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# EVALUATING RECYCLED PET FILAMENTS AS A SUSTAINABLE SOUND ABSORBING MATERIAL FOR BUILDING RETROFITTING

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## ABSTRACT

The development of sound absorbers made from PET fibres from recycled PET bottles presents a cheap and attractive solution for building retrofit applications. PET fibres of about 2-4 mm width are processed into a structure through random compaction and heat treatment, resulting in a sample that retains its shape. The normal incidence sound absorption coefficient of the samples was derived through measurements in an impedance tube, exhibiting potential effectiveness as a sound absorber. An innovative application of this material is the creation of transparent devices. This unique feature allows for sound attenuation without sacrificing natural light infiltration, addressing the common conflict between acoustic treatment and daylight access in architectural design. These items can serve as transparent partitions, sound absorbers, or design gadgets for lighting in areas near windows. Furthermore, using recycled PET fibres not only contributes to waste reduction but also promotes sustainability in construction, aligning the research's aim with contemporary environmental goals. By offering functional aesthetic solutions that enhance both acoustic comfort and visual appeal, these PET fibre-based sound absorbers hold potential for improving the habitability of retrofitted spaces.

**Keywords:** *Recycled materials, sound absorption, PET, building retrofitting*

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## 1. INTRODUCTION

The polymerisation process yields polyethylene terephthalate (PET), which involves two main chemical reactions: 1) esterification Reaction: this involves the reaction between terephthalic acid and ethylene glycol; 2) trans-esterification Reaction: The latter process involves the reaction between ethylene glycol and dimethyl terephthalate. In both processes, the resulting product is PET in the form of a molten, viscous mass. This can then be spun into fibres or extruded and moulded into various shapes. Commonly used for beverage packaging, polyethylene terephthalate (PET) bottles have found interesting applications. Their unique material properties, such as lightweight, durability, and ease of manipulation, make them suitable for acoustic applications. Mainly, researchers have explored the use of PET bottles in constructing sound-absorbing panels, resonators, and diffusers. These applications leverage the inherent characteristics of PET to enhance sound quality and control noise reflection in different environments. There may be some environmental advantages to using PET bottles in acoustics. For example, recycled PET bottles are used to make PET felt acoustic panels, which helps keep plastic trash out of landfills. This recycling method reduces the total environmental impact by using less water and energy compared to producing new fabric materials. The current manuscript explores the idea of using a material made from PET bottles that uses even less energy. PET felt panels also emit fewer volatile organic compounds (VOCs), which improves the quality of the air indoors. These panels' resilience and recyclability contribute to their sustainability and support a circular economy. Several studies have demonstrated the effectiveness of PET bottles in acoustic applications. One study investigated the acoustic properties of rigid polyurethane foam mixed with shredded PET bottle waste, finding that the composite material exhibited improved sound absorption properties [1]. Another study highlighted the use of PET felt acoustic panels, which are made from recycled PET bottles and offer enhanced acoustic performance along with environmental benefits [2]. Additionally, research has shown that PET bottle-based materials can be used to create effective sound diffusers. A study explored the use of PET bottles filled with different materials to create Helmholtz resonators, which were found to significantly improve sound absorption at specific frequencies [3]. Another investigation focused on the use of PET bottles in HVAC systems as Helmholtz resonators, demonstrating their potential to reduce annoyance from ventilation ducts [4]. These examples underscore the potential of PET bottles in creating sustainable acoustic solutions.

## 2. MATERIALS AND SAMPLES

The samples were prepared starting from plastic PET bottles fraied using a tool developed in the Applied Acoustics Laboratory (Figure 1). In this way, it was possible to obtain long PET filaments that were 0.5 mm thick and 4 mm wide.

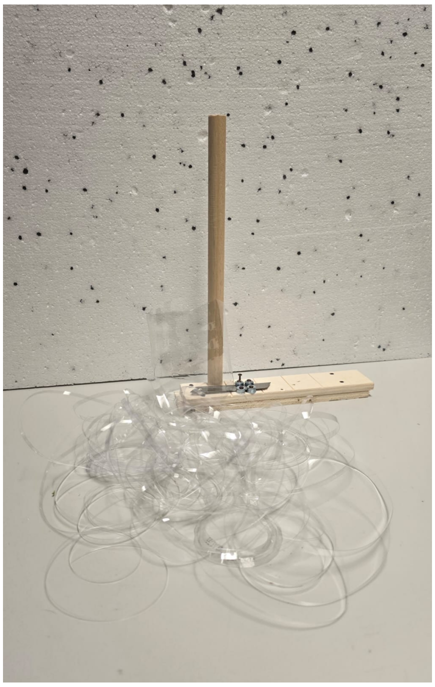

**Figure 1**. Tool used to obtain the PET filaments.

The filaments were placed inside the sample holder, an aluminium tube with a diameter of 46 mm and a length of 100 mm. Given the stiffness of the PET filaments, they cannot remain in place inside the tube because they tend to regain the original shape. For this reason, the PET filaments and the sample holder were placed inside an air fryer for 5 minutes at a temperature of about 80 °C. As shown in Figure 2, at the end of the thermal treatment, the sample could easily keep the desired dimensions and was ready to be tested in the impedance tube.

