USE OF SHREDDED TEXTILE WASTE AS MATERIAL FOR SOUND ABSORPTION

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Abstract. The issue of textile waste is a global concern, and Latvia, like many other countries, faces challenges related to the generation and management of textile waste. The textile industry is one of the largest contributors to environmental pollution, and the following points highlight the textile waste problem both in Latvia and on a global scale. Shredded textile waste, with its fibrous and porous composition, proves to be an excellent candidate for sound dampening materials. The irregular shapes and fine fibres inherent in shredded textiles create a structure that effectively absorbs sound waves, diminishing echoes and reducing overall noise levels. This inherent sound-absorbing property makes shredded textile waste an environmentally friendly alternative to traditional soundproofing materials. In addition to its acoustic benefits, the utilization of textile waste in sound dampening aligns with the principles of waste reduction and circular economy. The aim of this study is to develop a material with a good sound absorption capacity using textile waste. The textile used in the study was procured from a waste management firm located in North Vidzeme, Latvia. This company specializes in gathering uncontaminated textile waste from local residents. Shredding of textile waste was carried out using industrial shredding equipment. The particle size of the obtained textile fraction was 2X2 cm. Experiments with textile waste started in January 2024 in a laboratory. The created plates were tested for acoustic properties in the laboratory. The maximum sound absorption coefficient of the material obtained was 0.95 at a frequency of 4000 Hz. This is better than for synthetic mineral wool and slightly lower than for rock wool.

Keywords: sustainable materials, recycled textiles, environmental impact, waste management.

Introduction

Nowadays, there is a global trend towards the establishment of a sustainable and environmentally friendly economy, which is also observed in the European Union. Consequently, the utilization of recycled materials has become absolutely necessary [1; 2]. In the EU alone, a substantial amount of 9.35 million tonnes of textile waste is collected each year [3]. Numerous studies have proven that approximately 95% of this waste can be effectively recycled into valuable materials, thereby prolonging the lifespan of textiles [4]. Unfortunately, the actual textile recycling rates are quite low. Specifically, only about 25% of the textile waste in the EU is recycled. In recent years, the utilization of recycled materials in the field of acoustics has gained significant importance [5]. In order to achieve sustainability, scientists are now seeking novel, eco-friendly materials with sound absorption properties that are comparable to or even superior to those of commonly used materials derived from non-renewable sources [6; 7]. In essence, the reuse of waste materials clearly demonstrates its paramount significance in the era of the bioeconomy, as it diminishes the reliance on raw materials and contributes to the reduction of greenhouse gas emissions [8].

In an era characterized by the utmost significance of sustainability, industries are continuously engaged in the quest for innovative techniques to diminish waste and mitigate the impact on the environment. A specific domain of focus is the utilization of textile waste as an ecologically friendly filler to enhance the acoustic performance in partition systems [9]. As the world grapples with the consequences of excessive waste generation, repurposing materials in inventive manners not only alleviates the burden on landfills but also addresses the pressing need for environmentally conscious practices [10; 11]. Traditional partition systems often rely on conventional materials that may not prioritize sustainability or acoustic performance. However, by incorporating shredded textile waste into these systems, a dual advantage arises. Firstly, this approach grants textile waste a second lease on life that would otherwise be disposed of in landfills, thereby contributing to the reduction of environmental contamination and resource depletion. Secondly, it presents a promising solution for augmenting acoustic comfort within indoor environments, thereby addressing the mounting concern surrounding noise pollution and its adverse effects on health and well-being [12-14].

The aim of this study is to develop a material with a good sound absorption capacity using textile waste.

Materials and methods

The textile waste for the experiment was obtained from the Latvian North Vidzeme Waste Management Company, which collects textile waste from the population separately. After the textile waste was collected, it was manually sorted to reduce the presence of metal, plastic and other non-textile materials (see Fig. 1). An industrial shredder - Shred-Tech ST-25 was used to obtain the shredded textile mass for the experiment. After shredding the textiles, a fraction with the largest particle size of 2x2 cm was obtained (see Fig. 2).

Fig. 1. **Sorting of textile waste**

The industrial shredder for textile shredding has a collection of robust and flexible blades that are carefully designed to easily penetrate a variety of products and materials. These powerful blades have the ability to efficiently break down large volumes, transforming materials into smaller fragments. Each blade with a diameter of 19.7 cm provides sufficient force to effectively shred textiles (see Fig. 2).

