Textile & Leather Review

ISSN 2623-6281 | www.tlr-journal.com | 10.31881/TLR

Acoustic Characteristics of Jute and Coir Non-woven Fabric

Sukhvir Singh, Rishi Raj Kapoor

How to cite: Singh S, Kapoor RR. Acoustic Characteristics of Jute and Coir Non-woven Fabric. Textile & Leather Review. 2023; 6:306-319. https://doi.org/10.31881/TLR.2023.060

How to link: https://doi.org/10.31881/TLR.2023.060

Published: 23 June 2023

Acoustic Characteristics of Jute and Coir Non-woven Fabric

Sukhvir SINGH[1*], Rishi Raj KAPOOR[2]

[1]Dr. D. Y. Patil School of Design, Dr. D. Y. Patil Vidyapeeth, Pune, India

[2]School of Design, Mody University of Science and Technology, Rajasthan, India

*sukh7911@gmail.com

Article

https://doi.org/10.31881/TLR.2023.060

Received 12 May 2023; Accepted 23 June 2023; Published 23 June 2023

ABSTRACT

Effective noise reduction is essential because it can influence the health and well-being of living organisms significantly, both physically and psychologically. This necessitates the use of appropriate absorbing materials to minimize the negative impact of noise. In recent years, there has been growing interest in using jute, coir and natural fibre-based acoustic materials in architectural and interior applications due to their exceptional acoustic properties, eco-friendliness, cost-effectiveness and widespread availability. The study focuses on analysing the effects of some scrutinised testing parameters of jute, coir and jute-coir blended non-woven fabric samples on noise reduction coefficient through observing sound absorption coefficient. The sound absorption coefficient was measured using the impedance tube method as per the ASTM E-1050 standard. The mean value of the sound absorption coefficient observed at frequencies 250 Hz, 500 Hz, 1000 Hz, and 2500 Hz was used to calculate the noise reduction coefficient. A three-factor & three-level Box–Behnken experimental design was used for designing research and non-woven jute, coir and jute coir blended fabric sample planning. The experimental work showed that with an increase in non-woven jute fabric sample thickness from 15 mm to 45 mm, blending jute 50 % with coir 50% and non-woven fabric samples tested by creating air gaps (15 mm to 30 mm) resulted in higher sound absorption coefficient and improved noise reduction coefficient. The experimental findings and statistical analysis revealed that blending jute with coir and increasing the thickness of non-woven fabric led to a significant improvement in the acoustic performance of the tested samples. However, increasing the air gap resulted in only a marginal improvement in acoustic performance.

KEYWORDS

acoustic, jute, non-woven, noise reduction, sound absorption

INTRODUCTION

Noise has a significant impact on human well-being, as it can affect both productivity and overall health [1]. Noise pollution refers to high levels of sound that can significantly disrupt human activities, affecting both physical and psychological well-being [2]. The World Health Organization states that excess noise from various sources can have negative effects on humans, such as reducing activity levels, increasing stress, reducing work efficiency, causing hearing damage, and leading to sleep disorders and insomnia [3]. Numerous research studies have demonstrated that noises produced by machines, vehicles, and construction activities can have adverse effects on human health. However, using a textile-based acoustic absorber that is suitable for the purpose can help reduce the noise.

The use of jute and coir-based acoustic materials in architectural applications has gained attention in recent years due to their eco-friendliness, availability, and excellent acoustic properties. These materials may be used for acoustical applications and absorption in walls, ceilings, and floors of buildings to reduce noise pollution and improve indoor acoustic quality. Jute and coir-based acoustic panels and tiles have been developed successfully to evaluate their acoustic performance. The use of these materials not only contributes to sustainable building practices but also adds an aesthetically pleasing natural look to the interior design of buildings. The use of natural fibre-based textiles has gained popularity due to their highly porous nature, which allows for the dissipation of sound energy, as well as their low cost and minimal environmental impact. These materials have a bulky volume, soft texture, and high porosity, which make them ideal for various acoustic applications [4]. Jute and jute blends are increasingly used for acoustic insulation in interior and architectural applications due to their sound absorption properties, eco-friendliness, thermal insulation capabilities, breathability, versatility, and aesthetic appeal. Jute is a renewable and biodegradable material that traps sound waves, reduces heat transfer, promotes air circulation, and adds a natural and organic touch to designs. Blending jute with other fibres enhances its performance and customization options. Architects and engineers prefer using textile materials for acoustic applications over conventional materials due to their environmentally-friendly and porous nature, low cost, flexibility, durability, and widespread availability. Additionally, these materials have a low areal density, which further adds to their appeal [5]. Numerous studies were conducted to establish a connection between the acoustic performance of non-woven fabrics and non-woven fabric thickness, areal density, porosity, air gap while testing and the effect of blending [6-9].

