

A STUDY ON ACOUSTIC PROPERTIES OF POLYESTER AND HOLLOW POLYESTER NON WOVEN FABRICS

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ABSTRACT

Sound absorbing materials absorb most of the sound energy striking them and reflect very little. Therefore, sound-absorbing materials have been found to be very useful for the control of noise. They are used in variety of locations like close to source of noise in various paths and sometimes close to receiver. Porous sound absorbing materials have evolved into the advanced material over the year. Non-woven, as it's a web structure can absorb more sound waves than other fabric structure. Non-woven produced from hollow polyester fibers blended with solid polyester fibers which are to be tested for sound reduction property. In this study, the effects of physical parameters on sound reduction properties of nonwoven fabrics were investigated. The samples including 50% solid polyester and 50% hollow polyester resulted in the best sound reduction in the mid-to-high frequency ranges. The increase in the amount of fiber per unit area resulted in an increase in sound reduction of the material.

Keywords: *Hollow Polyester, Non Woven, Polyester, Sound Reduction Property.*

1. INTRODUCTION

Today much importance is given to the acoustical environment. Noise control and its principles play an important role in creating an acoustically pleasing environment. This can be achieved when the intensity of sound is brought down to a level that is not harmful to human ears. [1] Noise is a major cause of industrial fatigue, irritation, reduced productivity and occupational accidents. Continuous exposure of 90dB or above is dangerous to hearing. Installation of noise absorbent barriers (made from wood and textiles) between the source and the subjects is one of the main methods of noise control. [2] Measurement techniques used to characterize the sound absorptive properties of a material are reverberant field method, impedance tube method and steady state method. Noise absorbent textile materials especially nonwoven structures or recycled materials have low production costs, low specific gravity and are aesthetically appealing. Acoustic insulation and absorption properties of nonwoven fabrics depend on fiber geometry and fiber arrangement within the fabric structure. [3] Materials that reduce the acoustic energy of a sound wave as the wave passes through it by the phenomenon of absorption are called sound absorptive materials. They are commonly used to soften the acoustic environment of a closed volume by reducing the amplitude of the reflected waves. Absorptive materials are generally resistive in nature, either fibrous, porous or in rather special cases reactive resonators. [4] Classic examples of resistive materials are non-woven, fibrous glass, mineral wools, felt and foams porous materials used for noise control are generally categorized as fibrous medium or porous foam. Fibrous media usually consists of glass, rock wool or polyester fibers and hollow polyesters have high acoustic absorption. Sometimes fire resistant fibers are also

used in making acoustical products. [5] An absorber, when packed by a barrier, reduces the energy in a sound wave by converting the mechanical motion of the air particles into low grade heat. This action prevents a buildup of sound in enclosed spaces and reduces the strength of reflected noise. [4]

In this study the non woven fabrics were produced with spun lace technology, in future it can also be produced with thermal bonding and melt blown technology. Hollow polyester/ polyester have shown good sound absorption properties so that they can be used for different applications like draperies, ear muff, etc., with any kind of sound absorption chemical treatment also. [6]

2. MATERIALS AND METHODS

2.1 Materials

Solid polyester fibers and hollow polyester fibers are used for preparation of spun lace non-woven fabrics. A study also showed that fine denier fibers ranging from 1.5 to 6 denier per filament (dpf) perform better acoustically than coarse denier fibers. [7] Polyester fibers are blended with hollow polyester in 2:2, 3:1 ratios and 100% polyester with different GSM. Physical properties of the fibers are shown in Table 1.

Table.1 Physical properties of the fibers

Fiber	Count	Staple length
Solid polyester	6 denier	64 mm
Hollow polyester	6 denier	64 mm

2.2 Methods

The sourced and procured solid polyester and hollow polyester fibers were blended in three different ratios, to produce non- woven fabric by spun lace technology suitable for acoustic end use. The basic parameters like GSM, thickness and air permeability tests were analyzed for the non-woven fabrics and the sound reduction properties of non - woven fabric were also analyzed using sound reduction tester apparatus.