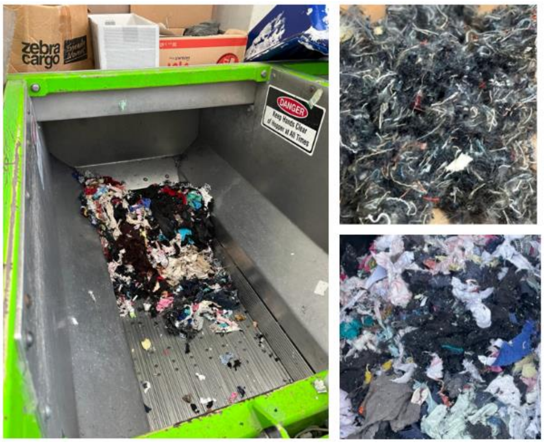

Fig. 2. **Shredding of textile waste**

To ensure that the shredded textile mass is a continuous material and holds together with uniform properties across its surface, the experiment continued by mixing the shredded textile with a binder. The ratio of textile to binder was 1:3 (Binder : Textile) (see Fig. 3). Spray adhesive was used as the binder. The spray adhesive comprises the following ingredients: 7% of rubber, 3% of dispersant, 25% of tackifying resin, 20% of varsol, 10% of chlorinated solvent and 35% of propellent.

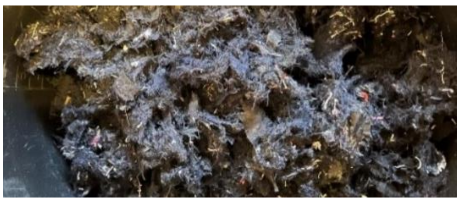

Fig. 3. **Shredded textile mixed with a binder**

In the next steps, a wooden mould measuring 150 x 250 mm and 30 mm thick was made and the shredded textile and binder mass were placed in it (see Fig. 4). Finally, a wooden cover was placed on the mould and clamped together with a vise. The drying time of the plate was 24 hours. After the binder had dried, the mould was opened and the plate removed.

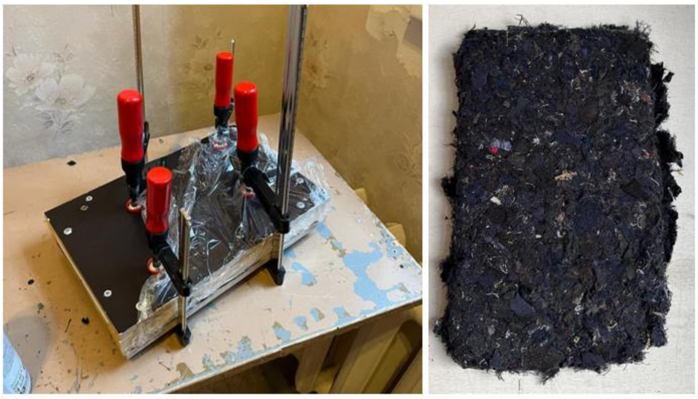

Fig. 4. **Wooden mould with formed material**

To assess the sound absorption capacity of the material made from shredded textile waste, we used an impedance tube AFD 1000 – the sound impedance tube (see Fig. 5). This specific equipment was used to accurately determine the sound absorption coefficients in the frequency range from 100 Hz to 4000 Hz. The measurement process started with cutting of a circular sample with a diameter of 40 mm. The prepared sample was then precisely inserted into the opening of the machine. Starting the measurement process, the machine determined the sound absorption coefficients at the specified frequencies.

Fig. 5. **AFD 1000 - sound impedance tube [15]**

During the testing process, the impedance tube made precise sound absorption measurements at different frequencies. Three samples (sample 1; sample 2; sample 3) were created from the material and sound absorption measurements were carried out on all samples. The samples were made of the same material and did not differ in composition or appearance. However, each sample represents a different area of the material formed. Sample 1 was taken from the centre of the material, sample 2 and sample 3 were taken from the edges of the material. Each sample was tested once, thus ensuring that the material created is tested three times.

This detailed measurement method facilitated the determination of an accurate sound absorption coefficient value. All necessary precautions were taken in this process and any influence of external factors was minimised. This was done in order to avoid errors, inaccuracies and to guarantee a reliable and authentic evaluation of the sound absorption data.

