

Sustainable Sound Insulation Panel from Used Textile

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DOI: <https://doi.org/10.30880/mari.2026.07.01.012>

Article Info

Received: 1 October 2025
Accepted: 30 November 2025
Available online: 15 January 2026

Keywords

Textile waste, acoustic insulation,
noise reduction, recycled fabric,
sustainable panel.

Abstract

Textile waste and noise pollution are two pressing environmental and health issues. This study proposes a sustainable solution by developing Sustainable Sound Insulation Panels (S-SIP) using recovered textile waste such as cotton, polyester, and blended materials. The primary objective is to mitigate both noise pollution and solid textile waste by creating affordable, eco-friendly acoustic panels. The methodology involves selecting suitable textile waste, constructing sandwich and multilayer panel architectures, and evaluating their acoustic performance using the impedance tube method. Results reveal that the developed panels exhibit notable sound absorption capabilities, particularly in the mid-to-high frequency range, comparable to conventional acoustic materials. This research supports the principles of the circular economy and contributes directly to Sustainable Development Goals (SDGs) 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production), and 13 (Climate Action).

1. Introduction

In the modern era, industrial noise pollution and the growing volume of textile waste have emerged as major environmental issues [1]. Because products are not biodegradable, conventional acoustic insulation materials like fiberglass and polyurethane foam pose long-term environmental problems, are expensive, and are derived from non-renewable resources, notwithstanding their efficiency. However, despite the possibility of repurposing them in practical engineering applications, substantial amounts of post-consumer textile waste are frequently dumped in landfills. These related problems highlight the need for cost-effective and environmentally friendly sound insulation options, especially compact interior spaces like classrooms, dorms, and low-income housing.

Textile materials, especially cotton, polyester, and mixed fabrics, are intriguing options for acoustic absorption because of their distinct physical properties. Cotton's soft, porous, and fibrous nature makes it easier for sound waves in the mid-to-high frequency range to be effectively absorbed [2]. Blended textiles provide a variety of qualities, while polyester adds strength and durability [3]. Multi-layered and sandwich-style panel constructions have been found to improve acoustic performance by boosting internal reflection and sound energy dissipation. Nevertheless, most of the current research focuses on large-scale industrial applications or expensive fabrication techniques that are not feasible for local noise control or community use [4].

The goal of this project is to create and assess a sandwich-structured sound-insulating panel using only recovered textile waste. To make the panels, four to eight sheets of cloth are layered as the core, sandwiched between two outer layers, and fastened to hardwood frames that measure 300 mm by 300 mm. In compliance with ISO 10534-2, acoustic performance is evaluated by measuring sound absorption coefficients (α) in the frequency range of 100 Hz to 1600 Hz using an impedance tube [5]. Each panel undergoes three repetitions to guarantee accuracy and dependability [6].

The objective of this study is to determine the ideal panel configuration in terms of thickness and material type, as well as to evaluate the sandwich structure's usefulness, robustness, and affordability. By converting textile waste from landfills into useful acoustic panels that can be made locally with little resources, this project also advances the idea of environmental sustainability. More generally, this study is in favor of the Sustainable Development Goals (SDGs), namely SDGs 11 (sustainable cities and communities), 12 (responsible consumption and production), and 13 (climate action). In Fig. 1, the entire figure of sustainable development goals is displayed.

