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SOUND TRANSMISSION LOSS PERFORMANCE OF BIO-COMPOSITE MICRO-PERFORATED PANELS BACKED BY NATURAL FIBERS

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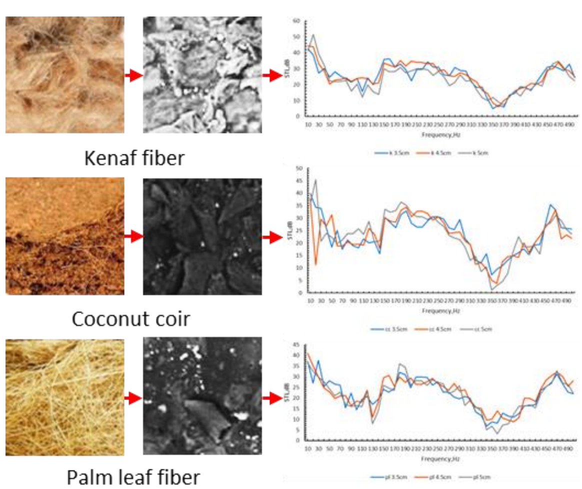
Graphical abstract



Abstract

Micro-perforated panels (MPPs) with natural fiber backing hold great potential for the development of acoustic panels due to their various advantages over conventional porous materials. Some aesthetic restrictions and the bulky nature posed by conventional porous materials have made natural fiber-reinforced MPP a more adaptable and compelling solution for acoustic efficacy. Therefore, in this paper, MPPs backed by coconut coir, kenaf fiber, and palm leaf fiber are the focused for assessing the sound transmission loss (STL) performance. The selection of these natural fibers is largely due to their favorable inherent natural characteristics and acoustic properties. To assess STL, the current study employed the impedance tube approach to analyze the performance of materials in attenuating sound pressure across varying frequencies. Results reveal that the MPP reinforced with coconut coir achieved the maximum STL at 42 dB in the mid-frequency range of 190 to 230 Hz, demonstrating that it may be a highly suitable material for applications that require soundproofing. Undoubtedly, natural fiber-backed panels offer a viable alternative and an effective solutions to mitigate different forms of sound transmission, including airborne and structure-borne noise, thereby enhancing overall acoustic insulation.

Keywords: Micro-perforated panel (MPP), natural fiber, sound transmission loss (STL), acoustic properties, impedance tube

1.0 INTRODUCTION

Micro-Perforated Panels (MPPs), which are specialized resonant acoustic panels, are broadly used in noise control applications across residential, commercial, and public settings. The concept behind the perforated panel is to achieve the appropriate acoustic resistance while reducing the mass reactance by creating several pore diameters that are sub-millimeter in size within the thin panel [1]. Depending on the context of their usage, the tiny perforations serve various purposes, from facilitating sound transmission loss (STL), absorption, and attenuation to diffusion. Often, the panels function effectively when the acoustic particle velocity in the pores attains its peak level and is positioned at a distance from a solid surface. The major benefits that MPPs have to offer include clean, lightweight, and simple-to-design sound absorbers that were first recognized in the preceding century [2]. In general, as the perforation ratio increases, the transmission loss decreases. Hence, the precise arrangement and dimensions of the perforations contribute to improving the quality of STL, offering a versatile solution to mitigate acoustic challenges in diverse environments.

Compared to traditional porous materials, MPPs may not be able to consistently provide optimal acoustic performance, particularly in environments where precise control of noise and reverberation is crucial. Larger perforations measured in centimeters are usually found in conventional perforated panels, which results in a negligible amount of acoustic resistance for sound absorption, as a higher perforation ratio improves sound-wave interaction, preferring absorption at high frequencies while providing minimal airflow resistance [3]. The limitations are also brought on by their inherent design constraints, as they can be bulky, and aesthetically restrictive. Innovative steps have been taken to overcome these issues by discovering the potential of various materials as sound barriers. However, although conventional porous materials are utilized for passive control, natural fibers have garnered interest in recent decades due to their low cost, easy availability, and satisfactory mechanical properties [4]. Hence, natural fiber composite has emerged as a compelling alternative to conventional porous materials for STL, due to its cost-effectiveness, renewable nature, and capacity to deliver comparable or better acoustic performance while reducing its impact on the environment.

Much of the existing literature predominantly discusses the performance of acoustic panels backed with natural fibers in the context of sound absorption. However, there is a discernible void in the current body of work, with limited studies focusing on STL using natural fiber-reinforced MPPs. In one of the recent observations, natural kenaf fiber as an acoustic absorber was proposed for composite materials because of its superiority as the filler [5]. Another finding described the sound absorption performance of MPP a as being enhanced when reinforced with polylactic acid (PLA)/corkwood and kenaf layers, offering 25% higher performance and integrated potential from cork-coconut fiber blends [6]. Furthermore, Beheshti et al. (2024) revealed the use of natural wastes such as fiber bundles of sugarcane and bagasse to improve the MPPs, resulting in greater sound absorption compared to synthetic panels, particularly at low frequencies [7]. Meanwhile, Hassan et al. (2020) explained that natural fibers derived from rice straw, tea leaves, coconuts, and kenaf fibers are excellent for the manufacture of sound-absorbing panels [8]. Among natural fibers, coconut coir, kenaf fibers, and palm leaf fiber are often more cost-effective, thereby making MPP more economically viable. It is known that the overall effectiveness of the MPP in terms of attenuation or impedance of sound transmission can be affected by the unique acoustic qualities, densities, and structural features of various natural fibers. The degree to which the fiber layer interacts with the perforated panel to disperse acoustic energy depends critically on these properties, which include fiber porosity, surface roughness, and mass per unit area. Therefore, the present study aims to leverage the advantages of MPP backed by different natural fibers and analyze the STL performance specifically among coconut coir, kenaf fibers, and palm leaf fiber-reinforced MPP. By contrasting these materials, the study also analyzes relationships between fiber properties and STL behavior, offering insights regarding how to choose the most appropriate fiber type for particular frequency targets or acoustic conditions. In addition to highlighting the unique performance characteristics of each fiber type, this comparison method aids in the development of specialized acoustic panel designs for particular industrial uses.