The Kruskal-Wallis test was applied for the statistical analysis of the data. Box plots were created using the Kruskal-Wallis test data. Box plots, also known as box and whisker plots, offer a concise visualisation method for understanding the numerical distribution of data. These graphs, consisting of a box plotting the interquartile range (IQR) and stretched bars indicating the range of the data set excluding outliers, provide important insights into the central tendency, distribution and possible outliers in the data. With the median line representing the mean and the quartiles marking the 25th and 75th percentiles, box plots facilitate comparisons between different groups or categories, making them an invaluable tool for data analysis and exploration.

Before the data analysis was carried out, all frequencies at which the sound absorption coefficient was determined were divided into three segments - low, medium and high frequencies. Low frequencies – 100 to 250 Hz; medium frequencies – 315 to 1000 Hz; high frequencies – 1250 to 4000. This was done to ensure a more accurate comparison of the data. The sound absorption coefficients of rock wool and mineral wool were used to analyse the data. The sound absorption coefficients of mineral wool were obtained from a publication by Jan Sikora and Jadwiga Turkiewicz [16]. The absorption coefficients for rock wool were obtained from Rockwool Ltd, a company specialising in the production of rock wool [17].

Results and discussion

The outcomes demonstrate average sound absorption coefficients across various frequencies ranging from 100 to 4000 Hz. The maximum sound absorption coefficient is detected at 4000 Hz, reaching a value of 0.95. Conversely, the minimum sound absorption coefficient is noted at 100 Hz, measuring 0.05. The newly created material exhibits optimal sound absorption within the frequency range of 1000 to 4000Hz (see Fig. 6).

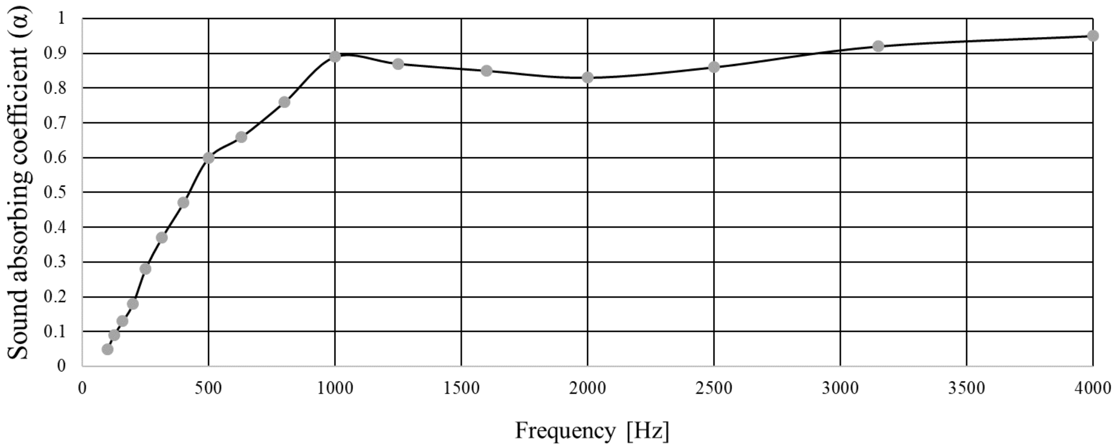

Fig. 6. **Average sound absorption coefficient of the material at the frequencies from 100 to 4000 Hz**

In the box plot of the data analysis at low frequencies, sample 1 and the rock wool sample have a larger amplitude that stands out among the other samples. Sample 1 has the highest mean and median. The lowest sound absorption is observed for rock wool and the highest for sample 1. The rest of the data can be seen in the data analysis in Figure 7.

