



# Analysis on Sound Reduction and Transmission Loss Using Compress Acoustic Chamber

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## ABSTRACT

Noise pollution has increasingly affected public health due to its impact on productivity, hearing loss and overall quality of life. Acoustic insulation is an effective and practical solution to reduce unwanted noise in various environments. However, most acoustic chambers used to evaluate insulation performance are large, costly and require specialized facilities. Therefore, this study aimed to design, construct and validate a reduced size acoustic transmission chamber according to ISO 10140-5 guidelines. The chamber was used to measure sound insulation properties of commonly available materials such as polyester felt and expanded polystyrene (EPS) foam. Testing methods involved recording Sound Pressure Level (SPL), Sound Transmission Loss (STL) and transmission coefficient across frequencies from 100 Hz to 5000 Hz. The study concluded that scaled-down acoustic chambers can reliably evaluate acoustic materials and confirmed that thickness, density and internal material structure significantly influence sound insulation effectiveness.

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## INTRODUCTION

Noise pollution is a growing concern in both industrial and residential settings due to its adverse effects on human well-being, including sleep disruption, stress, reduced concentration, and hearing loss. As environments become denser and more complex, the demand for effective and accessible acoustic insulation solutions continues to increase. Among available approaches, material-based sound insulation remains one of the most practical methods, relying on materials that absorb, reflect, or dampen sound waves. However, evaluating their performance typically requires standardized testing under controlled conditions.

Conventional testing is conducted using full-scale acoustic transmission chambers in accordance with standards such as International Organization for Standardization ISO 10140-5. While accurate, these facilities are costly, space-intensive, and often inaccessible to smaller institutions. To overcome these limitations, reduced-size transmission chambers have been proposed as a more practical alternative. Their

effectiveness, however, depends on proper control of acoustic factors such as modal behaviour, leakage, and scaling effects.

This study presents the design and validation of a reduced-size acoustic transmission chamber for educational and experimental use. The system consists of a source chamber, receiving chamber, and a central test interface, designed to minimize standing waves, improve diffusion, and prevent leakage. Constructed using lightweight and cost-effective materials, the chamber adopts a scaled geometry and non-parallel surfaces to enhance measurement reliability.

To evaluate its performance, polyester felt was tested under varying thicknesses and mass conditions using pink noise excitation. Acoustic performance was assessed using Sound Pressure Level Difference (SPLD), Sound Transmission Loss (STL), and Transmission Coefficient ( $\tau$ ) across a frequency range of 100 Hz to 5000 Hz. The results demonstrate that the proposed chamber provides consistent and meaningful measurements, with improved insulation performance observed at greater material thickness. Overall, the study confirms that a reduced-size acoustic transmission chamber can serve as a reliable, cost-effective alternative to full-scale facilities for material insulation testing.

## LITERATURE REVIEW

The properties of sound include frequency, wavelength, and amplitude. Frequency, measured in hertz (Hz), determines the pitch of the sound, with higher frequencies producing higher-pitched tones, while wavelength is the spatial distance over which the wave repeats itself and is inversely proportional to frequency. Amplitude measured in decibels (dB) is the maximum displacement of particles from their equilibrium position during oscillation and determines the sound's intensity or loudness. Sound can be categorized into audible sound (~16 Hz to 16 kHz), infrasound (<16 Hz), and ultrasound (>16 kHz), each with distinct applications ranging from communication to industrial uses [1].

### A. ISO and ASTM Standards

The ISO 10140 standard, particularly ISO 10140-5, outlines laboratory installation procedures, test room specifications, and measurement techniques for determining the airborne sound insulation of building elements. It provides detailed guidance on test conditions, microphone placement, room geometry, and frequency band resolution. ISO 10140-5 also recommends specific configurations such as minimum chamber volume (50 m<sup>3</sup>), surface diffusion, and microphone-source placement to ensure accurate data collection and minimal modal interference [2].