2.0 METHODOLOGY

An overview of the experimental process, from sample preparation to STL measurement, is presented in Figure 1. Figure 1 illustrates the preparation process of natural fibers, which were used for incorporation into the Bio-Composite Micro-Perforated Panel (BC-MPP). Subsequently, the STL measurement was conducted on the BC-MPP reinforced with the natural fibers. Additionally, scanning electron microscopy (SEM) analysis was performed on the natural fibers.

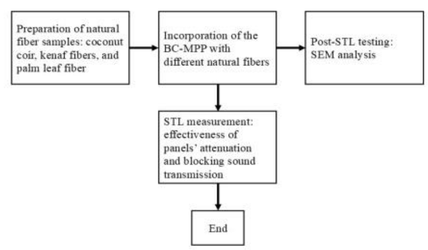


Figure 1 Overall experimental process.

2.1 Preparation of fibers

The natural fibrous materials used for the incorporation of MPPs, including coconut coir, kenaf fibers, and palm leaf fiber, were extracted from the coconut husk, the bark of the plant, and leaves of palm trees, respectively (Figure 2). Once harvested, the natural fibers undergo the cleaning process for the removal of surface impurities, excess wax, and any residual substances. This enhances the quality and purity of the fibers, ensuring that they are in optimal condition for further use. The fibers were then dried to attain the ideal moisture content. Proper drying is essential to prevent the growth of mold and maintain the fibers' stability.

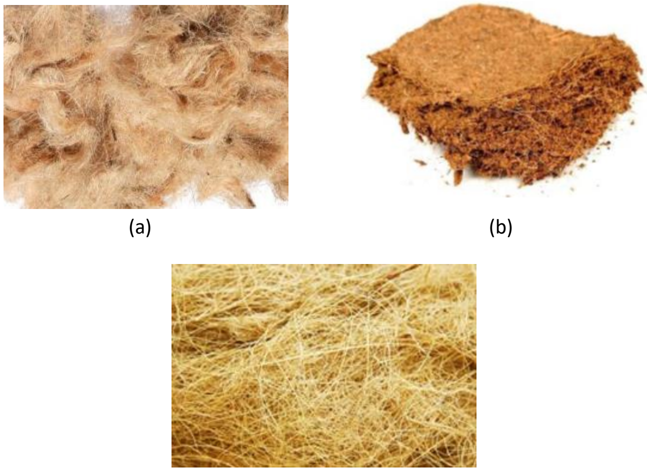


Figure 2 General overview of the structural and morphological characteristics of natural fiber specimens: (a) kenaf fibers, (b) coconut coir, and (c) palm leaf fiber.

2.2 Fabrication of BC-MPP

The BC-MPP was initially fabricated from polypropylene filled with 5 wt% of coconut coir and rice husk. The adoption of 5 wt% natural fibers into the BC-MPP not only provides considerable acoustic benefits but also maintains an affordable and simple fabrication process while balancing sound attenuation with polypropylene's integrity. In general, MPPs are made of thin films with holes perforated to a diameter of 1 mm, with a panel thickness of 1 mm and a hole-to-hole spacing of either 1.0 cm or 1.5 cm. These dimensions are carefully selected to balance acoustic performance, maximizing resistance to airflow and resonance inside the panel structure to provide efficient sound transmission loss. A small electric hand drill was used to ensure precision throughout the perforation execution, and the holes were arranged in a uniform grid pattern across the circular sample area to maintain consistency. Essentially, the fabricated BC-MPP was used for further processes, particularly the incorporation of natural fibers. Figure 3 illustrates the fabrication process of BC-MPP. The BC-MPP specimens fabricated with varying distances of perforated holes for the polypropylene-filled-coconut coir BC-MPP and polypropylene-filled-rice husk BC-MPP are presented in Figures 4 and 5, respectively.

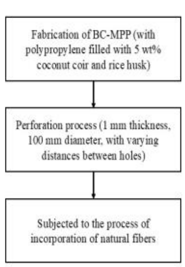


Figure 3 Fabrication process of BC-MPP samples.

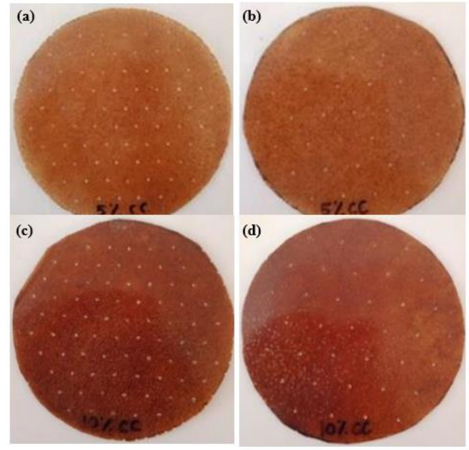


Figure 4 Fabrication of polypropylene-filled-coconut coir BC-MPP specimens with varying distances of perforated holes. (a) 5 phr 1.0 cm, (b) 5 phr 1.5 cm, (c) 10 phr 1.0 cm, (d) 10 phr 1.5 cm. *phr denotes parts per hundred of resin

