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INFLUENCE OF BINDER IN THE ACOUSTICAL BEHAVIOUR OF SAMPLES PREPARED FROM USED CIGARETTE FILTERS

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Abstract

Cigarette filters constitute a significant fraction of persistent urban waste, raising growing environmental concerns due to their widespread disposal and limited recycling pathways. In this context, their potential reuse as porous materials for acoustic applications have attracted increasing attention.

This work explores the role of different binding agents in the development of acoustic materials derived from used cigarette filters. The incorporation of binders is considered as a strategy to improve the mechanical integrity and handling of the samples, which are typically affected by the intrinsic heterogeneity of the raw material and the processing methods. At the same time, the addition of binders may alter the internal structure of the material, potentially influencing its sound absorption performance.

Several types of binders are evaluated, with particular attention to their impact on key acoustic properties. The study aims to identify trends relating to binder type and concentration with the resulting acoustic behavior, as well as to assess the balance between structural stability and acoustic efficiency.

Preliminary observations suggest that the selection and dosage of the binder play a critical role in determining the final performance of the material. Further work will complete the experimental assessment and consolidate the comparative analysis.

Keywords: *Cigarette butts, acoustical characterization, binders, sound absorption*

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1. Introduction

The valorization of waste materials as raw resources for the development of sustainable building products has gained increasing interest in recent years. Among the different waste investigated for this purpose, used cigarette butts represent an interesting yet challenging material due to their widespread availability and their cellulose acetate-based fibrous structure [1–3].

Previous research has demonstrated the potential of cigarette butt waste as a raw material to produce sound-absorbing materials. The acoustic behavior of the cellulose acetate fibers recovered from cigarette filters has been characterized, and subsequent studies have shown that samples manufactured from used cigarette butts can achieve significant sound absorption performance, with their acoustic response being influenced by parameters such as sample thickness and density [2–5]. These results support the feasibility of using cigarette butt waste in the development of alternative acoustic materials for building applications.

One of the main challenges associated with the manufacture of these materials is achieving sufficient cohesion between the recovered fibers. The incorporation of a binder can provide the structural stability required for handling and potential application in building systems. However, the binder is not an acoustically neutral component. Its incorporation may modify the internal structure of the material, affecting parameters such as porosity, density, and airflow resistance, which in turn can influence its sound absorption performance [6–8]. Therefore, the selection of an appropriate binder represents an important aspect in the development of acoustically functional composite materials.

Different types of binders have been investigated for

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fibrous materials, including conventional water-based adhesives and binders derived from renewable resources such as starch. White glue, typically based on polyvinyl acetate (PVA), has been used as a binding agent in fiber-based and waste-derived composite materials for building applications, where its contribution to the cohesion and structural integrity of the resulting panels and their acoustic performance has been investigated [9, 10].Starch-based binders have been successfully incorporated into fiber-based composites and building insulation materials, where their influence on the acoustic properties of the resulting materials has been evaluated [11–13].

In this context, the present study investigates the acoustic behaviour of samples manufactured from used cigarette butts using two different binders: white glue and cornstarch diluted in water at different concentrations. Their performance is comparatively evaluated to assess the influence of the binder on the sound absorption properties of the samples and to determine whether the use of a starch-based binder can provide comparable acoustic performance to that obtained with white glue.

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 [13].

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.

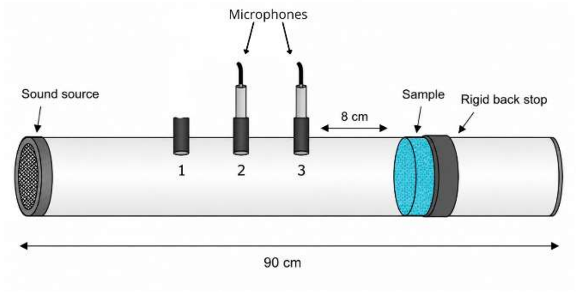

Figure 1. Diagram of sample placement for acoustic absorption measurements.

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

2.2 Materials

45 samples composed of disaggregated cigarette butts were analyzed with the 29 mm diameter holder. Characteristics of the sample set before the binder application are shown in Table 1.