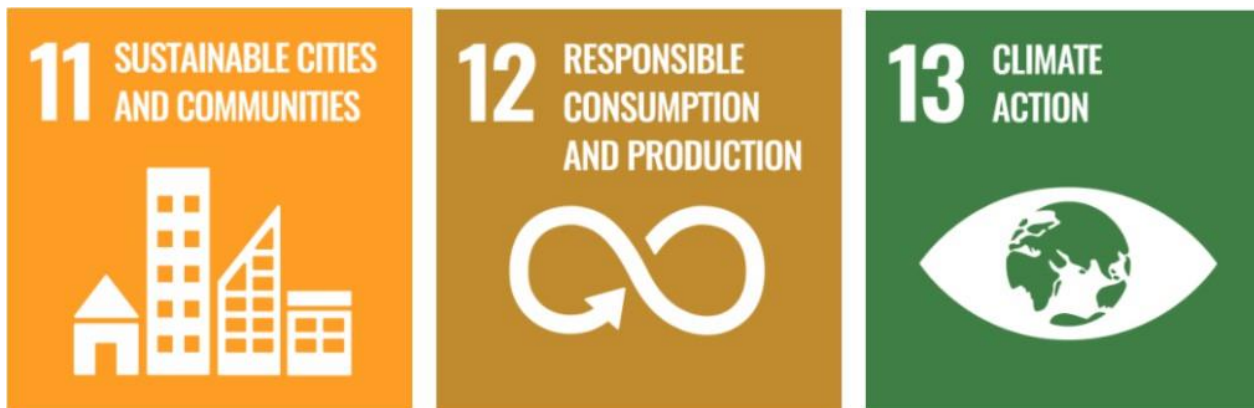


Fig. 1 Sustainable Development Goals

2. Methodology

In this project, a sandwich-structured soundproofing panel made entirely of recycled cotton fabric is built and tested. In comparison to a conventional layered arrangement, the sandwich construction offers superior mechanical stability and can increase sound absorption efficiency through the phenomena of twofold reflection between the material layers [7]. Furthermore, cotton cloth was selected as the primary material due to its soft, fibrous, and porous structure, which improves the absorption of sound waves. Cotton fabric is a good material for creating affordable and sustainable soundproofing panels since it is readily available from textile waste, recyclable, and environmentally benign. Material selection, initial testing of the layered cotton fabric, sandwich panel assembly, and acoustic test implementation are the primary components of the implementation technique.

2.1 Material Selection

100% cotton fabric that was sourced from surplus textiles and old apparel served as the primary material for this study. Because of its inherent fibrous and porous qualities, as well as its capacity to absorb sound waves, particularly those in the mid- to high-frequency range, this fabric was selected. Cotton is an excellent material for insulating interior spaces due to these qualities.

Cotton fabric collected from consumer trash was washed, dried, and cut to a standard size of 300 mm by 300 mm before usage in order to make assembly and installation in the panel frame easier. To ensure uniformity in the results, only fabrics with uniform thickness and no synthetic materials were chosen. Every fabric was ordered based on how many layers were needed for each panel layout.

2.2 Initial Experiments with Layered Cotton Fabrics

Preliminary experiments on cotton cloth layered without a frame structure were carried out prior to the sandwich panel's manufacture. The objective was to determine the ideal number of layers for effective sound absorption. In figure 2 shows that sound insulation panels were developed using recycled textiles and three configurations were test panels with 4 layers, 6 layers, and 8 layers of used fabric. Impedance tubes operating in the 100 Hz–1600 Hz frequency range were used to test the samples. The 6-layer cotton structure was the greatest option for use in the building of real sandwich panels, according to the results, as it offered the best sound absorption in the 315–400 Hz range. The layers that have been split up into multiple sections are depicted in Fig. 2.



(a) (b) (c)
Fig. 2 Sample layers used fabric for the test (i) 4 layers, (ii) 6 layers, (iii) 8 layers

2.3 Sandwich Structure Panel Construction

The panels are made in a sandwich design, with two extra layers of cotton fabric on the outside to improve surface polish and mechanical strength, and six layers of cotton fabric in the center, which serves as the primary absorption zone [8]. Using industrial staplers and eco-friendly adhesives, all layers of fabric are carefully put together on a 300 mm x 300 mm hardwood frame to guarantee the panel structure's stability and longevity during the test. To support sustainability principles, this design was chosen based on the results of preliminary testing on layered cotton fabric, which demonstrated optimal performance. Practical considerations such as light weight, low construction cost, ease of installation, and material recyclability were also taken into account.

2.4 Evaluation of Acoustic Performance

In accordance with the international standard ISO 10534-2, which is a standard procedure for calculating the normal incidence sound absorption coefficient (α), the finished panels were tested using an impedance tube system. The acoustic pressure reflected and transmitted when sound waves hit the panel surface is recorded by this system using two microphones installed in a tube. It is possible to precisely determine the α value for every frequency by using specialized software that is connected to the impedance tube. The test frequency range, which spans the range of typical indoor sounds including fans, air conditioning, voice, and appliance noise, is 100 Hz to 1600 Hz. Three tests were conducted on each panel configuration to guarantee the accuracy and dependability of the findings. The actual performance of each design was evaluated in the study using the average value of these three repetitions. To prevent outside noise interference from influencing the measurement results, the test was carried out in a controlled, anechoic room. According to the picture shown in Fig. 3, it is equipment for evaluating soundproof cotton.

The 6-layer arrangement absorbed sound more effectively than 4 or 8 layers, according to preliminary test results on layered cotton fabrics, particularly at frequencies between 315 and 400 Hz. Because it encompasses the basic sound of human speech, electrical devices, and indoor environmental noise from fans and air conditioners, this frequency range is important. It was discovered that the 8-layer panel tended to be too dense, allowing sound waves to be reflected before it could be entirely absorbed, while the 4-layer panel was too thin to efficiently capture sound energy. As a result, six layers were thought to be the best arrangement for balancing thickness, absorbency, and fabrication simplicity [9].