Fatima and Mohanty were the first to investigate the possibilities of jute materials in acoustical applications. Jute, which is widely available and inexpensive in India, is a biodegradable material that can be used effectively as a noise control material [10]. The researchers revealed that when sample thickness increases, and air gap decreased, the non-woven samples' sound absorption and noise reduction coefficients increased. The researchers also noticed that the jute and coir non-woven fabric samples had noise reduction coefficients that were greater at low and mid frequencies than a commercially available fibreglass panel [11]. Various natural fibres such as flax fibre, hemp fibre, kenaf fibre, jute fibre, agave fibre, bamboo fibre, coir fibre, and wool are also employed in acoustic applications [12-13]. Research indicates that both the density of fibres/ fabrics as well as the porous nature of the textiles can have a notable impact on the sound absorption coefficient. Porous textiles can convert sound energy into heat energy through viscous friction as well as heat exchange, resulting in sound absorption [14-16]. Jute is a viable, economical, and biodegradable alternative to traditional sound-absorbing materials for various acoustic applications. Studies have demonstrated that jute, coir, and blended natural fibres have the potential for acoustic applications, including domestic uses such as vacuum cleaning and refrigeration, as well as architectural applications as a sound-absorbing medium [17]. It was observed that as compared to the treated jute absorbents, untreated jute fibre displays superior sound absorption properties [18]. Earlier research has shown that jute fibres possess outstanding sound absorption characteristics, making them suitable for use as noise control materials that have minimal impact on the environment. Additionally, jute fibre fabrics can be utilized in noise reduction applications in the fields of architectural acoustics, interior, and automotive industry [19-21]. The studies suggested increasing the use of jute and jute blended fabrics in acoustic applications in various other fields due to easy availability, cost effeteness, environmental friendliness and sound absorbing characteristics [22-25].

Although there has been considerable research on the factors affecting the acoustic performance of porous textiles used in acoustic materials, there has been limited research conducted on non-woven fabrics blended with jute and coir. Therefore, there exists a need of studying non-woven fabric structural variables for acoustic performance of non-woven jute, coir and jute-coir blended fabric. Hence, a study was conducted using non-woven jute 100%, coir 100% and jute-coir (50:50 blend ratio) blended non-woven fabrics of 15 mm, 30 mm and 45 mm thickness which were tested without creating any air gap inside the impedance tube as well as by creating 15 mm and 30 mm air gap on acoustic performance.

EXPERIMENTAL

Materials

Non-woven fabric samples made up of 100% jute, 100% coir and 50% jute-50% coir blend ratio were prepared using locally available qualities of felts of areal density (grams per square metre) 380 g/m^2. Non-woven fabric samples of 100 mm diameter and 29 mm diameter of three different types (100% jute, 100% coir and 50% jute-50% coir blend) were cut in circular shapes of thickness 15 mm, 30 mm and 45 mm as per the research design. Jute fibre of density 1.45 g/cc, diameter ranging from 16 to 20 micrometre, 2.7 tex mean fibre fineness and 5 cm mean fibre length was used for study whereas coir fibre density was 1.21 g/cc, diameter 20 to 30 micrometres and 5 cm mean fibre length was used for sample preparation.

Methodology

A three-factor & three-level Box-Behnken design of the experiment was used for designing research and preparing the samples as per the standard runs. Three levels of non-woven fabric sample thickness, blend ratio and air gap (air cavity distance from rigid backing of the impedance tube wall and non-woven fabric sample) were considered for observing responses of acoustic performance including sound absorption coefficient as well as noise reduction coefficient. The non-woven fabric samples of jute 100%, coir 100% and 50% jute- 50% coir blend were cut to form loosely stitched multi-layered circular samples of thickness 15 mm, 30 mm and 45 mm and each sample is tested at 29 mm as well as 100 mm impedance tube diameter as per ASTM standards E-1050. The samples were tested by creating an air gap inside the impedance tube by creating an air cavity at 15 mm and 30 mm from the rigid backing of the tube as well tested without keeping any air gap by placing samples without allowing any air gap from the rigid backing of the impedance tube.

Table 1. Independent variables and corresponding levels for sample preparation and testing

Variables	Levels			Parameter type
	-1	0	+1	
Sample thickness (mm)	15	30	45	Quantitative
Blend ratio (%)	Coir (100)	Jute-Coir (50:50)	Jute (100)	Qualitative
Air gap (mm)	0	15	30	Quantitative

The sound-absorbing capacity of textile materials was assessed in terms of sound absorption coefficient can be represented by α, which ranges from 0 to 1 and indicates the material's effectiveness in absorbing acoustic energy. A value of 1 indicates complete absorption and 0 indicates no sound absorption. The normal incident absorption coefficient was obtained using the impedance tube method, which employs a two-microphone acoustic impedance tube and was employed as the standard test method for measuring sound absorption coefficient at a wider frequency gamut ranging from low frequencies at 250 Hz up to 6000 Hz.

In this study, the effect of non-woven fabric (jute, coir and jute-coir blended) sample thickness their blend ratio and air gap from rigid backing on sound absorption coefficient as well as on noise reduction coefficient was observed.