Table 1. Characteristics of sample set before binder application.

Sample number	Thickness	Density	Binder
30	21-25 mm	71- 84 kg/m^3	White glue
15	19-23 mm	67- 81 kg/m^3	Starch

The acoustic behavior of the samples was characterized both before and after binder application. White glue diluted in water was applied to 30 samples at five different concentrations (10%, 20%, 40%, 60%, and 80% glue-to-water ratio), with six replicate samples prepared for each concentration. Cornstarch (soluble, S9765 from Sigma-Aldrich) diluted in water was applied to an additional 15 samples at five concentrations (5%, 10%, 20%, 30%, and 40% starch-to-water ratio), with three replicate samples prepared for each concentration.

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3. Results and discussion

As mentioned earlier, 45 samples with similar characteristics were analyzed using two different binders. White glue was applied to 30 samples at five different concentrations (10%, 20%, 40%, 60%, and 80% glue-to-water ratio), with six samples tested for each concentration, while cornstarch was applied to the remaining 15 samples at concentrations of 5%, 10%, 20%, 30%, and 40% starch-to-water ratio, with three samples tested for each concentration.

3.1 White glue as binder

Results of previous works show that increasing the binder concentration leads to a more pronounced reduction in the measured sound absorption coefficient, particularly for samples treated with solutions containing 60% and 80% binder. In contrast, samples treated with lower binder concentrations, such as 10% and 20%, exhibit only minor variations in their acoustic behavior, especially above 3000 Hz, where the differences become almost negligible. This reduction in acoustic performance at higher binder concentrations can be attributed to a loss of porosity, as the increased amount of binder results in a more compacted material, negatively affecting its sound absorption properties.

3.2 Cornstarch as binder

Figure 3 compares the average values of the different binder concentration samples. 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.

The results show that the application of cornstarch binder has a noticeable influence on the sound absorption behavior of the samples, particularly at low and medium frequencies. Compared with the samples without binder, the samples treated with cornstarch generally exhibit lower absorption coefficients in the frequency range below 2500 Hz. At higher frequencies, the differences become less pronounced, although the samples with 5% and 10% binder show a gradual increase in absorption, reaching values close to or slightly below those of the untreated samples. While higher concentrations show comparatively lower absorption on the whole spectrum.

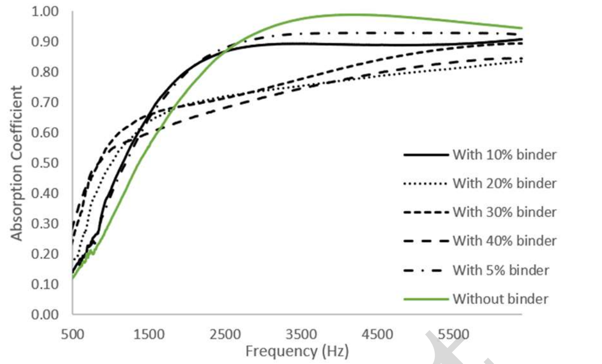

Figure 3. Average sound absorption coefficient before and after cornstarch application.

3.3 Binder comparison

By comparing the acoustic response of the samples before and after binder application, the study evaluates the effect of the binder type and concentration on the acoustic behavior of the material, as well as the reproducibility of the results.

It should be noted that not all sample groups are directly comparable, as comparisons between the two binders are only meaningful for concentrations at which the same binder-to-water ratio was applied. In the case of cornstarch, concentrations of 60% and 80% were not considered because the resulting mixtures became too solid and difficult to handle, preventing their proper application to the samples. Figure 4 presents the average absorption coefficient values for sets of samples with the same binder concentration.

The comparison between the two binders at the same concentrations reveals clear differences in their influence on the acoustic behavior of the samples. As shown in Figure 4, the samples prepared with white glue exhibit absorption curves that remain relatively close to those of the samples without binder for all the concentrations considered. At 10% and 20%, the differences are particularly small across most of the frequency range, while at 40% a moderate reduction in sound absorption can be observed, especially at higher frequencies. In contrast, the application of cornstarch produces a more pronounced modification of the acoustic response. At 10% starch, the absorption coefficient is already lower than that of the untreated sample over a broad frequency range, and this reduction becomes considerably more pronounced at 20% and 40%. In these cases, the samples show a progressive increase in absorption with frequency but do not reach the high absorption

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levels observed for the untreated samples or those treated with white glue.