Similarly, ASTM E90 describes the procedures for generating and capturing SPL differences, while ASTM E413 defines the calculation of Sound Transmission Class (STC), a simplified numerical representation of STL. Although ASTM standards are practical for construction applications, ISO 10140 allows for more precise frequency-based analysis, which is useful for detailed acoustic studies.

### B. Reduced Chamber Design

Standardized transmission loss chambers are large and expensive, often impractical for academic or small-scale testing. ISO 10140-5 recommends full-scale rooms with volumes above 50 m<sup>3</sup> to ensure reliable results, particularly in the low-frequency range. These rooms are designed with non-parallel walls and diffusive surfaces

to encourage uniform sound fields and reduce modal peaks. To make acoustic testing more accessible, several studies have investigated reduced-scale chambers. When geometrically scaled (e.g., 1:4 or 1:8 ratios), small chambers can replicate the acoustic behavior of full-size rooms, provided that wave interaction, reflection, and absorption conditions are preserved. Key considerations include chamber shape, wall composition, and seal integrity.

Balmori et al. successfully demonstrated the use of a reduced-scale chamber for comparative insulation studies using solid panels. Their chamber was constructed with layered materials and tested using pink noise across a controlled frequency range by developing a 0.11 m<sup>3</sup> scaled chamber using a wood-based structure, showing that valid frequency trends can still be obtained under scaled-down conditions. [3]. This project adopts similar methods, using a 0.12 m<sup>3</sup> chamber constructed from plywood and acoustic foam, designed with a trapezoidal geometry to suppress standing wave interference.

### C. Acoustic Materials – Porosity and Thickness

Porosity is a critical parameter that affects the acoustic properties of materials in terms of sound reduction, insulation, and transmission. Porous materials are defined as those that contain interconnected voids that enable the entry of sound waves and their dissipation by mechanisms like viscous friction and thermal conduction.

Another major factor influencing STL include material thickness since this would determine how the sound waves will be intercepted. Studies analysed the relationship between material thickness and STL, using birch plywood with different thicknesses. It was found that increasing the thickness increases the sound transmission loss, majority within the range of 600-800Hz. However, these results showed diminishing returns on performance beyond a certain thickness. This was due to other factors like material density and porosity playing an important role in acoustic performance.

### D. Modal Behaviour and Diffusivity

In smaller chambers, modal behaviour significantly influences acoustic measurements. Modal In smaller chambers, modal behaviour significantly influences acoustic measurements. Modal resonances cause amplification or cancellation of sound energy at specific frequencies depending on the dimensions and surface reflections of the chamber. These effects are more pronounced below 400 Hz in small volumes due to the longer wavelengths relative to room dimensions.

A major challenge in reduced chambers is achieving a diffuse field, an evenly distributed sound energy condition assumed in most transmission loss equations. ISO 10140-5 addresses this by recommending non-parallel walls and the inclusion of surface absorbers. Without such modifications, certain frequency bands may experience skewed SPL values due to constructive or destructive interference. resonances cause amplification or cancellation of sound energy at specific frequencies depending on the dimensions and surface reflections of the chamber. These effects are more pronounced below 400 Hz in small volumes due to the longer wavelengths relative to room dimensions. A major challenge in reduced chambers is achieving a diffuse field. ISO 10140-5 addresses this by recommending non-parallel walls and the inclusion of surface absorbers. Without such modifications, certain frequency bands may experience skewed SPL values due to constructive or destructive interference. Figure 1 shows the types of modal behaviour in acoustic measurements.

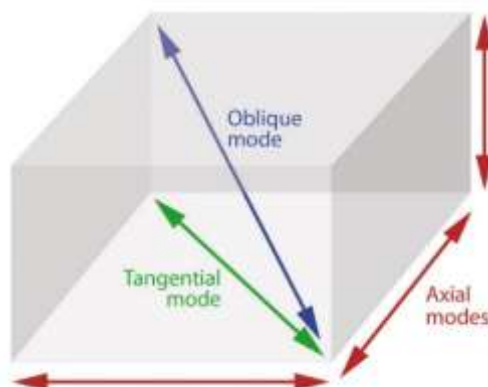


Figure 1. Types of modal behaviour.