The non-woven fabric samples were tested using the impedance tube method as per the standards ASTM E-1050. The combined type impedance tube as shown in Figure 1 has an inner diameter of 100 mm for samples tested at low frequencies 100 Hz to 500 Hz and a 29 mm inner diameter is provided for acoustic testing at 500 Hz to 6400 Hz. The sample size was kept similar to the inner diameter of the impedance tube while testing nonwoven fabric samples at different frequencies. The average value of the sound absorption coefficient at 6000 Hz was considered for comparison among differently prepared fabric samples. This is because the sound absorption coefficient value at different frequencies is variable. A multi-layered sample of non-woven fabric of mean fabric thicknesses 15 mm, 30 mm and 45 mm was investigated using the impedance tube method to judge the acoustic performance of the prepared samples.

The sound absorption coefficient was measured using Equation 1 and Equation 2.

$$\alpha= I_i/I_r= (P^2_i-P^2_r)/ P^2_i = 1- (n-1/n+1)^2 = 4n/(1+n)^2 \quad (1)$$

$$n= P_{max}/P_{min} \quad (2)$$

Where:

α is the sound absorption coefficient.

I_i and I_r are the intensities of the incident and reflected waves respectively.

P_i and P_r denote the pressure of incident and reflected waves respectively.

n is the standing wave ratio, which is the ratio of the maximum to the minimum pressure of the sound wave.

P_{max} and P_{min} are the maximum and minimum values of sound wave pressure respectively.

The noise reduction coefficient is one of the simplest indicators which provide the information on percentage which is being absorbed by the material surface. The noise reduction coefficient can be described as the percentage of sound which strike the surface of non-woven fabric samples but is not reflected. Then, the mean value of the sound absorption coefficient was calculated by observing & considering responses at frequencies 250 Hz, 500 Hz, 1000 Hz and 2500 Hz for calculating the noise reduction coefficient as per equation (3). The noise reduction coefficient is a measure of how effectively a fabric can absorbs sound in the frequency range of 250 Hz to 2500 Hz. The noise reduction coefficient was measured using Equation 3.

$$\text{Noise reduction coefficient}= (\alpha\ 250\ \text{Hz} + \alpha\ 500\ \text{Hz} +\alpha\ 1000\ \text{Hz}+ \alpha\ 2000\ \text{Hz})/4 \quad (3)$$

Figure 1. Impedance tube method used for measuring normal incident sound absorption coefficient [21]

The fabric samples were kept under standard atmospheric conditions, specifically in a tropical environment with a temperature of 27 °C ± 2 °C and a relative humidity of 65 ± 2%. The number of readings taken was determined based on the variability of each fabric sample, ensuring a 95% confidence interval. The number of non-woven fabric samples tested was determined based on the coefficient of variation in each case, as per the experimental design.

RESULTS AND DISCUSSION

The independent variables (shortlisted factors) having coded values along with corresponding observed responses of sound absorption coefficient and noise reduction coefficient are given as per Table 2.

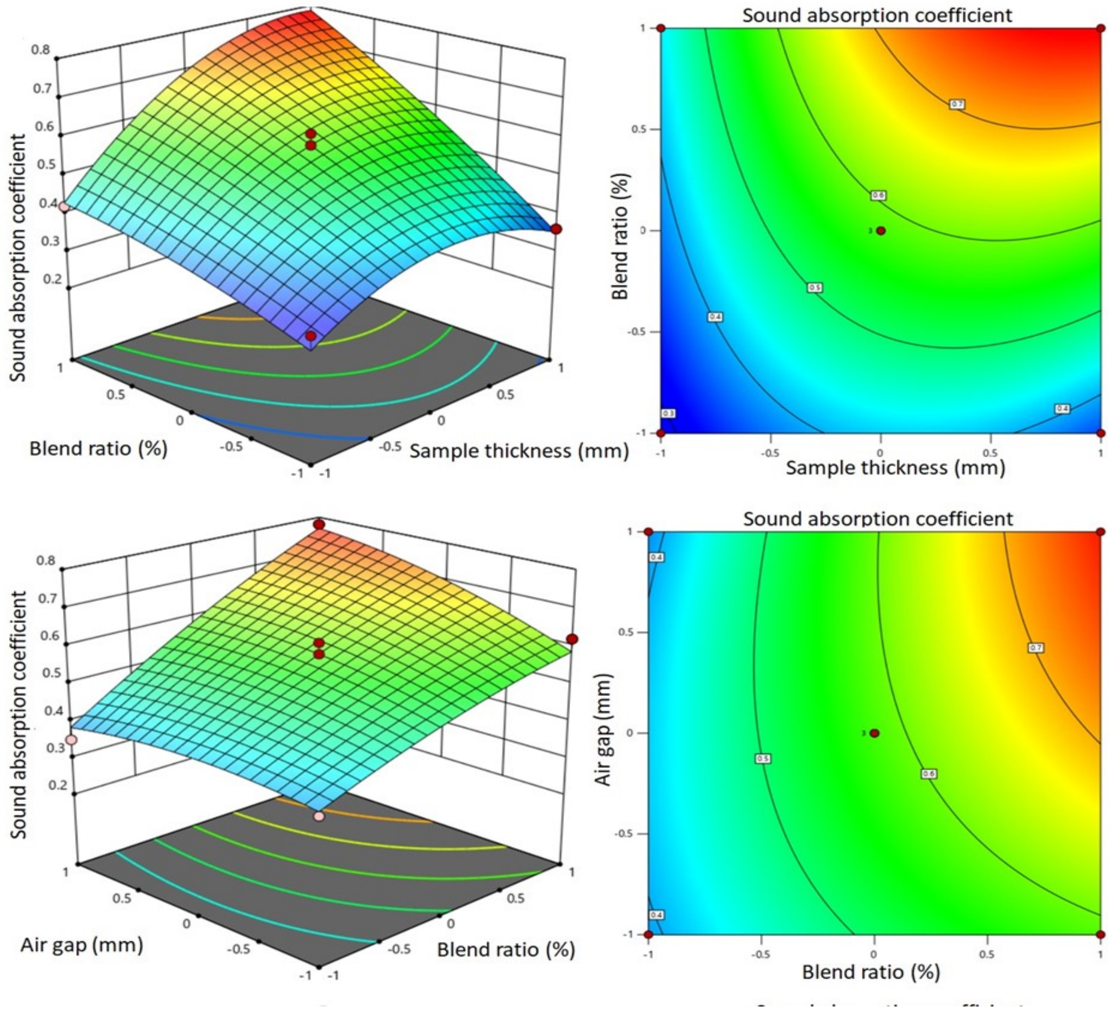
Table 2. Independent variables and their corresponding responses