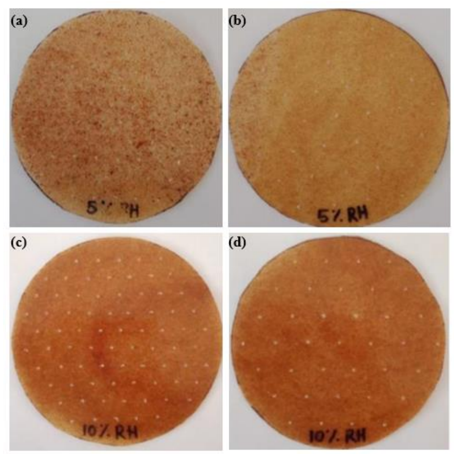
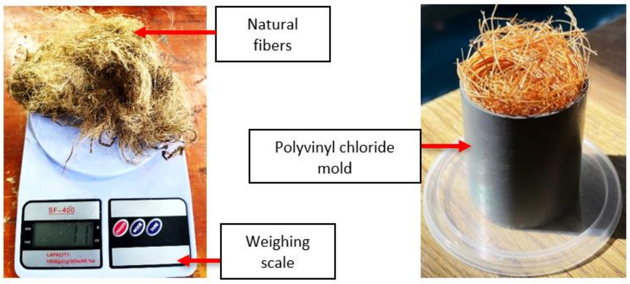


Figure 5 Fabrication of polypropylene-filled-rice husk BC-MPP specimens with varying distances of perforated holes. (a) 5 phr 1.0 cm, (b) 5 phr 1.5 cm, (c) 10 phr 1.0 cm, (d) 10 phr 1.5 cm. *phr denotes parts per hundred of resin

2.3 Incorporation of BC-MPP with Natural Fibers

A standard mass of 6 g of natural fibers was weighed for each configuration. Following that, the molding process was conducted by placing the fiber composite into a cylindrical-shaped polyvinyl chloride (PVC) mold with a 4 cm inner diameter, as shown in Figures 6(a) and 6(b). Subsequently, the mold was left to cool at ambient temperature. Once the composite sheets were removed from the mold, the nominal thickness was approximately 3.5 cm. The mixing process involved preheating the machine to 175 °C for about 10 min. The mixing blades were set to rotate at a constant speed of 15 rpm to ensure uniform fiber dispersion. The blended composite was then allowed to cool for 30 min prior to the hot press procedure, in which the material was compressed using an electrically heated hydraulic press (Model GT-7014-A300C) at 175 °C for 10 min. Upon cooling to room temperature, the samples were removed and trimmed into circular shapes. The 1 mm perforated holes were then drilled using a small electric hand drill, ensuring that precise alignment was obtained while maintaining uniformity in hole size and spacing. Behind the fabricated BC-MPP, different types of natural fibers were applied as a backing layer. The incorporation process is demonstrated in Figure 7.



(a) (b)

Figure 6 Natural fibers (a) weighing process, (b) molding process.

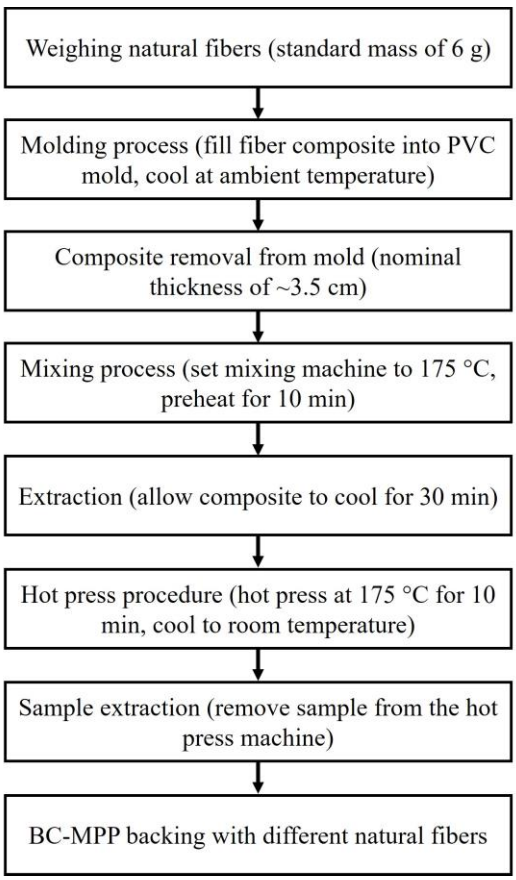


Figure 7 Incorporation process of BC-MPP with natural fibers.

2.4 Scanning Electron Microscopy (SEM) Analysis

The SEM microscopy technique was used to evaluate the porosity and examine the fibers' internal and microstructure properties. To ensure the visibility of the pores, several adjustments were made in terms of contrast enhancement, noise minimization, and image thresholds. Furthermore, an image segmentation algorithm was implemented, which is essential for providing a more detailed representation of the sample. This critical process allows for the identification and isolation of specific features of interest, such as pores within the composites. The main approach was to use the equal area concept to transform irregular pores into circles or spheres, and the porosity was calculated using the equation below [9]:

$$\varphi = \frac{S_\varphi}{S} \text{ x } 100\%$$

where φ is the porosity (%), S_φ is the pore area, and S is the total area of the image.