2.2.1 Fabric weight (GSM)

Fabric sample of 5 cm X 5 cm was taken and weighed (w). The weight (w) is used to calculate GSM using the formula,

$$\text{GSM} = (w * 25) / 10000$$

2.2.2 Fabric Thickness

The thickness of the fabric is measured using the standard TS 7128 EN ISO 5084. A piece of fabric is placed on the reference plate of the instrument ensuring that there are no creases in the fabric. While placing the fabric it should not be subjected to any stretch. The pressure foot is gradually brought down and after allowing it to rest on the fabric for 30 sec, the gauge reading is taken.

2.2.3 Air permeability

The fabric transport property most sensitive to fabric structure is air permeability, defined as the volume flow rate per unit area of a fabric when there is a specified pressure differential across two faces of the fabric. Air permeability of the samples were measured based on the standard TS 391 EN ISO 9237 method, using FX 3300 air permeability tester. The measurements performed at a constant pressure drop of 100 Pa (20 cm² test area). All the tests were performed under standard atmospheric conditions (20°C, 65 %RH).

2.2.4 Thermal Conductivity

There are number of possibilities to measure thermal conductivity. The most commonly used methods are Searle's method and Lee's disc method, for good and bad conductors of heat respectively, each of them being suitable for a limited range of materials, depending on the thermal properties and the medium temperature. In this study Lee's disc method is used to determine the thermal conductivity of a bad conductor, e.g. Glass. The formula used for the calculation is

$$\text{Thermal conductivity} = \frac{msd}{\pi r^2} \times \frac{d\theta dt}{\theta_1 - \theta_2} \times \frac{r + 2h}{2r + 2h} \text{ Wm}^{-1}\text{K}^{-1}$$

Where,

m - Mass of the Lee's disc = 870 x 10⁻³ kg

s - Specific heat capacity = 370 J Kg⁻¹ K⁻¹

d - Thickness of the sample (m)

r - Radius of the Lee's disc (m²)

θ₁ - steam chamber temperature (°C)

θ₂ - metal chamber temperature (°C)

2.2.5 Evaluation of sound insulation

Measurement techniques used to characterize the sound absorptive properties of a material are: a) Reverberant Field Methods and b) Impedance Tube Methods. [8]A simple testing apparatus has been set up to measure the permeability of sound through a spun laced non - woven fabric. It consists of sound insulating box made of thick cardboard sheet with removable top lid. Inside one vertical wall of this box a sound source and decibel meter is fixed. On the other side (to adjust the distance between sound source and receiver) of the vertical wall a decibel meter is fixed opposite to the sound generator to measure the sound intensity. In between these two decibel meters the sliding arrangement is kept to fix the sample vertically.

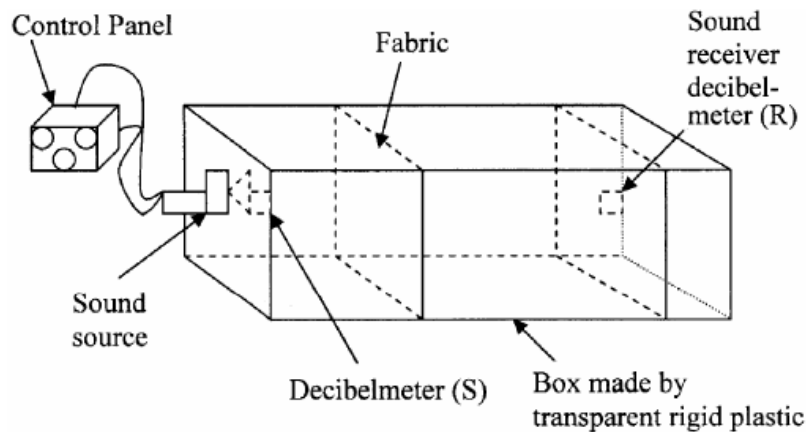


Fig. 1 Schematic view of the experimental set-up

The sound of particular decibel is created by the control panel. The source decibel and recipient decibel have been measured by two decibel meters S and R respectively without and with fabric sample. The reduction responsible for fabric which is expressed in the measure of sound insulation can be calculated as given below