	Variables			Acoustic responses of nonwoven fabric	
Runs	Sample thickness (mm)	Blend ratio (%)	Air gap (mm)	Sound absorption coefficient (at 6000Hz)	Noise reduction coefficient
1	-1	-1	0	0.32	0.27
2	1	-1	0	0.36	0.31
3	-1	1	0	0.42	0.37
4	1	1	0	0.75	0.68
5	-1	0	-1	0.33	0.28
6	1	0	-1	0.47	0.41
7	-1	0	1	0.34	0.29
8	1	0	1	0.68	0.59
9	0	-1	-1	0.38	0.32
10	0	1	-1	0.62	0.56
11	0	-1	1	0.35	0.30
12	0	1	1	0.78	0.71
13	0	0	0	0.61	0.55
14	0	0	0	0.55	0.50
15	0	0	0	0.58	0.53

Effect of Variables on the sound absorption coefficient

It has been observed that with the increase in non-woven fabric thickness from 15 mm to 30 mm sound absorption coefficient increases but with the further increment in fabric thickness from 30 mm to 45 mm, there is no significant improvement in the mean value of sound absorption coefficient. Increasing the non-woven fabric thickness typically has a positive impact on its sound absorption coefficient. This is because thicker non-woven fabrics have more surface area and therefore more opportunities for sound waves to be absorbed. Non-woven fabrics are porous materials that can absorb sound energy through a combination of mechanisms, including frictional losses, viscous losses, and thermal losses. Thicker non-woven fabrics can increase the total surface area of the material and provide more opportunities for sound waves to interact with the fibres, leading to greater absorption of sound. However, it's worth noting that there may be limits to the effectiveness of increasing thickness. At a certain point, the material may become saturated and further increases in thickness may not result in a significant increase in the sound absorption coefficient.

The experimental results reveal that compared to 100% coir fabric samples, the sound absorption coefficient improved upon blending with jute and the acoustic performance of 100% jute samples was found better compared to jute coir blended fabric and 100% coir fabric samples. The combined effect of higher fabric thickness and 100% jute fabric results in the highest reported value of sound absorption coefficient as shown in Figure 2.