**Figure 2**. Example of a sample after thermal treatment and a 100 mm sample ready to be tested in the impedance tube.

## 3. EXPERIMENTAL SETUP

### 3.1 Impedance tube measurements

We tested the sample in a four-microphone impedance tube in accordance with the ASTM E2611 standard [5]. The applied technique allows the determination of the sound pressure and particle velocity at either side of the sample and thus its transfer matrix. As standard results, the normal incidence sound absorption, and the Transmission Loss (TL) of the sample are available at the end of the testing procedure. Nonetheless, the available results can be extended to other quantities, like the wave number, the speed of sound in the material, the surface impedance, and the characteristic impedance (inside the material). For the preliminary study presented in the current manuscript, only the sound absorption and the TL will be presented and discussed.

At one endpoint of the tube, a loudspeaker generates a wide-band white noise test signal. The tube mounts the sample for testing in its central section, sandwiched between two pairs of microphones. You can equip the tube's second endpoint with either anechoic or reflecting termination, enabling you to conduct tests with two distinct boundary conditions. Being able to compare signals from four microphones helps to separate the sound wave into the parts that are coming in and bouncing back on both sides of the sample. The custom-made impedance tube consists of two segments of length 1200 mm and internal diameter 45 mm. The corresponding cross-section allows keeping the plane-wave assumption valid up to about 3800 Hz. The source endpoint features a loudspeaker of 100 mm enclosed in a sealed volume, while the second endpoint can be connected to a rigid reflective termination or to an anechoic termination. The microphone ports for high-frequency measurements are spaced 45 mm apart; the ports for low-frequency measurements are spaced 500 mm. The sample can be placed in a separate segment of tube of the most appropriate length, which can subsequently be installed between the two measurement sections described above. Four BSWA Type MPA416 microphones housed in o-ring-equipped ports have been used. The diaphragm of the microphones is recessed with respect to the side wall of the tube. We connect the transducers to an OROS Type OR36 analyser, which measures the complex transfer functions between the microphones. During the measurements, the coherence function is also monitored to check that the signal-to-noise ratio is high enough over all the frequency range of interest. The white noise employed as a test signal is generated by the analyser itself.

For symmetric samples, only a single boundary condition for the tube termination is necessary. To avoid strong standing waves, we decided to apply a soft end boundary condition (as much absorbing as possible) in the case at hand. The standard procedure adopted in the laboratory implies switching the microphones positions to correct the transfer functions for amplitude and phase mismatches. This time a new calibration system was developed and tested so that all the necessary corrections between the reference microphone and the other three can be computed only once, avoiding having to repeat the measurement four times. The part of the tube representing the calibration section of the tube was 3D printed using a Bambu Lab A1 Mini with a Bambu PLA filament (Figure 3). The calibration device is placed in the central section of the tube, as in the sample case.

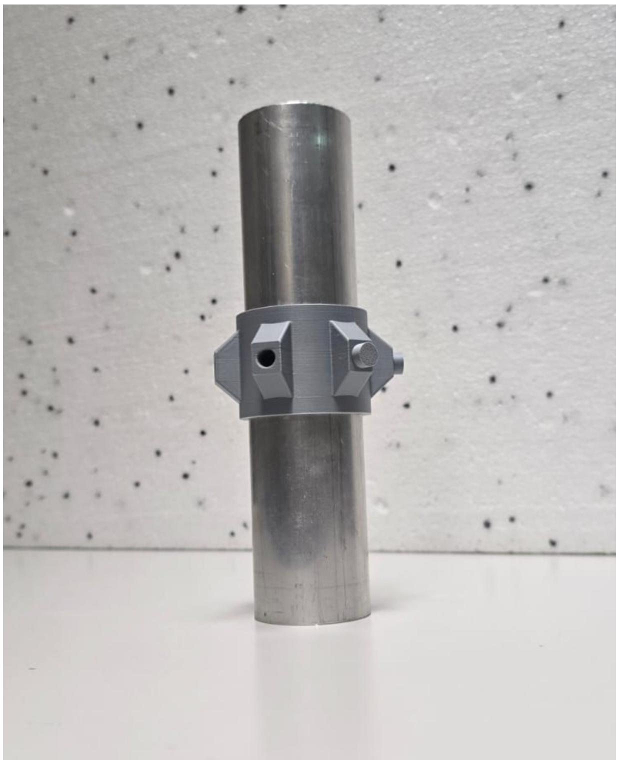

**Figure 3**. Calibration device.

## 4. RESULTS AND DISCUSSION

Figure 4 shows the normal incidence sound absorption coefficient for the tested sample. A sample inside a four-microphone impedance tube behaves like a 1/4 wavelength resonator. This means that at room temperature, for a 100 mm thick sample, an absorption resonance should occur at around 850 Hz. In the case at hand, the absorption coefficient curve shows a maximum at 610 Hz, meaning that the celerity of the sound wave is slowed down by the tortuosity of the material. As a matter of fact, the speed of sound in the material has an asymptotic behaviour, with a maximum celerity of 244 m/s (Figure 5). This allows us to determine also the tortuosity of the sample, which results in being around 2.