$$dB_F = (\text{Decibel Reduction with Sample}) - (\text{Decibel Reduction without Sample})$$

$$dB_F = (dB_S - dB_R)_{ws} - (dB_S - dB_R)_{wos}$$

Where, dB_F - sound reduction responsible for fabric; dB_S - sound intensity at source; dB_R - sound intensity at receiver; WS- with sample; WOS-without sample. The samples were tested applying the above procedure and results were obtained.

3 RESULTS AND DISCUSSION

3.1 Non woven fabrics GSM

Table 2. GSM of the non woven fabrics

Fiber Proportion	GSM of the non woven fabrics	
	82 GSM	52 GSM
100% Polyester	Sample A	Sample A1
25/75 (Hollow Polyester/Polyester)	Sample B	Sample B1
50/50 (Hollow Polyester/Polyester)	Sample C	Sample C1

Based on the GSM, the samples with 82 GSM were named as A, B, C for 100% polyester, 25/75 (Hollow Polyester/Polyester), 50/50 (Hollow Polyester/Polyester) respectively and the samples with 52 GSM were named as A1, B1, C1 for 100% polyester, 25/75 (Hollow Polyester/Polyester), 50/50 (Hollow Polyester/Polyester) respectively.

3.2 Fabric Thickness

Table 3. Fabric Thickness of the non woven fabrics

Sample Name	Thickness (mm)
A	0.54
A1	0.46
B	0.58
B1	0.49
C	0.76
C1	0.57

The thickness of the non-woven samples measured using thickness gauge was given in Table 3. Numerous studies that dealt with sound absorption in porous materials have concluded that low frequency sound absorption has direct relationship with thickness.[9] It is observed that the samples with higher GSM (A, B, C) showed higher thickness than the samples A1, B1, C1. Thicker the material better the sound absorption values.

3.3 Air Permeability & Thermal Conductivity

Table 4. Air Permeability & Thermal Conductivity of the non woven fabrics

Sample Name	Air Permeability (cm ³ /cm ² /s)	Thermal Conductivity (Wm ⁻¹ K ⁻¹)
A	249.1	0.02
A1	1245.1	0.01
B	415.6	0.14
B1	1239	0.06
C	311.38	0.02
C1	1245.1	0.01

Table 4 shows the air permeability and thermal conductivity of the non-woven samples. The samples A1, B1, C1 shows higher air permeability rate than the samples A, B, C which shows comparatively lesser air permeability. Also fibers interlocking in non-woven are the frictional elements that provide resistance to acoustic wave motion. [10] This is also due to density of fibers being high in samples with higher GSM which reduces air transfer rate. The thermal conductivity co-efficient of the non-woven fabric samples A, B, C, A1, B1, C1 are 67%, 70%, 50%, 33%, 30% and 50% respectively. 100% polyester fabrics and fabrics with higher GSM show higher thermal conductivity. Also Samples C, C1 which has equal percentage of polyester and hollow polyester fibers showed same percentage of thermal conductivity.