#### E. Research Gap

Significant research in soundproofing technologies and acoustic material studies tend to focus on high-cost, advanced materials like composites, perforated panels, and aerogels. These material studies are integral in advancing the field of sound and acoustics but are usually dependent on sponsorships or research grants and are out of reach for low-budget applications. On the other hand, commonly available materials have remained underexplored with respect to their sound reduction properties under controlled conditions. Additionally, there is a lack of standardized small-scale testing frameworks for these materials, which creates inconsistencies in evaluating their performance. While standards provide guidelines for acoustic testing, much of the research emphasizes idealized conditions or advanced setups, leaving a gap in practical, low-cost chamber designs tailored for everyday materials. This project attempts to fill this knowledge gap by investigating the acoustic properties of some commonly found materials, focusing on their cost-effectiveness and practicality.

## METHODOLOGY

#### A. Chamber Design

The acoustic transmission chamber was designed based on reduced-scale ISO 10140-5 criteria. It consisted of two compartments, a source room and a receiving room. They are separated by a centrally clamped interface for test material installation. Each compartment was constructed from 12 mm plywood panels, internally lined with 50 mm acoustic foam to reduce internal reflections and external leakage. Figure 2 shows design of open chambers.



Figure 2. Open Chambers. Source Chamber (left), Receiving Chamber (right).

The receiving chamber adopted a trapezoidal geometry to minimize standing waves, and the internal volumes were approximately 0.12 m<sup>3</sup> for both compartments, corresponding to a 1:8 scaling ratio relative to standard test rooms. To allow material testing, a gap was created between the chambers, reinforced with rubber padding and compressive lips to create a tight seal and reduce leakage. The interface clamp was designed to accommodate materials of varying thickness while ensuring repeatable edge alignment. Figure 3 shows two chambers clip together in between.



Figure 3. Chamber being clip together with the sample in between

#### B. Sound Source and Microphone Setup

The sound source was a Visaton FR87 speaker, mounted flush inside the source chamber wall, facing the test material as shown in Figure 4. It was selected for its wide frequency response and low distortion in small enclosures. The receiving SPL was measured using a MicW i436 omnidirectional microphone, positioned at a fixed location in the receiving chamber as seen in Figure 5. Pink noise was used as the excitation signal, generated using Room EQ Wizard (REW). This broadband signal allowed frequency-specific evaluation across 1/3 octave bands. Environmental conditions were held constant during testing. All tests were performed in a quiet indoor environment to minimize background interference.

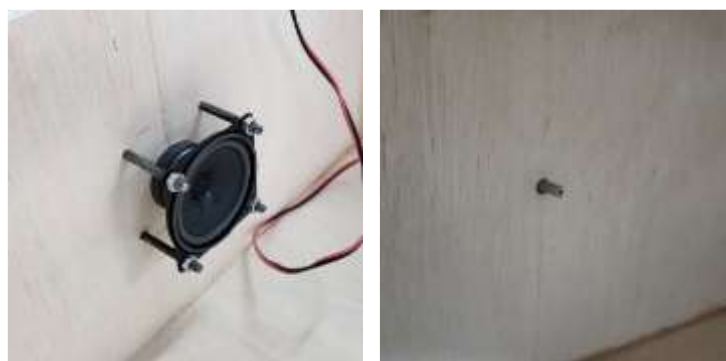


Figure 4. Speaker (left), & Microphone (right) Mount.

#### C. Validation of Chamber

To ensure the experimental results are reliable and consistent, the acoustic transmission chamber was validated using four key techniques adapted from ISO 10140-5 and previous research. These validation steps confirmed the chamber's suitability for transmission loss testing within a reduced-scale configuration. The first step involved assessing the background sound leakage between the source and receiving compartments. Following the approach, pink noise was played in the source chamber with no material

sample installed, and SPL was measured in the receiving chamber. A significant SPL difference ( $>30$  dB) indicated that the chamber structure provided sufficient acoustic separation for reliable transmission loss measurement.