2.5 STL Measurement

The transfer function method (TFM), in accordance with ISO 10534-2, was employed. This test procedure utilized a digital frequency analysis system (LMS SCADAS mobile), dual microphone positioning, and an impedance tube for the measurement of STL (Figure 8). To interact with the test specimen, a loudspeaker-generated incident sound wave was transmitted through the impedance tube. Two microphones, placed at calibrated distances, captured sound pressure both before and after the sample. Based on the decibel difference between the incident and transmitted sound pressures across frequencies, the STL was computed. During testing, the sound degradation was measured as the microphones were installed far apart or in different locations from their intended sound source. Average STL values were obtained to ensure repeatability and minimize experimental variability for each fiber-thickness combination, which were evaluated in triplicate (n = 3). STL was tested at a frequency of ≤ 500 Hz to assess how effectively it reduces the transmission of low-frequency noise. Since managing long-wavelength sound energy is particularly difficult in real-world acoustic settings, the emphasis on frequencies up to 500 Hz offers insight into the material's barrier performance. Meanwhile, assessing the sound attenuation effectiveness at lower frequencies enables a more rigorous evaluation of the soundproofing properties of a material, since these frequencies penetrate materials more readily. The differences in sound pressure level or decibel variance between incident (incident intensity level) and permeated sound (transmitted intensity level) were measured.

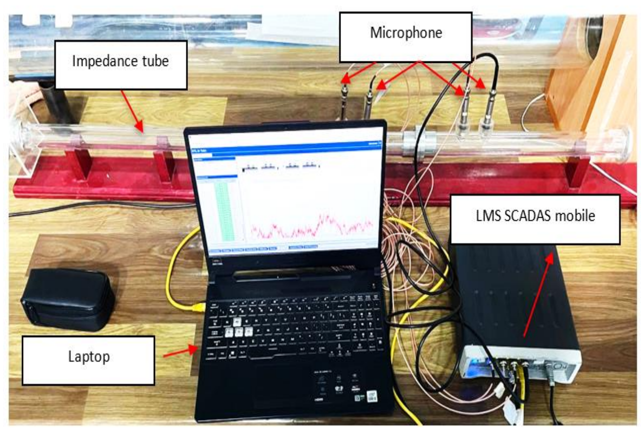


Figure 8 The impedance tube setup for STL measurement, featuring microphones, LMS SCADAS Mobile, and a laptop for the control and analysis of signals across a wide frequency range.

3.0 RESULTS AND DISCUSSION

3.1 Internal Microstructure Comparison Of Natural Fibers

The distinctive features of natural fibers in terms of cellular arrangement, surface morphology, and porosity area were examined using SEM analysis as shown in Figure 9. According to the observation, the SEM image depicts the coconut coir with a complex arrangement of microscopic individual fibers, forming a fibrous network, which indicates a porous structure and thereby contributes to its remarkable sound-absorbing attributes. The composition of kenaf fiber was homogeneous, with cells composed of long filaments that shape the tiny bundles. This underlying structure typically implies possible flexibility and strength advantages. Despite the palm leaf fiber exhibiting a more heterogeneous composition, the cellular arrangements of different sizes and forms are visible. In this regard, the overall complexity and adaptability of the fiber are closely correlated with the presence of diverse cell varieties and configurations. SEM analysis plays a crucial role in establishing a link between natural fibers' microstructural features and their acoustic performance in MPPs, especially when used as backing materials in MPP. The properties of fiber-reinforced composite materials are significantly influenced by the morphology of the reinforcing natural fibers [10]. Through SEM analysis, fibers with morphological characteristics compatible with MPP design requirements can be identified, aiding in the attainment of desired STL results over relevant frequency ranges.

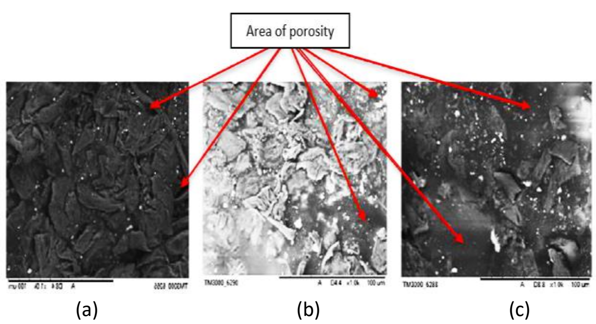


Figure 9 SEM images of the internal structure of natural fibers: (a) coconut coir, (b) kenaf fiber, and (c) palm leaf fiber.

3.2 Sound Transmission Loss (STL) Analysis

In this study, the STL analysis was conducted on several desired natural fibers, namely, coconut coir, kenaf fiber, and palm leaf fiber. Each type of natural fiber exhibited distinctive acoustic properties that can be tailored to specific frequency bands, allowing for optimized sound insulation performance. Due to their porosity and fibrous structure, natural fibers generally possess intrinsic acoustic characteristics that allow them to efficiently absorb and disperse sound waves, thus rendering them excellent for soundproofing applications. Some natural fibers are particularly valued for their excellent sound-absorbing characteristics, longevity, affordability, ecological compatibility, and other important attributes. In this regard, such properties have rendered them suitable alternatives for conventional synthetic materials in sound absorption treatments [11]. Given the growing emphasis on ecological consciousness and mitigating the environmental impact of materials used in construction, natural fibers offer a viable alternative to conventional, petroleum-derived acoustic products. These natural fibers implemented in BC-MPP can produce soundproofing composites that exhibit high-performance acoustic qualities alongside positive environmental effects. The purpose of this finding is to evaluate the intriguing potential of these selected natural fiber-backed BC-MPPs, demonstrating how effective they are in attenuating sound transmission over a variety of frequencies.