3.4 Evaluation of sound insulation

3.4.1. Sound insulation of Sample A

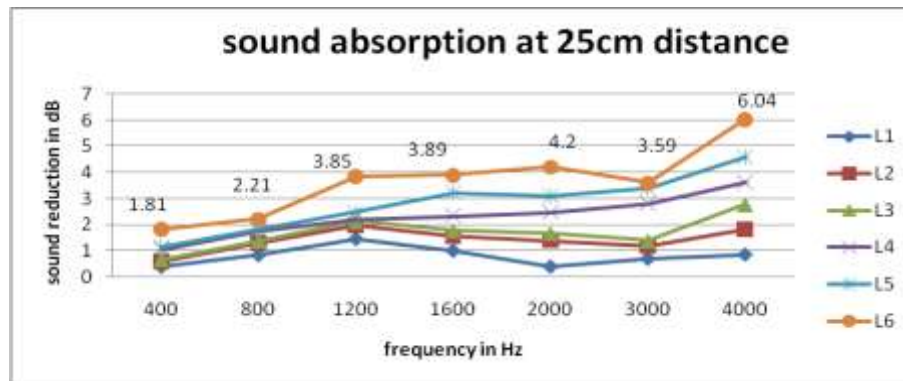


Fig. 2 Sound absorption of sample A at 25 cm distance

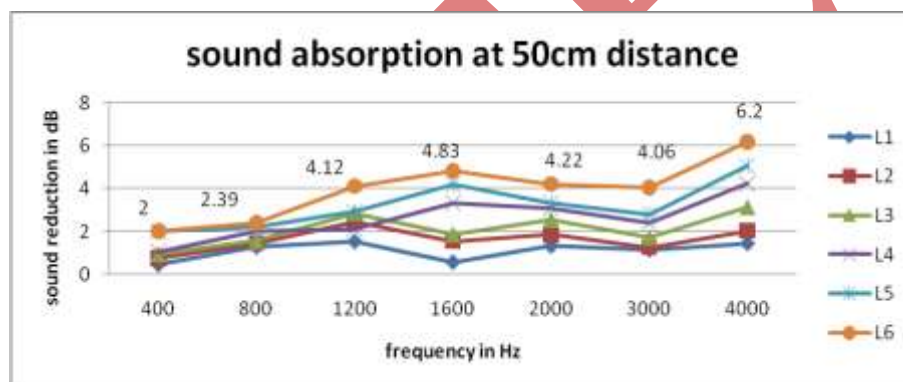


Fig. 3 Sound absorption of sample A at 50 cm distance

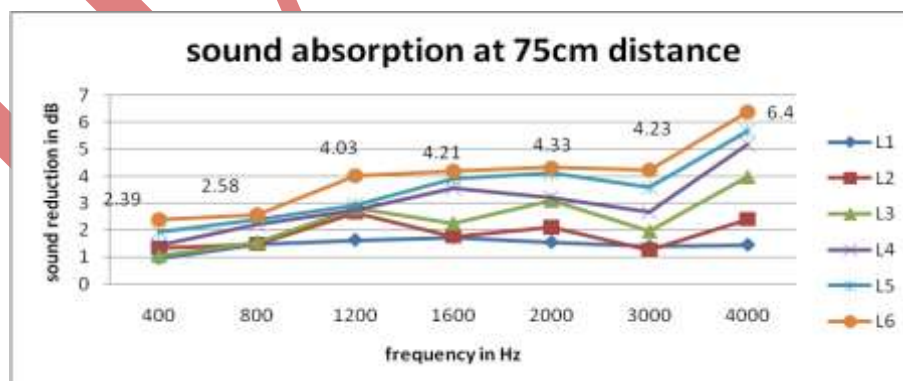


Fig. 4 Sound absorption of sample A at 75 cm distance

Fig. 2, 3, 4 shows the sound absorption property of sample A (100% polyester) non-woven fabric with 82gsm, which is evaluated with the frequency of 400 to 4000 Hz at a distance of 25cm, 50 cm, 75 cm respectively. The fabric was evaluated up to 6 layers; it is inferred that the sound reduction increased with increase in layers of fabric at a maximum frequency of 4000 Hz.