#### D. Material Testing

The Polyester Felt were mainly used alongside with EPS Foam was chosen for their distinct and contrasting acoustic properties as shown in Figure 5. It is a dense, flexible material with excellent sound absorption properties, particularly in mid-frequency ranges. Its fibrous structure allows it to dissipate sound energy effectively, making it a practical choice for interior noise control solutions such as wall linings and furniture padding. Table 1 show the experimental configuration for sound absorption.



Figure 5. Polyester Felt

Table I: Experimental Configurations

Comparison	Constant	Variable	Code
Material Thickness	Felt	20mm	FE20
		40mm	FE40
		60mm	FE60
Material mass	200g	Felt	FE200
		Foam	FO200

#### E. Testing Procedure

The test itself begins with determining the baseline sound level within the chambers. This is done to both determine the sound isolation of the chamber as well as to collect the initial SPL of the chamber without material. Pink Noise is played through the Visaton FR87 speakers in the source room while the MicW-i436 microphone in the receiving room measures the sound pressure levels (SPL) in both the source and receiving rooms without the material in place. Data of the SPL is simultaneously collected in 1/3 octave bands across the 100Hz to 5000Hz range. These readings provide a baseline for comparison.

The test material is then clamped between the two chamber sections. Pink noise, which has equal energy per octave will be used again as the sound source. The SPL will be recorded in the source room and receiving room with the material in place. This step will be repeated for all four experimental comparisons with the same duration and sound volume to ensure accuracy and the data averaged. The sound source will cover the same

frequency range of 100Hz to 5000Hz, a range that encompasses most practical noise control applications.

#### F. Data Collection & Analysis

The primary data collected from the experiments will be of SPL from both the source and receiving rooms. These readings will be used to calculate the Sound Transmission Loss (STL), Sound Pressure Level Difference (SPLD) and Transmission Coefficient. This will provide a quantitative method in comparing and conducting comprehensive analysis on each material in very test configuration. The equations to calculate the SPLD, STL and Transmission Coefficient can be seen below:

Formula for STL Calculation:

$$STL = \log_{10} \left( \frac{P_{incident}}{P_{transmitted}} \right) \quad (1)$$

where:

$P_{incident}$ : SPL in the source room without the material.

$P_{transmitted}$ : SPL in the receiving room with the material in place.

Formula for SPLD Calculation:

$$SPLD = SPL_i - SPL_m \quad (2)$$

where:

$SPL_i$  is the SPL in the chamber without material.

$SPL_m$  is the SPL in the chamber with material.

Formula for Transmission Coefficient Calculation:

$$\tau = 10^{-\frac{STL}{10}} \quad (3)$$

where:

$\tau$  is the transmission loss or % of energy transmitted.

$STL$  is the measured and calculated STL of the material.

## RESULTS AND DISCUSSION

The results are presented in relation to the project objectives, focusing first on validating the chamber's capability to deliver consistent and accurate SPL readings, followed by the analysis of material transmission loss across the frequency range of 100 Hz to 5000 Hz using 1/3 octave bands. Some samples were tested at different thicknesses, to observe how thickness affects sound transmission. Throughout the tests, certain factors like speaker position, microphone distance, and pink noise volume were kept constant. Variables such as material type and thickness were manipulated. The data collected

includes SPL readings and calculated transmission loss (TL) values across 1/3 octave bands.

#### A. Chamber Validation (Isolation and Containment)

Before testing the materials, the acoustic transmission chamber was validated to ensure it provided reliable conditions for sound isolation measurement. The validation process focused on confirming background noise insulation, directional sound flow, and chamber integrity, aligning with ISO 10140-5 and practices from [6]. Two main tests were performed: measurement of ambient sound pressure level (SPL) and SPL containment testing using pink noise with no test material installed. These results confirm that the system meets the acoustic requirements for comparative material testing. The graph in Figure 6 shows the average ambient SPL measured inside the receiver chamber and outside the box under room conditions. The results demonstrate that the SPL inside the chamber was consistently lower than the SPL outside, with a difference ranging from approximately 3 dB at low frequencies (100 Hz) to over 15 dB above 800 Hz. This suggests that the chamber construction effectively reduces environmental noise intrusion.