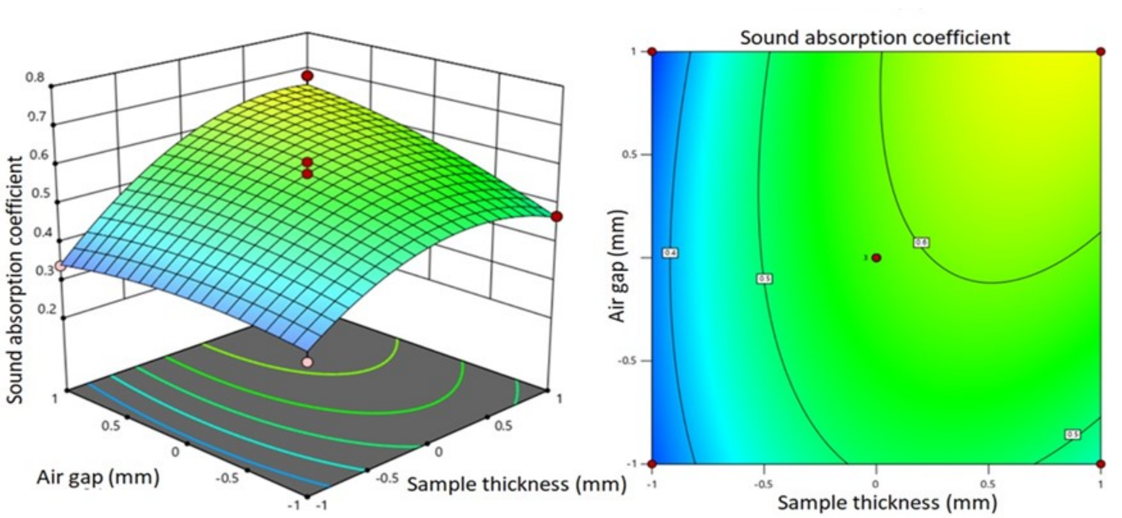


Figure 2. Effect of variables on the sound absorption coefficient

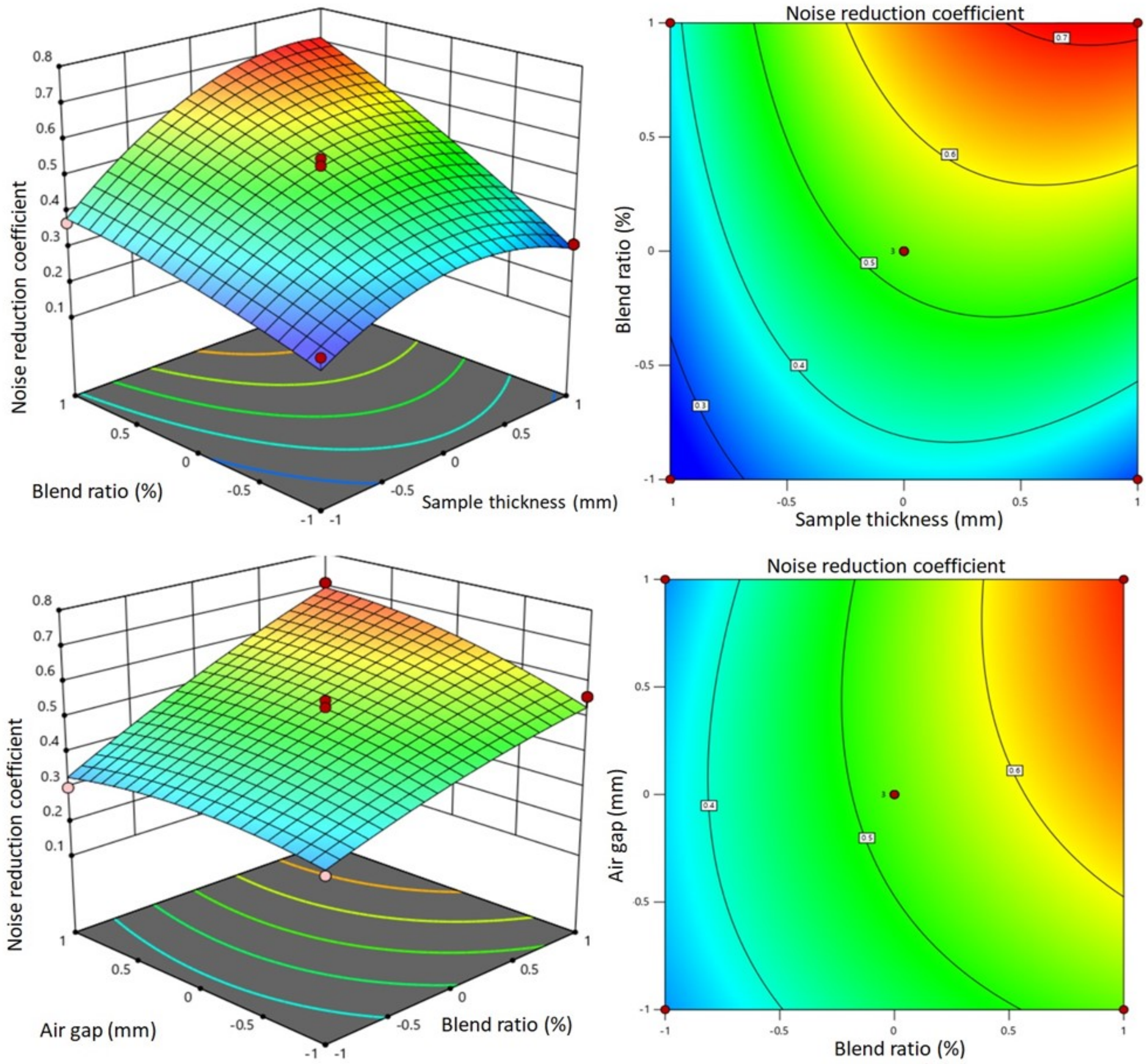
It was found that with an increase in air gap from 15 mm to 30 mm there is only marginal improvement in sound absorption coefficient of non-woven fabric samples. The experimental results showed that samples produced with 100% jute and tested at a 30 mm air gap reported improved sound absorption coefficient compared to the rest of the samples produced using a jute-coir blend and 100% coir. Moreover, the combined effect of increased fabric thickness and air gap in the impedance tube resulted in better acoustic performance compared to the samples tested at rigid backing inside the tube without any air cavity. The air gap can allow for the development of a resonant cavity between the termination plate and the non-woven fabric sample. This can cause an increase in absorption coefficient at certain frequencies due to the resonance effect. However, the magnitude of this effect will depend on the thickness and properties of the non-woven fabric, the size of the air gap, and the frequency range of interest.