3.4.2. Sound insulation of Sample A1

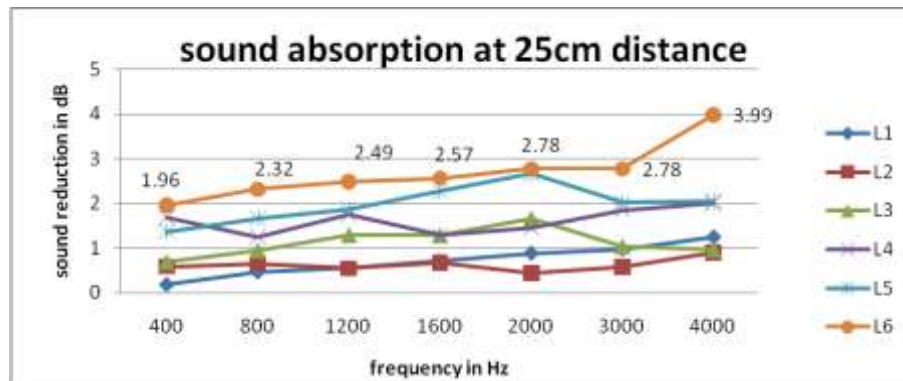


Fig. 5 Sound absorption of sample A1 at 25 cm distance

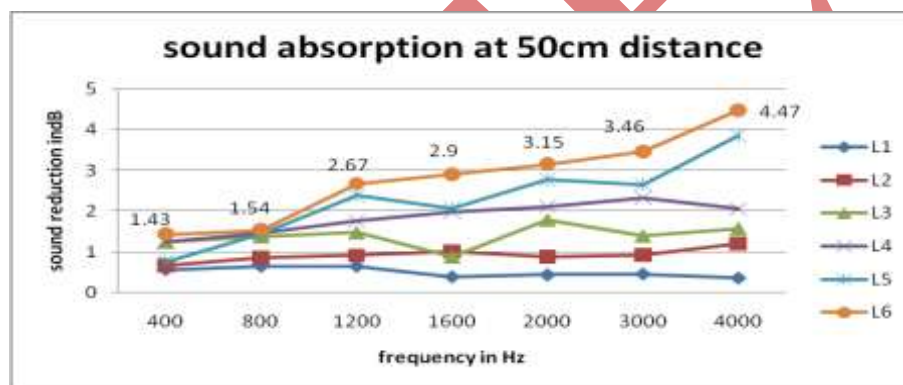


Fig. 6 Sound absorption of sample A1 at 50 cm distance

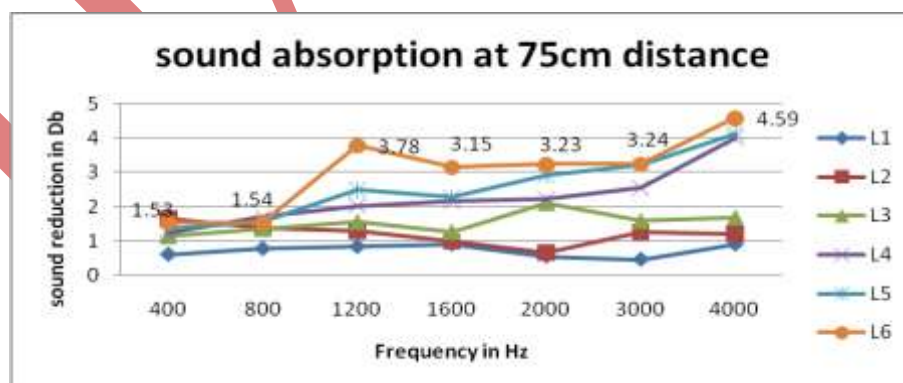


Fig. 7 Sound absorption of sample A1 at 75 cm distance

Fig. 5, 6, 7 shows the sound absorption property of sample A1 (100% polyester) non-woven fabric with 52gsm, which is evaluated with the frequency of 400 to 4000 Hz at a distance of 25cm, 50 cm, 75 cm respectively. The

fabric was evaluated up to 6 layers; it is inferred that the sound reduction increased with increase in layers of fabric at a maximum frequency of 4000 Hz.