3.2.1 STL on Coconut Coir

Coconut coir fiber can be used as an alternative to traditional products due to its strong acoustic qualities at both low and high frequencies [12]. The measurement of STL, when MPP is reinforced with coconut coir of varying thickness, is shown in Figure 10. Results indicate that with an increase in the thickness of coconut coir, there is a discernible improvement in the attenuation of sound transmission. A steady surge of STL at the frequency of 120 Hz was observed as the thickness of coconut coir increased from 3.5 cm to 5 cm. However, at 350 Hz, samples exhibited the lowest STL values (<30 dB), indicating that the effectiveness in attenuating sound at that particular frequency is minimal. This notable drop around 350 Hz is likely due to resonance phenomena and acoustic impedance mismatch, between the fiber layer and the perforated panel, where absorption within this challenging mid-low frequency band is not adequately supported by the fiber structure and pore size. This dip may also reflect an interaction between the excitation frequency, fiber structure, and panel shape that lowers energy dissipation efficiency. In general, these factors could be attributed to resonance effects, improper panel thickness, frequency-specific shortcomings, or inadequate acoustic impedance matching. Several factors may affect the transmission of sound waves through the coconut coir, including absorption peaks, resonant frequencies, panel geometry, fiber properties, and structural resonance. In essence, the acoustic characteristics of the sample vary with frequencies. To improve attenuation at the critical dip, variables such as grain size, fiber-to-grain composition ratio, chemical concentration, and fiber size may be considered [13]. Furthermore, results show that the 5 cm-thick coconut coir delivered the highest STL within the frequency range of 170 to 180 Hz. This suggests that coconut coir of this thickness is well-suited for reducing or blocking the propagation of sound in these targeted mid-frequency bands. These findings suggest that STL behavior is frequency-dependent and heavily impacted by structural resonance, panel geometry, and fiber characteristics. Future optimization may take into consideration altering the density of the backing fiber, reducing the thickness of the panel, or fine-tuning the perforation layout in order to increase attenuation at this crucial dip.

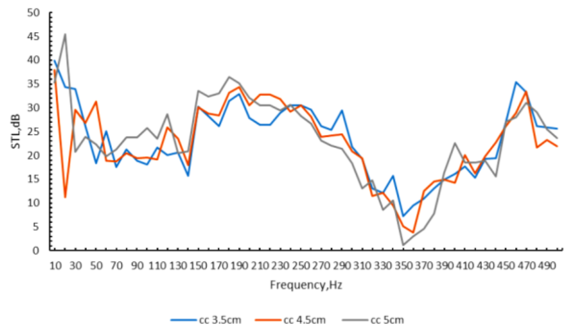


Figure 10 STL measurement with different thicknesses of coconut coir (cc).

3.2.2 STL On Kenaf Fiber

Kenaf fiber is currently receiving exponential interest as reinforcement in composite materials owing to its advantages, including being low-density, organically degradable, cost-effective, renewable, and ecologically beneficial [14]. The analysis of STL conducted on kenaf fibers is illustrated in Figure 11, featuring various thicknesses. Across various thicknesses, the optimal performance was exhibited by kenaf fiber with a thickness of 5 cm, having an STL value of ~35 dB specifically at 470 Hz. This implied that the sample has an enhanced soundproofing property and is important for designing acoustic solutions where desired sound insulation in the vicinity of 470 Hz is crucial. As seen in all samples, the peak of STL dropped in the frequency range of 350 to 380 Hz. Irrespective of the thickness, there is a frequency point where the samples may exhibit reduced efficient soundproofing properties and hence, the lowest STL. Moreover, the finding shows a consistent decline in STL values within the frequency range from 190 to 310 Hz. According to Figure 11, the observation that thicker samples do not always yield higher STL values in the frequency range of 50 Hz to 330 Hz is valid. While thicker samples generally improve soundproofing, this study reveals that in the 50 Hz to 330 Hz range, thickness alone does not guarantee better STL. Other factors, such as material properties and frequency-specific behavior, also play critical roles. An important parameter to consider for the optimization of porous absorbers is fiber flexibility, whereby it can enhance energy dissipation, especially at low frequencies, with a great influence on sound absorption [15].

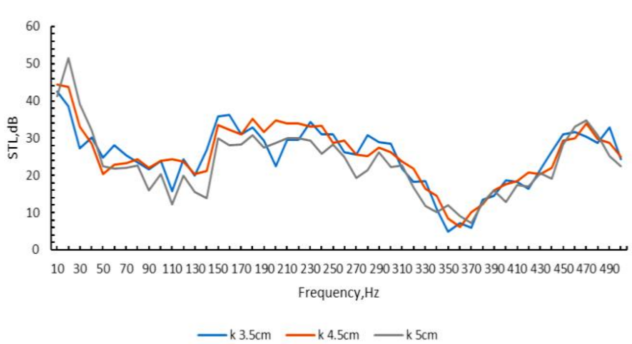


Figure 11 STL measurement with different thicknesses of kenaf (k) fiber.