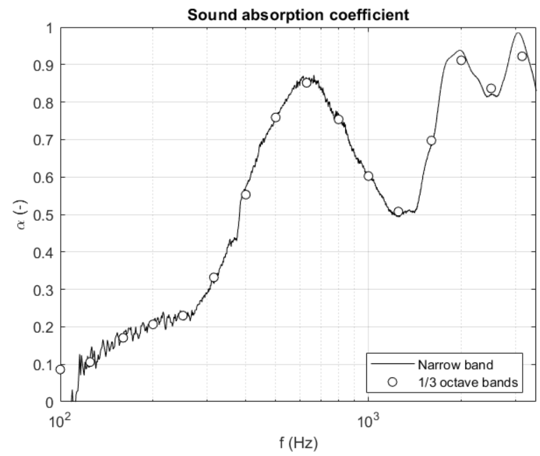


**Figure 4**. Normal incidence sound absorption coefficient.

The sound absorption graph shows good values also above 600 Hz, with a decrease of the coefficient around 1250 Hz ($\alpha = 0.5$) and then a sudden increase to values of 0.92, 0.84 and 0.92 for the 2000 Hz, 2500 Hz and 3150 Hz 1/3-rd octave frequency bands.

Finally, Figure 6 shows the TL values. The sample is so porous and light that the resulting insulation is lower than 6 dB in the investigated frequency range. for this reason, if the PET filaments must be used as soundproofing material, it would be necessary to improve the mass per unit area and lower the porosity.

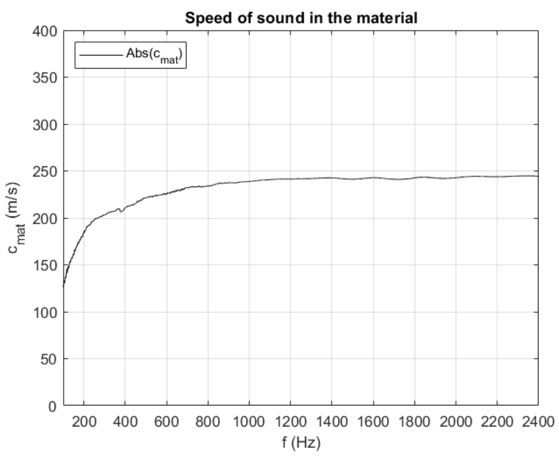


**Figure 5**. Speed of sound

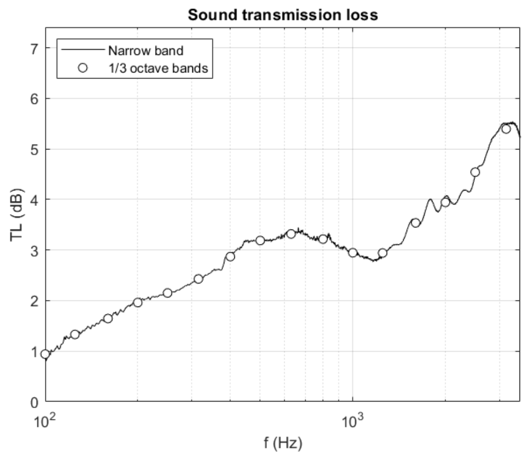


**Figure 6**. Transmission loss

## 5. CONCLUSIONS

The experimental analysis of PET filaments from plastic bottles using a four-microphone impedance tube has yielded interesting results regarding their acoustic properties. The findings indicate that PET filaments exhibit excellent sound absorption capabilities, making them a promising material for applications requiring effective noise reduction in confined spaces. The advantage of this type of material is that since it is transparent it allows the light to come through so it can be a potential solution for making windows less reflective. However, the sound insulation performance of PET filaments was found to be suboptimal, suggesting that while they can absorb sound efficiently, they are less effective at preventing sound transmission.

These results highlight the potential of PET filaments in environments where sound absorption is critical without sacrificing natural light infiltration, such as in acoustic panels for correction of rooms placed close to windows. Nevertheless, for applications where sound insulation is equally important, further modifications or alternative materials may be necessary to achieve the desired acoustic performance. Future research should focus on enhancing the sound insulation properties of PET filaments or exploring composite materials that can offer a balanced combination of sound absorption and insulation.

## 6. ACKNOWLEDGMENTS

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