3.4.3. Sound insulation of Sample B

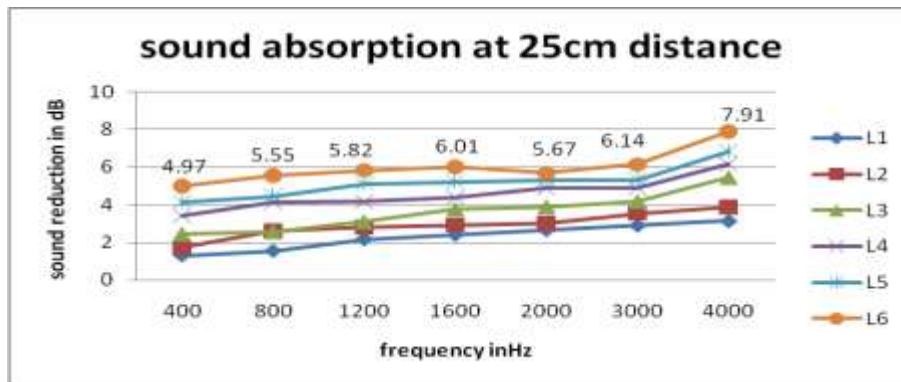


Fig. 8 Sound absorption of sample B at 25 cm distance

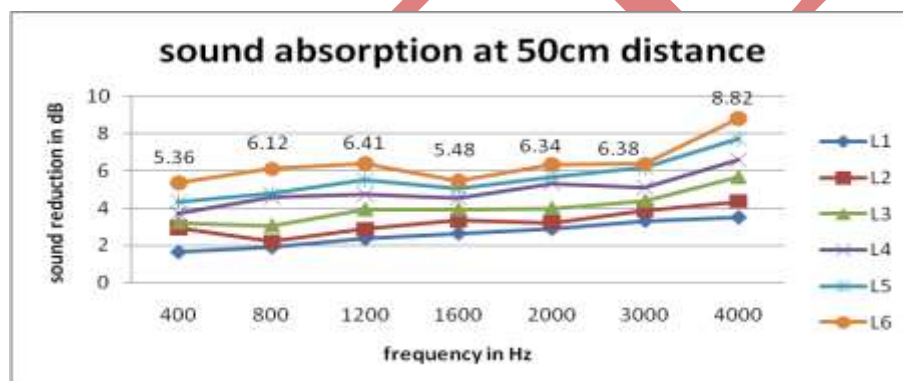


Fig. 9 Sound absorption of sample B at 50 cm distance

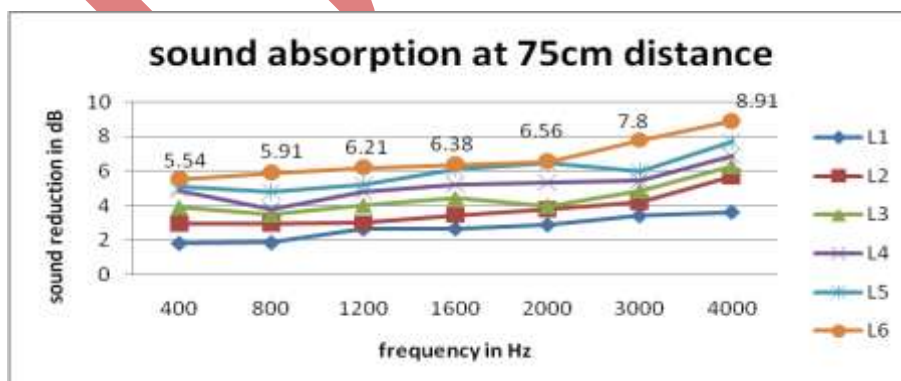


Fig. 10 Sound absorption of sample B at 75 cm distance

Fig. 8, 9, 10 shows the sound absorption property of sample B (25/75 Hollow Polyester/Polyester) non-woven fabric with 82gsm, which is evaluated with the frequency of 400 to 4000 Hz at a distance of 25cm, 50 cm, 75 cm respectively. The fabric was evaluated up to 6 layers; it is inferred that the sound reduction increased with increase in layers of fabric at a maximum frequency of 4000 Hz.