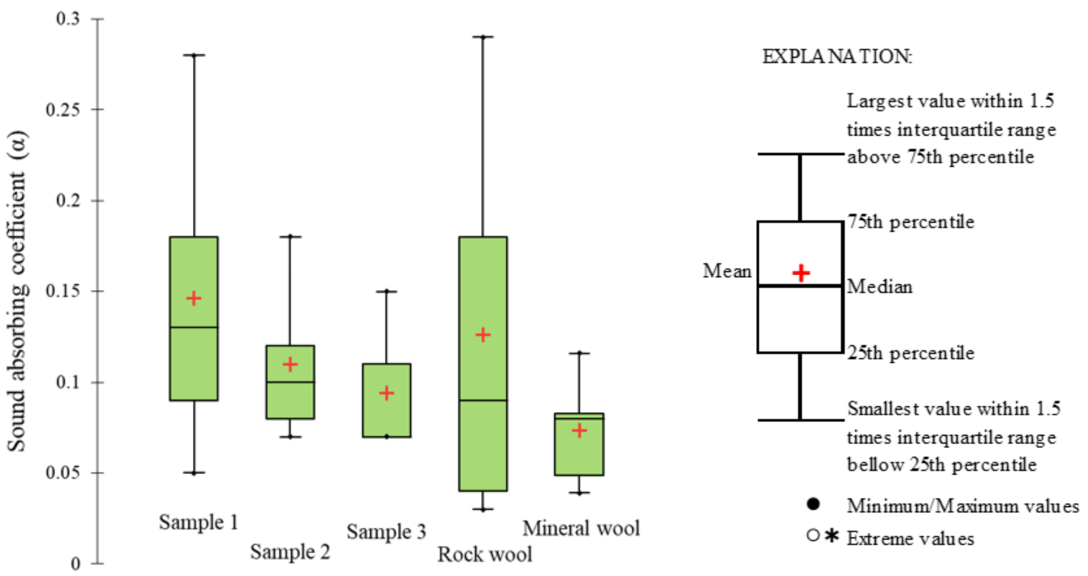

Fig. 7. **Sound absorption coefficients at low frequencies (100-250 Hz)**

In the box plot of the data analysis at medium frequencies, mineral wool sample has a larger amplitude, which stands out among the other samples. Sample 1 and rock wool sample has the highest mean and median. The lowest sound absorption is observed for sample 3 and the highest for rock wool sample. The rest of the data can be seen in the data analysis in Figure 8.

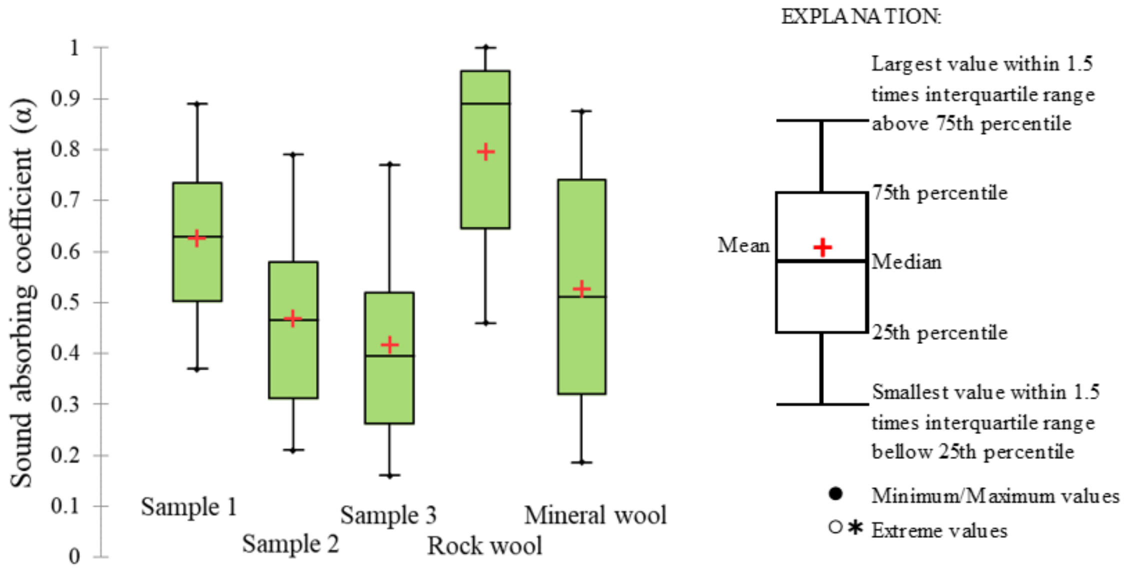

Fig. 8. **Sound absorption coefficients at medium frequencies (315-1000 Hz)**

The box plot of the data analysis shows that at high frequencies the rock wool sample has a larger amplitude which stands out among the other samples. The rock wool sample has the highest mean and median. The mineral wool sample has the lowest sound absorption and the rock wool sample the highest. Sample 1, sample 2 and sample 3 have very close sound absorption values which are slightly lower than the rock wool sample. The rest of the data can be seen in the data analysis in Figure 9.