3.2.3 STL On Palm Leaf Fiber

Palm waste fibers are regarded as sound-absorbing materials, cultivated due to their high productivity [16]. The outcome of STL conducted on palm leaf fibers with different thicknesses is depicted in Figure 12. Results suggest that the thicker palm leaf fiber (5 cm) serves as an appropriate material for attenuating sound at lower frequency bands, notably at 190 Hz. Due to their increased density and mass, palm leaf fiber with a thickness of 5 cm can impede the penetration of sound waves effectively, therefore making it a greater sound barrier for these longer wavelengths. It also becomes apparent that there is a progressive enhancement in STL values from the lowest thickness to the highest. For example, the thinnest sample (3.5 cm) records a value of 24 dB, whereas the thickest sample (5 cm) achieves 29 dB when measured at 150 Hz. On the other hand, at the frequency of 250 Hz, there is a close approximation of STL value (~28 dB). This typically infers that a baseline level of sound insulation is present at this particular frequency. Even in the absence of variation in fiber thickness, there could be a similar inherent effectiveness of the samples in attenuating sound transmission. Generally, for the same thickness, softer and smaller-diameter fibers may exhibit higher sound absorption performance at lower densities [17].

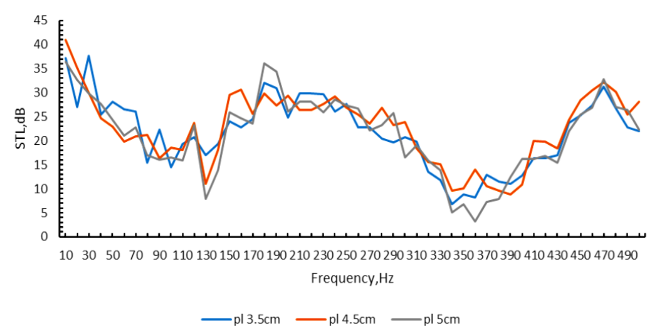


Figure 12 STL measurement with different thicknesses of palm leaf (pl) fiber.

3.3 STL Performance on BC-MPP

The prospective use of BC-MPP as viable and ecologically sound acoustic insulation solutions is demonstrated by their STL performance. By employing perforated structures reinforced with BC composites that behave as sound-absorbing layers, BC-MPPs are produced to decrease the transmission of sound waves. Naturally derived fibers like kenaf, palm leaf, and coconut coir are incorporated into these panels to enhance their acoustics and enable customizable performance over a wide range of frequencies. Typically, sound waves can penetrate BC-MPPs through their perforations and interact with the natural fibers, causing energy to be dissipated as heat and friction. This, in turn, minimizes the transmission of noise. Some BC-MPP configurations, for example, are efficient at lowering mid-frequency noise, thereby making them suitable for use in residential, industrial, and urban environments. Moreover, using BC-MPPs aligns with international initiatives to employ renewable resources to mitigate the environmental impact of material use. While fostering the use of environmentally friendly resources, the adaptability of STL effectiveness via the composition of materials and structural design emphasizes the responsiveness of BC-MPPs as solutions to various kinds of acoustic challenges.

For STL performance, a material with a high percentage of natural fiber is thought to be ideal. Commonly, a decreased fiber diameter would lead to an increased natural fiber content in a composite material and a higher surface area of air molecules that, eventually, generate more viscous friction. Inevitably, this can have a beneficial effect on the reduction of the transmission of sound from one side to the other through improved damping, absorption, or reflection of sound energy. A finding stated that larger fiber content composites indeed had a greater sound absorption coefficient than composites with lower fiber content [18]. Natural fibers with acoustic properties, for example, in this case, coconut coir, kenaf fiber, and palm leaf fiber, are considered effective soundproofing materials since they possess the ability to obstruct sound waves, thereby enhancing STL. Their unique characteristics, such as a porous and fibrous structure, can further improve STL by impeding the propagation of sound waves. This is because the pores are structured in a way that allows the “trapping” of sound waves, enabling internal reflections of the wave and, thereby resulting in a loss of sound energy and absorption [19-20].

To assess each material's acoustic performance, different natural fiber materials and their STL characteristics were examined as BC-MPP backing materials over a range of frequencies measured in Hz. The STLs of various natural fiber samples are graphed in Figure 13. A clear pattern in the STL values was observed for each natural fiber backing material used in the study. The BC-MPP, which exhibited a perforation distance of 1 cm and a backing made of 10% rice husk combined with coconut coir, demonstrated the highest STL at 42 dB within the frequency range of 190 to 230 Hz. With respect to this, coconut coir showcased remarkable efficiency in reducing the transmission of sound, especially in the mid-frequency range (190 to 230 Hz). Meanwhile, a consistent STL performance was seen across frequencies for kenaf fiber, thus making it a reliable option for modulating sound transmission over a broader spectrum. While palm leaf fiber showed better performance at higher frequencies, it is marginally less effective in the mid-frequency region compared to the other materials. Based on the acoustic results, the material’s distinctive capabilities in managing specific sound frequency ranges are worth exploring for diverse applications.

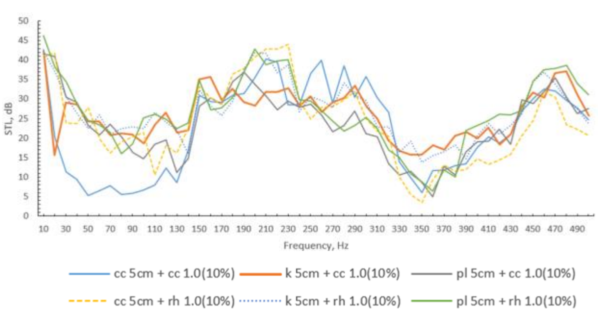


Figure 13 The STL performance in BC-MPP backed by coconut coir (cc), kenaf fiber (k), and palm leaf fiber (pl).