Hence, it was found that the effect of non-woven fabric thickness and blend ratio (adding jute to coir) has a significant impact on sound absorption coefficient as shown in Figure 2 whereas the effect of air gap was found minimal. The statistical analysis validates the findings based on the p-value analysis of variance (ANOVA) by adopting linear and quadratic models as indicated in Table 3 and Table 4.

Effect of Variables on noise reduction coefficient

To calculate the noise reduction coefficient of a material, the average sound absorption coefficients at specific frequencies of 250 Hz, 500 Hz, 1000 Hz, and 2500 Hz are typically used. According to the study, the impact of the control variables on the sound absorption coefficient exhibited similar trends to their impact on the noise reduction coefficient. The experimental results reveal that non-woven fabric samples made up of 100% jute of thickness 45 mm tested by creating an air gap or air cavity of 30 mm inside the impedance tube showed the highest value of noise reduction coefficient compared to the rest of the fabric samples. The 50% Jute-50% coir blended fabric samples witnessed better sound absorption compared to 100% coir samples. The combined effect of an increase in the air gap and fabric thickness and air gap result in an increase in noise reduction coefficient and improved acoustic performance compared to fabric samples with low thickness and tested either at a 15 mm air gap or tested without creating any air cavity by keeping rigid backing inside the impedance tube as shown in Figure 3.

Hence, the effect of non-woven fabric sample thickness followed by blend ratio (in the case of 100% jute and blending jute with coir) was found significant on noise reduction coefficient whereas the effect of air gap was found marginal. The experimental results were also validated through the analysis of variance (ANOVA) by studying linear as well as quadratic and comparing p-values as shown in Table 3 and Table 4.



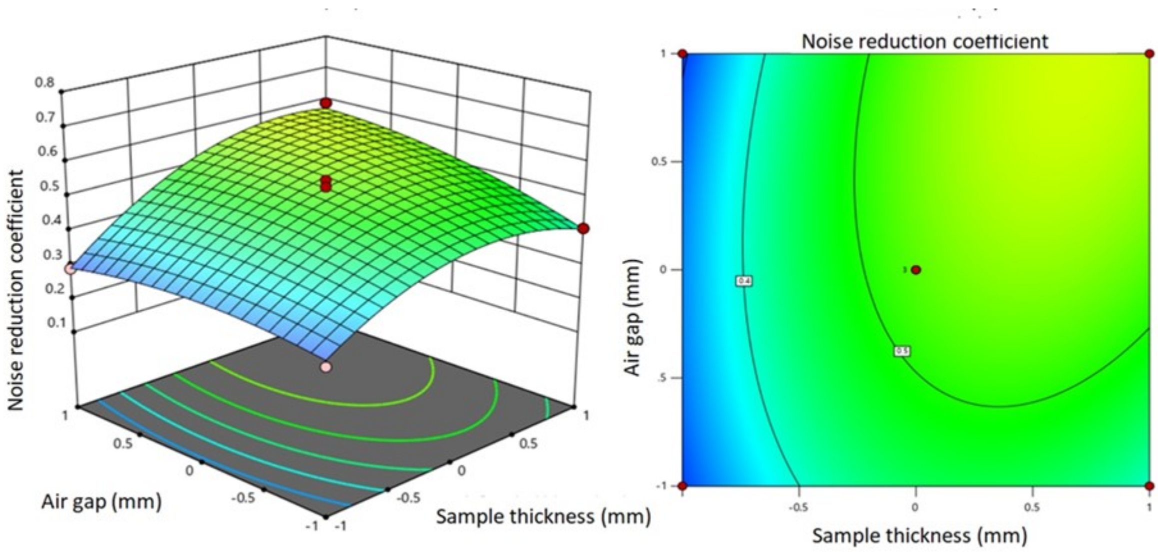


Figure 3. Effect of variables on noise reduction coefficient

Statistical analysis of variance

The study employed ANOVA at a 95% confidence level to statistically analyse the impact of the independent control variables, using statistical software.

Table 3. ANOVA general linear model for sound absorption coefficient

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.2738	3	0.0913	11.75	0.0009	significant
A-Sample thickness	0.0903	1	0.0903	11.62	0.0058	
B-Blend ratio	0.1682	1	0.1682	21.65	0.0007	
C-Air gap	0.0153	1	0.0153	1.97	0.1880	
Residual	0.0855	11	0.0078			
Lack of Fit	0.0837	9	0.0093	10.33	0.0913	not significant
Pure Error	0.0018	2	0.0009			
Cor Total	0.3593	14				

The p-value was used to determine the significance of the results, where a p-value of ≤ 0.05 indicated a strong effect of the control factor on the response, while a p-value of > 0.05 indicated a weak effect.