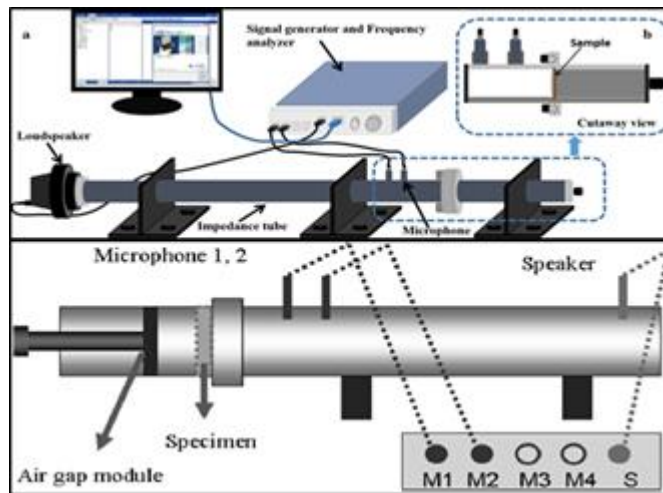


Fig. 3 An impedance tube (Kundt's tube)

The sandwich construction panel with a 6-layer cotton core demonstrated consistent mid-frequency sound absorption capability, with double reflection between the inner layers contributing to its enhanced efficacy. This design preserved the panel's physical rigidity and structural stability while simultaneously increasing sound absorption efficiency. Fig. 4 illustrates how to create a good model by going through each phase of the procedure.

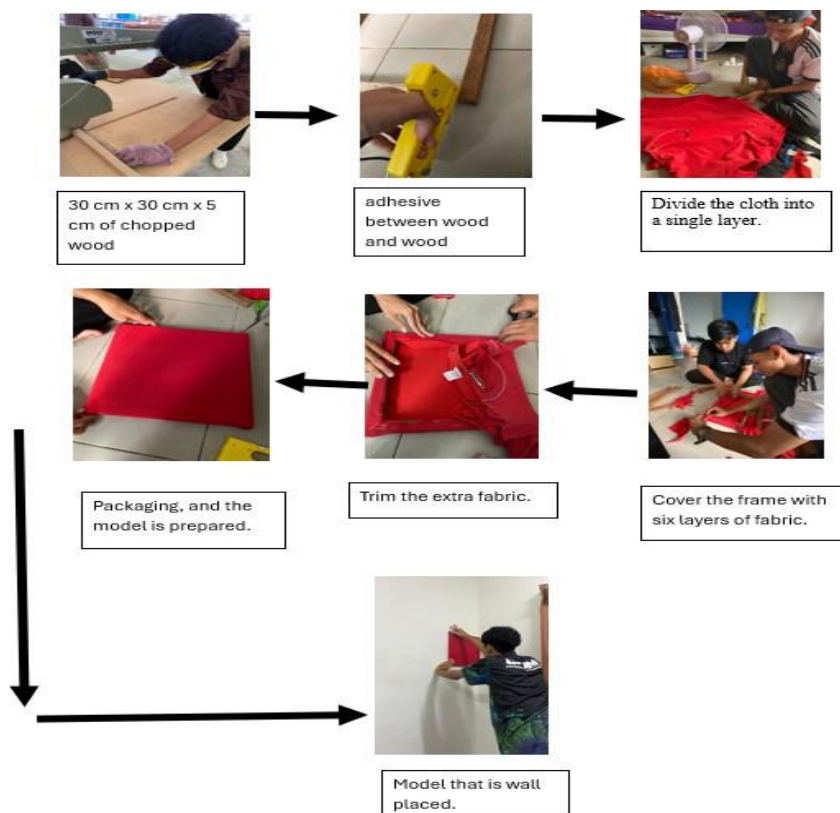


Fig. 4 The entire process of creating panels

3. Results and Discussion

The difference in sound absorption coefficients for recycled cotton panels made with 4, 6, and 8 layers, tested at frequencies between 100 Hz and 400 Hz, is shown in Fig. 5. The comparison demonstrates how layer thickness, especially in the mid-frequency band, affects acoustic performance.