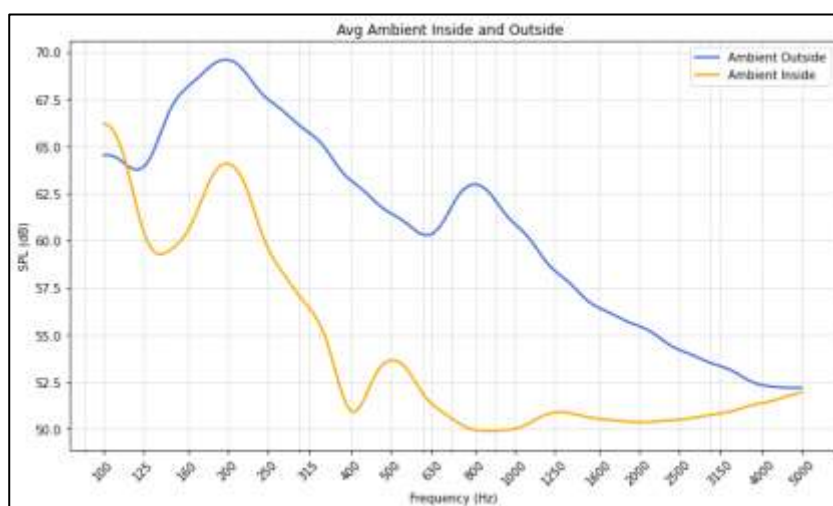


Figure 6. Ambient Inside and Outside Chamber.

In the second test to assess the baseline isolation of the chamber system, pink noise was played inside the source room at a consistent level, and SPL was measured both in the receiver chamber and outside the box. Figure 7 presents the resulting SPL across the 1/3 octave frequency bands. The SPL recorded inside the box reached peaks of approximately 100 dB in the 800 Hz to 1600 Hz range, while the outside SPL remained below 70 dB across most bands. This demonstrates an average attenuation of at least 30 dB, validating the chamber's capacity to isolate airborne sound without the influence of test material.

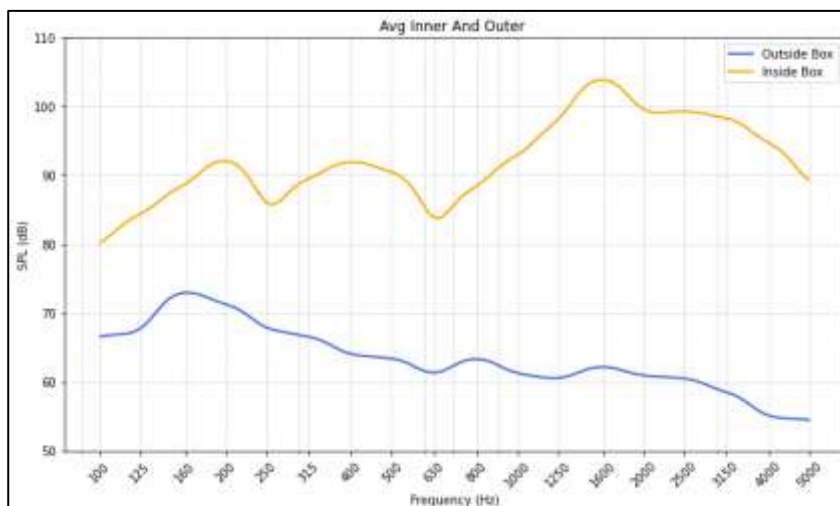


Figure 7: Pink-Noise Inside and Outside Chamber.

B. SPL Measurements –Different Thickness

The SPL values represent the actual sound levels measured inside the receiving chamber after the pink noise signal was transmitted through the test material. A higher SPL indicates more sound energy passed through the material (i.e., lower sound insulation) while a lower SPL reflects better attenuation performance. Across the full frequency range of 100 Hz to 5000 Hz, all three felt samples exhibit distinct frequency-dependent transmission characteristics and a clear thickness-dependent trend. As seen in the Figure 8, thicker samples consistently produce lower transmitted SPL, confirming that felt thickness directly improves sound attenuation.