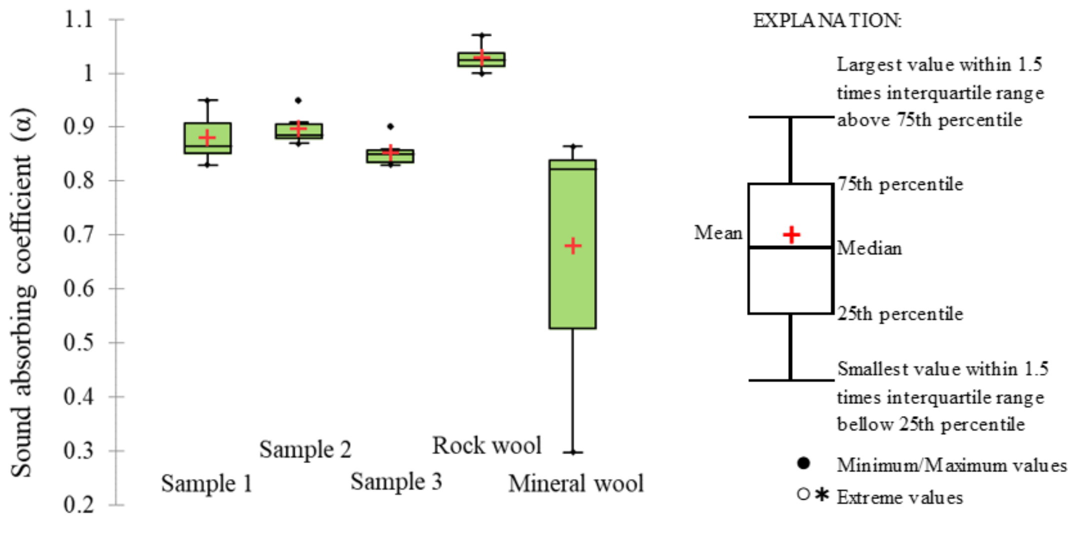

Fig. 9. **Sound absorption coefficients at high frequencies (1250-4000 Hz)**

Various studies have examined the sound absorption coefficients of sound-absorbing plates created using textile waste. Ružickij et al. discovered that composite panels composed of 100% wool waste fibres exhibited absorption coefficients exceeding 0.5 above 500 Hz and surpassing 0.9 above 1 kHz [18]. Vejelis et al. investigated waste generated from woollen yarn production and observed that soft boards manufactured from this waste showcased absorption coefficients ranging from 0.4 to 0.9 at a board density of 40 kg·m^{-3} [19]. In our research, the absorption coefficient at the optimal performance level (1000-4000 Hz) varied between 0.83 and 0.95, aligning with the utilization of non-separated textiles.

Conclusions

This research examined the acoustic absorption characteristics of the newly created material, emphasizing its efficacy in reducing sound waves across various frequencies. The findings reveal that the composition, density, and surface structure of the material play a crucial role in determining the effectiveness of sound absorption. Main conclusions:

1. The absorption coefficient for the developed material at the optimum performance level (1000-4000 Hz) ranged from 0.83 to 0.95, corresponding to the use of unseparated textiles.
2. At low frequencies (100-250 Hz), the textile waste material has a similar sound absorption capacity to rock wool.
3. At medium frequencies (315-1000 Hz), the sound absorption capacity of textile waste material is similar to that of mineral wool. Compared to rock wool, the sound absorption capacity of the material produced is slightly lower.
4. At high frequencies (1250-4000 Hz) the sound absorption of the textile waste material is slightly lower than that of rock wool and slightly higher than that of mineral wool.
5. The material developed from shredded textile waste can be used as a sound absorbing material.

The results are important for rural development as the material has a high sound absorption potential. Further development of the material will allow its use as a sound absorber in construction and in improving room acoustics. Most textile waste storage facilities are located outside cities. This can develop business and industry in rural areas.

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Author contributions

All the authors have contributed equally to creation of this article.

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