These results suggest that, for the same binder concentration, cornstarch has a greater impact on the acoustic performance of the material than white glue. In addition to these acoustic differences, a significant amount of residual starch in the form of loose powder was observed after drying and handling the samples, which may represent a practical limitation for their potential application.

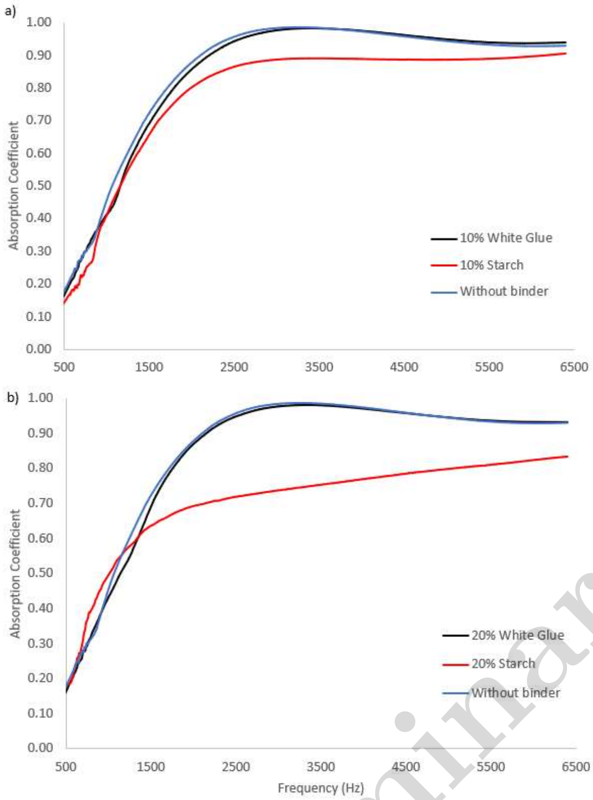
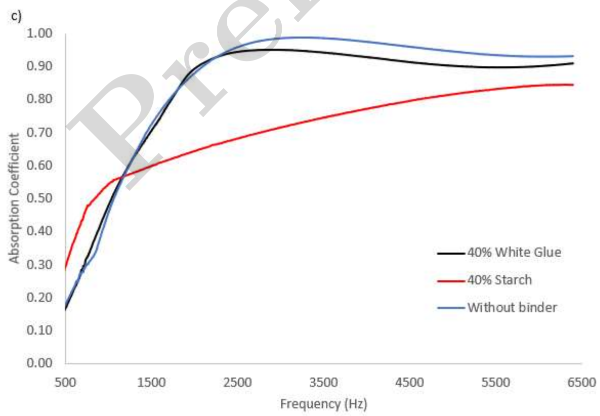


Figure 4. Comparison between same binder concentration.



4. Conclusions

The results obtained in this study demonstrate that the type and concentration of binder have a significant influence on the acoustic performance of materials manufactured from used cigarette butts. White glue generally preserves the sound absorption properties of the untreated samples, particularly at low concentrations, whereas the incorporation of cornstarch produces a more pronounced modification of the acoustic response, with a greater reduction in sound absorption as the starch concentration increases.

In addition to the acoustic performance, practical aspects related to the use of the binder must also be considered. The significant amount of residual starch powder observed after drying and handling the samples represents a limitation for its potential long-term application. Therefore, under the conditions investigated, white glue appears to be a more suitable option than cornstarch for maintaining the acoustic performance and practical usability of the material.

However, the differences observed between the two binders highlight the importance of binder selection in the development of acoustic materials based on recycled cigarette butts. Further research should therefore focus on investigating and comparing additional binders with different compositions and properties, particularly more sustainable alternatives, in order to identify the most suitable solution for achieving an optimal balance between acoustic performance, structural integrity, durability, and environmental impact.

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