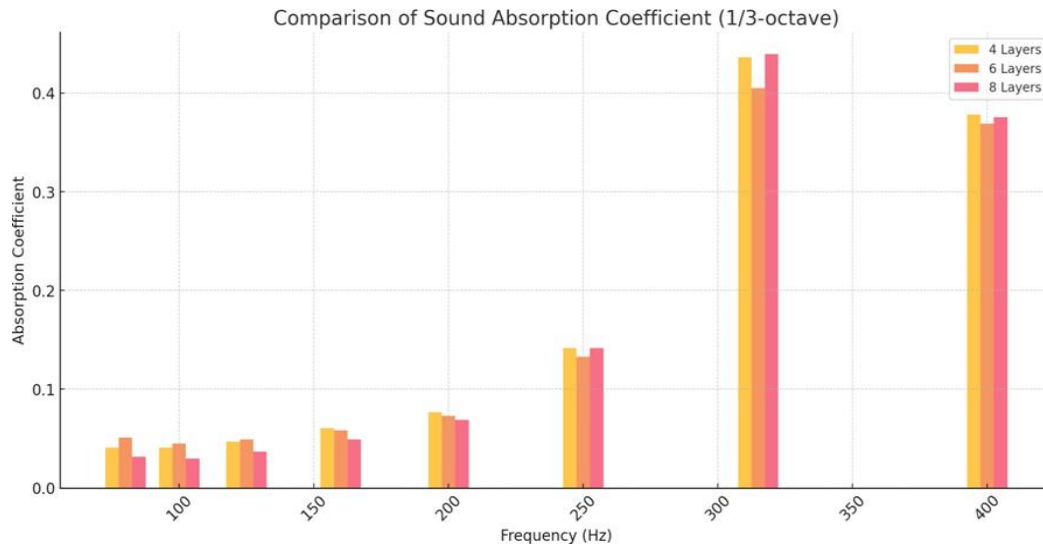


Fig. 5 Sound Absorption Coefficient

Comparing the sound absorption coefficients of panels constructed with 4, 6, and 8 layers of recycled cotton fabric over a frequency range of 100 Hz to 400 Hz is shown in Figure 3. Generally speaking, the absorption coefficient rises with frequency, which is consistent with the way porous materials typically behave, where shorter wavelengths allow for greater absorption at higher frequencies.

All three panel types have modest absorption coefficients (between around 0.02 and 0.08 at lower frequencies (100–200 Hz). At these frequencies, the 6-layer panel performs marginally better than the others, while the 8-layer panel performs somewhat worse. This implies that the number of layers has no discernible influence on absorption in low-frequency ranges since the relatively thin panel structures are unable to efficiently absorb the long wavelengths.

However, after 250 Hz, there is a discernible rise in absorption. The sound absorption of the 6-layer and 8-layer panels increases significantly, especially at 315 Hz and 400 Hz. For all 6 and 8 layers, the absorption coefficient reaches roughly 0.45 at 315 Hz, showing very good sound absorption performance. Increased layering enhances acoustic performance, particularly in the mid-frequency range, as seen by the 4-layer panel's constant lower absorption throughout all frequencies.

This behavior is explained by the multi-layered panels' increased density and thickness of material, which improves internal friction and sound energy dissipation and scattering. Better sound attenuation results from the layered structure's increased surface area and air pockets for interaction. Classrooms, libraries, dorms, and enclosed workspaces are among the practical applications for this design because of its reliable performance and affordable production costs.

4.0 Conclusion

The potential of recycled cotton fabric as a crucial component in the creation of environmentally friendly sandwich-structured soundproofing panels is methodically investigated in this study. Six layers of recycled cotton are used as the core material in the sandwich construction of the panels, which are then encased between two outer layers and fixed onto straightforward timber frames. The use of simple equipment and supplies like glue and staples keeps the building process affordable and widely available.

The first tests are conducted using a standardized experimental protocol, specifically measuring the sound absorption coefficients in accordance with ISO 10534-2. An impedance tube is used to test panels in the frequency range of 100 Hz to 1600 Hz. The six-layer panel performs the best among the studied configurations, especially in the frequency range of 315 Hz to 400 Hz, which is crucial for reducing indoor speech-related noise and environmental disturbances [9].

In addition to providing a clean look, physical durability, and ease of installation, the finished panel design, which has a six-layer cotton core in a sandwich structure, consistently absorbs mid-frequency vibrations. Reusing recovered textiles directly reduces waste, which is consistent with ecologically friendly building techniques and sustainable development goals.

This low-cost panel presents a practical and effective noise reduction solution for communities, particularly for applications in classrooms, libraries, temporary structures, and other indoor spaces that require acoustic control without the high cost of commercial soundproofing materials. With future enhancements in fire

resistance or water protection, this panel holds strong potential as a sustainable, economical, and functional alternative for wider adoption in building design.

Acknowledgement

This research is made possible through monetary assistance from Centre for Diploma Studies, Universiti Tun Hussein Onn Malaysia via the final year project fund allocation.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Muhammad Nabil bin Mohd Azri, Wan Muhammad Alimie bin Wan Ali, Muhammad Nur Luqman bin Darus; **data collection:** Muhammad Nabil bin Mohd Azri, Wan Muhammad Alimie bin Wan Ali, Muhammad Nur Luqman bin Darus; **analysis and interpretation of results:** Muhammad Nabil bin Mohd Azri, Wan Muhammad Alimie bin Wan Ali, Muhammad Nur Luqman bin Darus; **draft manuscript preparation:** Muhammad Nabil bin Mohd Azri, Wan Muhammad Alimie bin Wan Ali, Muhammad Nur Luqman bin Darus, Hairuddin bin Mohammad. All authors reviewed the results and approved the final version of the manuscript.

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