Table 4. ANOVA general linear model for a noise reduction coefficient

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.2456	3	0.0819	11.41	0.0011	significant
A-Sample thickness	0.0760	1	0.0760	10.60	0.0077	
B-Blend ratio	0.1568	1	0.1568	21.85	0.0007	
C-Air gap	0.0128	1	0.0128	1.78	0.2086	
Residual	0.0789	11	0.0072			
Lack of Fit	0.0777	9	0.0086	13.62	0.0702	not significant
Pure Error	0.0013	2	0.0006			
Cor Total	0.3246	14				

Table 3 and Table 4 showed that the non-woven fabric thickness and blend ratio had a low p-value ($\leq$ 0.05), indicating that they strongly influenced both the sound absorption coefficient and noise reduction coefficient, whereas the air gap had a high p-value ($>$ 0.05), suggesting a weak relationship with the observed responses in the linear ANOVA model.

CONCLUSION

The present study was focused on investigating the effect of non-woven fabric thickness, material type (jute, coir and jute-coir blended fabric) and testing air gap inside impedance tube acoustic performance of uniquely prepared fabric samples. The sound absorption coefficient (at 6000 Hz) was considered to observe the effects of the aforementioned factors on acoustic characteristic responses. The following are the major findings of this study:

- It was observed that the thicker non-woven fabric samples produced using 100% jute showed relatively improved mean values of sound absorption coefficient and increased noise reduction coefficient compared to 50% jute-50% coir and 100% coir samples. The value of the sound absorption coefficient and noise reduction coefficient increases significantly when sample thickness increases from 15 mm to 30 mm but upon increasing sample thickness further from 30 mm to 45 mm only a marginal increment was observed.
- The combined effect of higher fabric thickness (45 mm) for samples produced using 100% jute and tested by creating a 30 mm air gap inside the impedance tube reported the best acoustic performance.
- The effect of air gap on the acoustic performance of non-woven fabric was found marginal. Moreover, the fabric samples tested by creating a higher air gap (30 mm) inside the impedance tube showed slightly better acoustic performance compared to the samples tested at a 15 mm air gap and by keeping rigid backing.

100% jute & 50% jute-50% coir showed satisfactory acoustic performance. Hence, Jute non-woven fabrics can be used as wall and ceiling panels, flooring, and furniture upholstery to improve acoustic performance and create a more comfortable environment. However, the effect of the jute & coir fibre fineness, shape & size of the pores and pore size distribution may also influence sound-absorbing properties of non-woven fabric through changing fabric porosity. Due to research design limitations, these aforementioned factors were not studied.

Author Contributions

Conceptualization – Singh S and Kapoor Rishi R; methodology – Singh S; formal analysis – Kapoor Rishi R; investigation – Kapoor Rishi R; writing-original draft preparation – Singh S and Kapoor Rishi R; writing-review and editing – Kapoor Rishi R; visualization – Singh S; supervision – Singh S. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

Funding

This research received no external funding.

REFERENCES

[1] Pandya GH. Assessment of traffic noise and its impact on the community. International Journal of Environmental Studies. 2003; 60(6):595-602. https://doi.org/10.1080/0020723032000093973

[2] Thirumurugan Velayutham, Ramesh Kumar M, Sundararajan P, Chung IM, Prabakaran M. A Study on the Effect of Natural Regenerated and Synthetic Non-woven Fabric Properties on Acoustic Applications. Journal of Natural Fibers. 2021; 19(13):6553-6563. https://doi.org/10.1080/15440478.2021.1929645

[3] Franssen EAM, van Wiechen CMAG, Nagelkerke NJD, Lebret E. Aircraft noise around a large international airport and its impact on general health and medication use. Occupational and Environmental Medicine. 2004; 61(5):405–413. https://doi.org/10.1136/oem.2002.005488

[4] El Wazna M, Gounni A, El Bouari A, El Alami M, Cherkaoui O. Development, characterization and thermal performance of insulating nonwoven fabrics made from textile waste. Journal of Industrial Textiles. 2019; 48(7):1167-1183. https://doi.org/10.1177/1528083718757526

[5] Kucuk M, Korkmaz Y. Sound absorption properties of bilayered nonwoven composites. Fibers and Polymers. 2015; 16(4):941-948. https://doi.org/10.1007/s12221-015-0941-9

[6] Basu G, Datta M, Sengupta S, Nath D, Debnath S. Jute Felt for Noise Reduction: Understanding Effect of Pore Size Distribution. Journal of Natural Fibers. 2021; 19(13): 6482-6496. https://doi.org/10.1080/15440478.2021.1921663