These results imply that depending on the frequency range of interest, natural fibers like kenaf, palm leaf fibers, and coconut coir provide distinct advantages, demonstrating that panels with natural fiber backing provide a useful and effective way of reducing different types of sound transmission originating from airborne and structure-borne noise, enhancing overall sound insulation. Recent studies reinforce these findings; for instance, Montava Belda et al. [21] demonstrated that adding a coconut fiber layer to natural seed-based panels can enhance the sound-absorption coefficient. This makes coconut coir an appealing selection for use in environments with high levels of noise in this range, such as urban areas or factories. Recognizing that kenaf fiber performs consistently across all frequencies, as revealed in a study by Rezaieyan et al. [22], which demonstrated that MPP absorbers composed of composites with a kenaf backing layer behind corkwood-based MPPs can significantly enhance acoustic performance, it therefore remains suitable for general acoustic applications where reliable sound modulation over an extensive range is necessary. Palm leaf fiber, in contrast, is less favorable in the mid-range but displays some potential for high-frequency noise control. Although their acoustic potential, especially for high-frequency attenuation, is yet to be fully explored, recent studies [23] emphasize the increasing interest in oil palm fibers (OPFs) due to their enhanced acoustic absorption properties, damping properties, and noise reduction coefficient. Many insulation materials, such as impact sound insulation materials, blowing insulation, pouring insulation, and acoustic soundproofing, could potentially be made from natural fibers for a variety of applications. In substitution for conventional materials, BC-reinforced panels continue to gain traction in the latest studies [24] for sound absorption utilization, providing efficient noise reduction solutions, particularly in environments with substantial levels of mid-frequency noise, while maintaining eco-friendly credentials.

4.0 CONCLUSION

With advances in material technology, there is a growing diversity in the incorporation of MPP with natural fiber composites. Due to the unique acoustic properties of the natural fibers, their incorporation has been demonstrated to positively improve the capacity of the panel to attenuate sound transmission. Natural fibers could potentially outperform conventional porous materials, as their fibrous nature and intricate arrangements can efficiently dissipate and absorb sound. With an emphasis on their capacity to reduce STL at various frequencies, such as airborne and structure-borne transmission, this study evaluated a variety of natural fiber-reinforced BC-MPPs. In this study, the STL characteristics of BC-MPP were estimated through an impedance tube approach. The impedance tube technology allowed for reliable and reproducible STL measurements when combined with precision microphones and LMS SCADAS mobile data gathering. It was determined that natural fibers exhibit qualities suitable for serving as acoustical panels, making them promising materials for the reduction of STL. The present results demonstrated that the highest STL was achieved by coconut coir-reinforced BC-MPP at 42 dB in the mid-frequency span, suggesting that it may be useful as a soundproofing material, notably in an environment where controlling mid-frequency sound is essential. Natural fibers like kenaf fibers may be tailored to meet particular acoustic demands, as shown by their consistent performance across frequencies. The versatility of these natural fibers in controlling sound transmission over a variety of frequency ranges presents a wide range of applications in various contexts. Furthermore, employing degradable and renewable resources in soundproofing systems has substantial environmental benefits, as it mitigates carbon footprints when compared to conventional acoustic materials. Overall, the usage of natural fibers in designing and manufacturing acoustical panels not only offers eco-friendly alternatives but also aids in minimizing the ecological impact of sound management solutions. Given the observed differences in performance between fiber types, it would be prudent to carefully choose natural fibers according to their structural characteristics (e.g., kenaf for broader range control, coir for mid-frequency control).

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Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper

References

[1] Yuvaraj, L., & Jeyanthi, S. 2019. Acoustic performance of countersunk micro-perforated panel in multilayer porous material. Building Acoustics, 27(1): 3 20. DOI: https://doi.org/10.1177/1351010X19886588

[2] Cobo, P. 2021. Modelling of microperforated panel absorbers with circular and slit hole geometries. *Acoustics, 3*: 665-678. DOI: https://doi.org/10.3390/

[3] Mohammadi, M., Ishak, M. R., Sultan, M. T. H., & others. 2025. A comprehensive review of factors influencing the sound absorption properties of micro-perforated panel structures. *Journal of Vibration Engineering & Technologies, 13*: 319. DOI: https://doi.org/10.1007/s42417-025-01849-y

[4] Khalid, M. Y., Arif, Z. U., Sheikh, M. F., & Nasir, M. A. 2021. Mechanical characterization of glass and jute fiber-based hybrid composites fabricated through compression molding technique. *International Journal of Materials Forming*, 14: 1085–1095. DOI: https://doi.org/10.1007/s12289-021-01624-w

[5] Lim, Z. Y., Putra, A., Nor, J. M., & Yaakob, M. Y. 2018. Sound absorption performance of natural kenaf fibres. *Applied Acoustics, 130*(7): 107-114. DOI: 10.1016/j.apacoust.2017.09.012

[6] Rezaieyan, E., Taban, E., Berardi, U., Mortazavi, S. B., Faridan, M., & Mahmoudi, E. 2024. Acoustic properties of natural fiber reinforced composite micro-perforated panel (NFRC-MPP) made from cork fiber and polylactic acid (PLA) using 3D printing. *Journal of Building Engineering, 84*: 108491. DOI: https://doi.org/10.1016/j.jobe.2024.108491

[7] Beheshti, M. H., Khavanin, A., Jafarizaveh, M., & Tabrizi, A. (2024). A novel acoustic micro-perforated panel (MPP) based on sugarcane fibers and bagasse. *Journal of Materials Science: Materials in Electronics*, 19(35): 1–15. DOI: https://doi.org/10.1186/s40712-024-00173-9

