figure 4.d) and 80% (Figure 4.e) of binder. On the contrary, samples treated with solutions with low binder content, such as 10% and 20% (Figure 4.a and Figure 4.b, respectively), show a minimal variation in acoustic behavior, particularly above 3000 Hz, where the difference becomes almost negligible. This decline in acoustic efficiency for high binder ratios can be attributed to a loss of porosity in the samples: the higher the binder content, the more compacted the material becomes, which has a negative impacts on acoustic absorption properties.

These results are corroborated by the data presented in Figure 6, which shows the average differences between each set of samples before and after binder application. It can be observed that, particularly above 3000 Hz, samples with 10% and 20% binder concentration show virtually no differences, while at lower frequencies, the differences remain below 5%. For samples with higher binder concentrations (60% and 80%), the difference increase, reaching a maximum of approximately 12% and 30%, respectively.

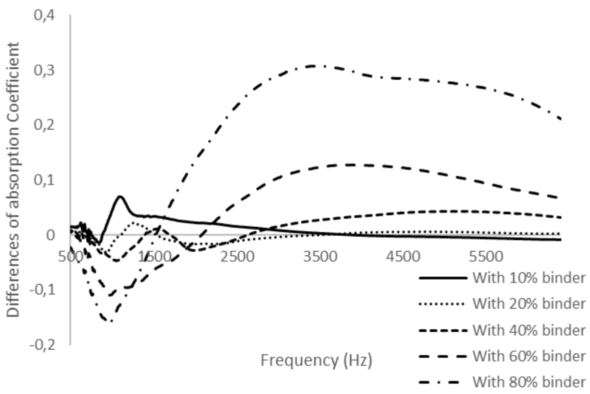


Figure 6. Average differences in sound absorption before and after binder application by concentration

The effect of the binder on the porosity of the samples is shown in Figure 7, which shows two samples: the one on the left was treated with a 10% binder-to-water ratio, while the one on the right was treated with an 80% solution. At 80% binder concentration, the sample becomes completely rigid, resulting in a significant loss of surface porosity.

Figure 7. Effect of the binder on the samples: 10% concentration on the left, 80% on the right.

4. CONCLUSIONS

The use of white glue as a binder in samples composed of cigarette butts presents a valuable opportunity to enhance the structural integrity of the material, preventing deformation during handling.

When applying a low binder-to-water ratio—between 10% and 20%—the acoustic performance of the samples remains unaffected, with no significant reduction in the absorption coefficient upon the introduction of the binder. However, higher binder concentrations, ranging from 60% to 80%, have a notable impact on acoustic behavior, leading to absorption coefficient values up to 40% lower compared to samples without binder. This decrease is attributed to a loss of porosity in the material.

Therefore, it can be concluded that using low binder concentrations is beneficial, as it results in a more mechanically stable material without compromising its acoustic properties. This behavior will be further validated through an expanded sample set and the evaluation of alternative natural binders in future studies.

5. ACKNOWLEDGMENTS

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