[7] Yusuf S, Garip G, Kenan YS, Hasan K. Investigation of the Acoustic and Mechanical Properties of Homogenous and Hybrid Jute and Luffa Bio Composites. Journal of Natural Fibers. 2020; 19(4): 1217-1225.https://doi.org/10.1080/15440478.2020.1764446

[8] Bansod PV, Teja TS, Mohanty AR. Improvement of the sound absorption performance of jute felt-based sound absorbers using micro-perforated panels. Journal of Low Frequency Noise, Vibration and Active Control. 2017;36(4):376-398. https://doi.org/10.1177/1461348417744307

[9] Yixuan Chen, Zixiong Yin, Xiaoning Tang. Fabrication of Sound Absorption Gypsum/Hempcrete Composite with Robust Antistatic Electricity by Taguchi Optimization Method. Journal of Natural Fibers. 2022; 19(17): 15891-15901. https://doi.org/10.1080/15440478.2022.2135668

[10] Fatima S, Mohanty AR. Acoustical and fire retardant properties of jute composite materials. Applied Acoustics. 2011; 72:108–114. https://doi.org/10.1016/j.apacoust.2010.10.005

[11] Sambandamoorthy S, Narayanan V, Chinnapandi LBM, Aziz A. Impact of fiber length and surface modification on the acoustic behaviour of jute fiber. Applied Acoustics. 2021; 173-107667: 1-9. https://doi.org/10.1016/j.apacoust.2020.107677

[12] Berardi U, Iannace G. Acoustic characterization of natural fibers for sound absorption applications. Building and Environment. 2015; 94 (2), 840–852. https://doi.org/10.1016/j.buildenv.2015.05.029

[13] Patnaik A, Mvubu M, Muniyasamy S, Botha A, Anandjiwala RD. Thermal and sound insulation materials from waste wool and recycled polyester fibers and their biodegradation studies. Energy and Buildings. 2015; 92(1):161–169. https://doi.org/10.1016/j.enbuild.2015.01.056

[14] Qiu X. Principles of Sound Absorbers. In: Padhye R, Nayak R, editors. Acoustic Textiles. Singapore: Springer; 2016. p. 43-72. https://doi.org/10.1007/978-981-10-1476-5_3

[15] Patnaik A. Materials used for acoustic textiles. In: Padhye R, Nayak R, editors. Acoustic Textiles. Springer, Singapore; 2016. p. 73-92. https://doi.org/10.1007/978-981-10-1476-5_4

[16] Yang T, Hu L, Xiong X, Petrů M, Noman MT, Mishra R, Militký J. Sound Absorption Properties of Natural Fibers: A Review. Sustainability. 2020; 12(20):8477. https://doi.org/10.3390/su12208477

[17] Kassim DH, Putra A, Ramlan R. Enhancement of sound absorption of coir fiber using thin layer of kapok fibers, Journal of Natural Fibers. 2023; 20(1): 2164103. https://doi.org/10.1080/15440478.2022.2164103

[18] Sambandamoorthy S, Narayanan V, Chinnapandi LBM, Aziz A. Impact of fiber length and surface modification on the acoustic behaviour of jute fiber. Applied Acoustics. 2021; 173-107667: 1-9. https://doi.org/10.1016/j.apacoust.2020.107677

[19] Raj M, Fatima S, Tandon N. Recycled materials as a potential replacement to synthetic sound

absorbers: a study on denim shoddy and waste jute fibers. Applied Acoustics. 2020; 159:107070. https://doi.org/10.1016/j.apacoust.2019.107070

[20] Singh S, Kapoor RR. Acoustic Characteristics of Woven Jute Fabric. Textile & Leather Review. 2022; 5:497-508. https://doi.org/10.31881/TLR.2022.61

[21] Singh S, Kapoor R. ArchiTextile: A Review on Application of Textiles in Architecture. Journal of Textile and Apparel, Technology and Management. 2021;12 (1): 1-16.

[22] Alia A, Fantozzi G, Godin N, Osmani H, Reynaud P. Mechanical behaviour of jute fibre-reinforced polyester composite: Characterization of damage mechanisms using acoustic emission and microstructural observations. Journal of Composite Materials. 2019; 53(24): 3377-3394. https://doi.org/10.1177/0021998318822128

[23] Sakthivel S, Senthil KB. Studies on influence of bonding methods on sound absorption characteristic of polyester/cotton recycled nonwoven fabrics. Applied Acoustics. 2021; 174: 107749. https://doi.org/10.1016/j.apacoust.2020.107749

[24] Bogale M, Sakthivel S, Kumar SS, Kumar BS. Sound absorbing and thermal insulating properties of recycled cotton/polyester selvedge waste chemical bonded nonwovens. The Journal of the Textile Institute. 2023; 114(1):134-141. https://doi.org/10.1080/00405000.2021.2024377

[25] Boominathan S, Bhuvaneshwari M, Sangeetha K, Pachiyappan KM, Devaki E. Influence of fiber blending on thermal and acoustic properties nonwoven material. Journal of Natural Fibers. 2022; 19(15): 11193-11203. https://doi.org/10.1080/15440478.2021.2021123