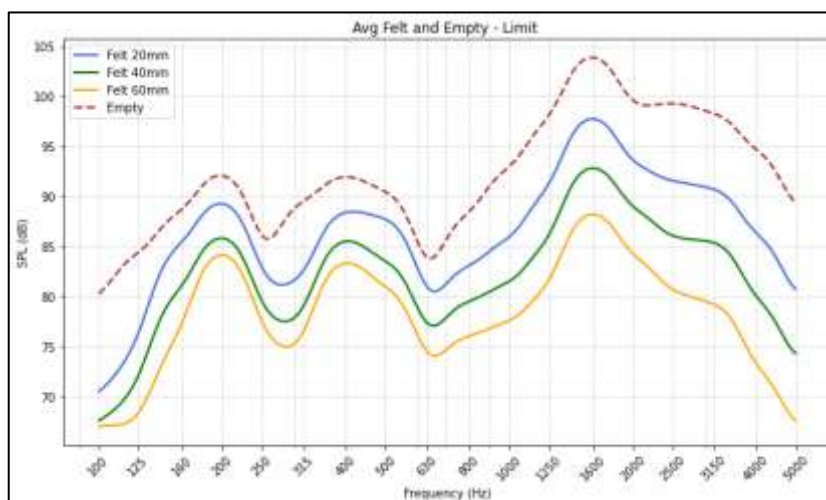


Figure 8. Data from Felt at 20mm, 40mm and 60mm with Baseline.

Table 2. Felt Thickness Comparison

Frequency Band	Performance	Observation
100–250 Hz	SPL slightly decreases with thickness	Low-frequency attenuation
400–1000 Hz	SPL drops up to 10 dB from FE20 to FE60	Thickness improves mid-band dissipation
1000–5000 Hz	SPL improves moderately with thickness	High-frequency scattering and reduce transmission

C. SPLD / STL Measurements

The Sound Pressure Level Differences (SPLDs) and Sound Transmission Loss' were calculated using the formula equation (1), (2) and (3). Since the project was limited by only a single microphone, the STL and SPLD values calculated are the same. Figure 9 and 10 shows data from felt at different distances at mass 200 grams.

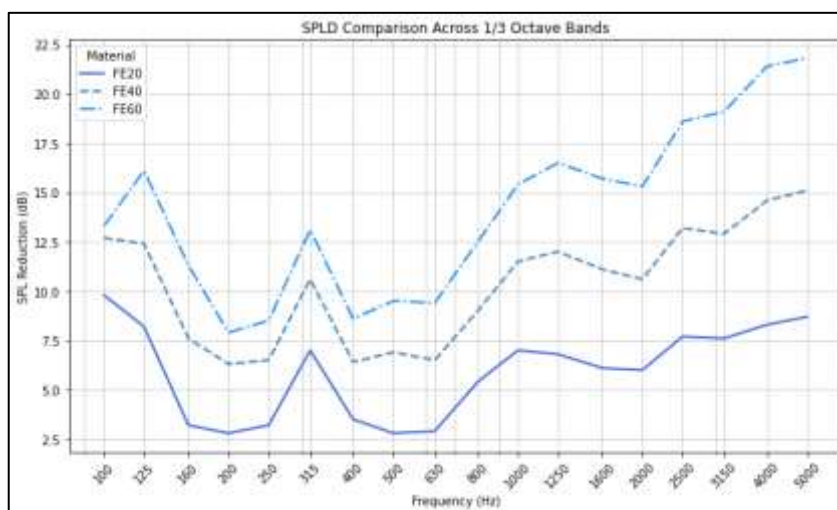


Figure 9. Data from Felt at 20mm, 40mm and 60mm.