[8] Hassan, T., Jamshaid, H., Mishra, R., Khan, M. Q., Petru, M., Novak, J., Hromasova, M. 2020. Acoustic, mechanical and thermal properties of green composites reinforced with natural fibers waste. *Polymers, 12*(3): 654. DOI:10.3390/polym12030654

[9] Shi-Jia, M. A., Yuan-Jian, L. I. N., Jiang-Feng, L. I. U., Kundwa, M. J., Ishimwe, H., & Pei-lin, W. A. N. G. 2021. Multiscale research on pore structure characteristics and permeability prediction of sandstone. *Geofluids,* 2021: 3356645. DOI: https://doi.org/10.1155/2021/3356645

[10] Rahman, M. F., Wu, J., & Tseng, T. L. 2021) Automatic morphological extraction of fibers from SEM images for quality control of short fiber-reinforced composites manufacturing. *CIRP Journal of Manufacturing Science and Technology, 33*: 176–187. DOI: https://doi.org/10.1016/j.cirpj.2021.03.010

[11] Berardi, U., & Iannace, G. 2015. Acoustic characterization of natural fibers for sound absorption applications. *Building and Environment*, *94:* 840–852. DOI: https://doi.org/10.1016/j.buildenv.2015.05.029

[12] Saini, M. K., Bagha, A. K., & Kumar, S. 2019. Experimental study to measure the transmission loss of double panel natural fibers. *Materials Today: Proceedings*, *26:* 482–486. DOI: https://doi.org/10.1016/j.matpr.2019.12.107

[13] Mamtaz, H., Fouladi, M. H., Al-Atabi, M., & Namasivayam, S. N. 2016. Acoustic absorption of natural fiber composites. *Journal of Engineering*, *2016*. 1-11. DOI: https://doi.org/10.1155/2016/5836107

[14] Samaei, E. S., Berardi, U., Taban, E., Soltani, P., & Mohammad Mousavi, S. 2021. Natural fibro-granular composite as a novel sustainable sound-absorbing material. *Applied Acoustics*, *181*: 108157. DOI: https://doi.org/10.1016/j.apacoust.2021.108157

[15] Cucharero, J., Ceccherini, S., Maloney, T., Lokki, T., & Hänninen, T. 2021. Sound absorption properties of wood-based pulp fibre foams. *Cellulose*, *28*(7): 4267–4279. DOI: https://doi.org/10.1007/s10570-021-03774-1

[16] Taban, E., Amininasab, S., Soltani, P., Berardi, U., Abdi, D. D., & Samaei, S. E. 2021. Use of date palm waste fibers as sound absorption material. *Journal of Building Engineering*, *41*. DOI: https://doi.org/10.1016/j.jobe.2021.102752

[17] Abdi, D. D., Monazzam, M., Taban, E., Putra, A., Golbabaei, F., & Khadem, M. 2021. Sound absorption performance of natural fiber composite from chrome shave and coffee silver skin. *Applied Acoustics*, *182*. DOI: https://doi.org/10.1016/j.apacoust.2021.108264

[18] Kudva, A., Gt, M., & K , D. P. 2022. Physical, thermal, mechanical, sound absorption and vibration damping characteristics of natural fiber reinforced composites and hybrid fiber reinforced composites: A review. *Cogent Engineering,* 9(1): 1–30. DOI: https://doi.org/10.1080/23311916.2022.2107770

[19] Taban, E., Mirzaei, R., Faridan, M., Ghalenoei, M. 2020. Morphological, acoustical, mechanical, and thermal properties of sustainable green Yucca (Y. gloriosa) fibers: An exploratory investigation. *Journal of Environmental Health Science and Engineering,* 18(3): 883–896. DOI: https://doi.org/10.1007/s40201-020-00513-9

[20] Hajimohammadi, M., Soltani, P., Semnani, D., Taban, E., & Fashandi, H. 2022. Nonwoven fabric coated with core-shell and hollow nanofiber membranes for efficient sound absorption in buildings. *Building and Environment*, *213*. DOI: https://doi.org/10.1016/j.buildenv.2022.108887

[21] Montava Belda, I., Juliá Sanchis, E., Segura Alcaraz, J., & Gadea Borrell, J. 2024. Acoustic characterisation of boards manufactured with fruit stones mixed with coconut fibre. *Building Acoustics,* 31(4): 363–375. DOI: https://doi.org/10.1177/1351010X241267707

[22] Rezaieyan, E., Taban, E., Berardi, U., Mortazavi, S. B., Faridan, M., & Mahmoudi, E. 2024. Acoustic properties of natural fiber reinforced composite micro-perforated panel (NFRC-MPP) made from cork fiber and polylactic acid (PLA) using 3D printing. *Journal of Building Engineering, 84*: 108491. DOI: https://doi.org/10.1016/j.jobe.2024.108491

[23] Gan, S., Chen, R. S., Padzil, F. N. M., Moosavi, S., Tarawneh, M. A., Loh, S. K., & Idris, Z. 2023. Potential valorization of oil palm fiber in versatile applications towards sustainability: A review. *Industrial Crops and Products, 199*: 116763. DOI: https://doi.org/10.1016/j.indcrop.2023.116763

[24] Olanrewaju, O., Oladele, I. O., & Adelani, S. O. 2025. Recent advances in natural fiber reinforced metal/ceramic/polymer composites: An overview of the structure-property relationship for engineering applications. *Hybrid Advances, 8*: 100378. DOI: https://doi.org/10.1016/j.hybadv.2025.100378