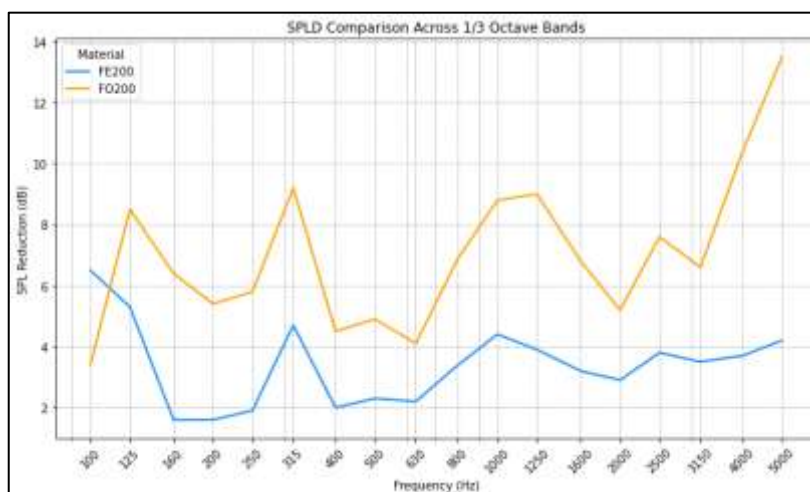


Figure 10. Data from Felt and Foam at mass 200g.

In this study, SPLD is treated as an accurate practical approximation of STL, and the terms are used in parallel where relevant. Each SPLD value represents the material’s frequency-specific transmission loss, and higher values indicate stronger sound-blocking performance as shown in Table 3.

Table 3. SPLD/STL Comparisons for Felt.

Sample	SPLD Performance	Observation
FE20	3–8 dB	Limited attenuation, especially in low and high bands
FE40	6–12 dB	Noticeable improvement in mid-band
FE60	8–20 dB	Strong broadband attenuation, peak STL > 20 dB
FE200	2–7 dB	High density, but very thin — poor performance overall

E. Transmission Coefficients Measurements

Figure 13 analyses the transmission coefficient ( $\tau$ ) of felt samples across one-third octave frequency bands, offering a dimensionless representation of the proportion of sound energy transmitted through each material. A lower transmission coefficient indicates better sound-blocking performance, while a value approaching 1.0 signifies almost complete sound passage as shown in Figure 11 and Table 4 observations.

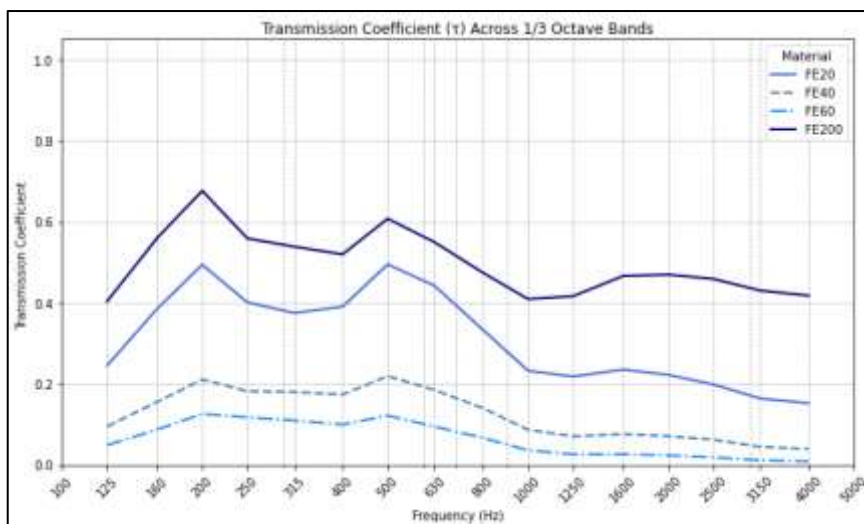


Figure 11. Data from Felt at 20mm, 40mm, 60mm & 200 grams.

Table 4. Transmission Coefficient Comparisons for Felt

Sample	Performance	Min $\tau$	Observation
FE20	$\tau = 0.3\text{--}0.6$	$\sim 0.17$	Weak at all frequencies
FE40	$\tau = 0.1\text{--}0.4$	$\sim 0.08$	Effective in mid-high bands
FE60	$\tau = 0.03\text{--}0.3$	$\sim 0.02$	Strong broadband transmission loss
FE200	$\tau = 0.4\text{--}0.65$	$\sim 0.35$	Dense but thin = poor performer

This study assessed the sound insulation performance of felt using a reduced-size acoustic transmission chamber. Validation confirmed the setup's accuracy, with SPL measurements.

## CONCLUSIONS

This study successfully achieved its primary objective. The design and construction of a reduced-size acoustic transmission chamber were accomplished, adhering to ISO 10140-5 guidelines. The chamber's design incorporated layered wall construction, sealed interfaces, and precise speaker–microphone alignment, ensuring consistent sound transmission testing. Validation procedures confirmed the chamber's capability to isolate sound between compartments and produce reliable data across the frequency range of 100 Hz to 5000 Hz. The study analysed and identified the acoustic properties of commonly available materials on polyester felt. Measurements of Sound Pressure Level Difference (SPLD), Sound Transmission Loss (STL), and transmission coefficients revealed that polyester felt could be done on across all frequency bands when thickness was controlled. Felt samples demonstrated strong mid-to-high frequency attenuation, with SPLD values exceeding 15 dB and transmission coefficients dropping below 0.1 at 60 mm thickness. Overall, the study validates the reduced-size acoustic transmission chamber as a reliable tool for material comparison. The findings underscore the importance of both material structure and geometric configuration in influencing sound insulation, particularly in the mid-frequency band relevant to environmental and speech-related noise.

In terms of performance, the chamber demonstrated the highest accuracy and sensitivity between 630 Hz and 4000 Hz, where SPL and transmission coefficient trends were most stable and repeatable. Within this range, the chamber consistently captured the differences in material behaviour, particularly for mid-to-high frequency attenuation. This aligns with the critical range for human speech intelligibility and typical indoor noise. Below 500 Hz, minor fluctuations were observed due to the limited internal volume and resulting modal effects, which are common in small-scale acoustic chambers.

Future studies should investigate additional materials, including recycled or natural fibres, to broaden sustainable options. Hybrid configurations combining absorptive and reflective layers could improve performance across frequencies. Scaling the chamber closer to ISO-specified volumes would enhance low-frequency accuracy. Integrating simulation tools with physical testing could also improve design predictability.

## REFERENCES

- [1] Lectures, T., Xiang, N., & Blauert, J. (2021). Acoustics for Engineers. <https://doi.org/https://doi.org/10.1007/978-3-662-63342-7>.
- [2] ISO 10140-5 Acoustics — Laboratory measurement of sound insulation of building elements — Part 5: Requirements for test facilities and equipment. (2021).
- [3] Balmori, J. A., Casado-Sanz, M., Machimbarrena, M., Quirós-Alpera, S., Mostaza, R., & Acuña, L. (2024). The Use of Waste Tyre Rubber Recycled Products in Lightweight Timber Frame Systems as Acoustic Insulation: A Comparative Analysis of Acoustic Performance, *Buildings*, Volume 14(1), 35 <https://doi.org/10.3390/buildings14010035>
- [4] Miao, Z., & Huang, Y. (2023). A simulation study on the influence of aircraft panel thickness on the cabin sound quality. *INTER-NOISE and NOISE-CON Congress and Conf. Proceedings*, 265(3), 4569–4580. [https://doi.org/10.3397/IN\\_2022\\_0657](https://doi.org/10.3397/IN_2022_0657).
- [5] Xu, Qian., & Huang, Yi. (2019). *Anechoic and reverberation chambers: theory, design, and measurements*. John Wiley & Sons Ltd.
- [6] Szelağ, A., Baruch-mazur, K., Brawata, K., Przysucha, B., & Mleczko, D. (2021). Validation of a 1:8 scale measurement stands for testing airborne sound insulation. *Sensors*, 21(19). <https://doi.org/10.3390/s21196663>