3.4.4. Sound insulation of Sample B1

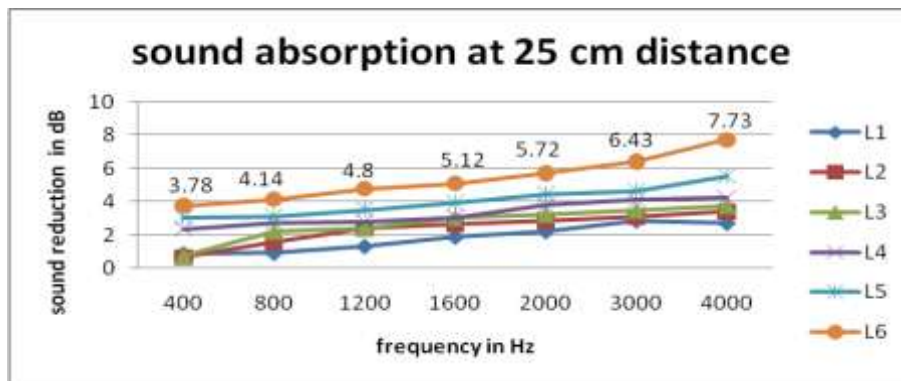


Fig. 11 Sound absorption of sample B1 at 25 cm distance

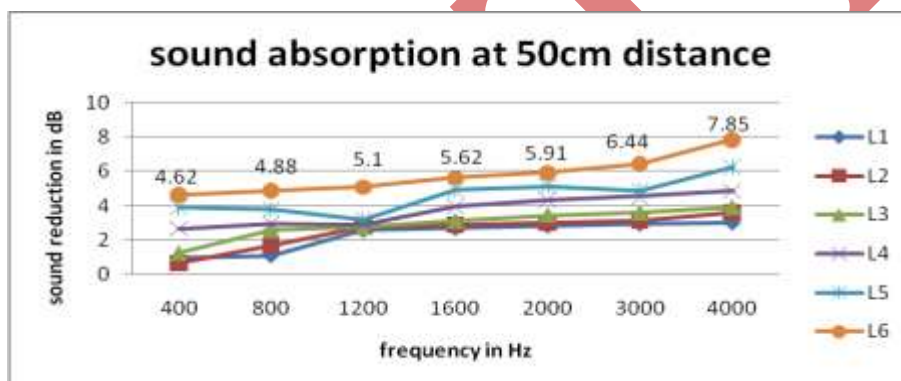


Fig. 12 Sound absorption of sample B1 at 50 cm distance

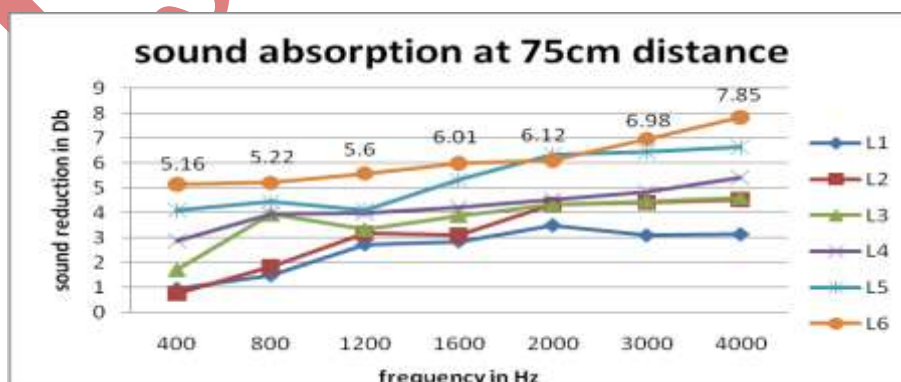


Fig. 13 Sound absorption of sample B1 at 75 cm distance

Fig. 11, 12, 13 shows the sound absorption property of sample B1 (25/75 Hollow Polyester/Polyester) non-woven fabric with 52gsm, which is evaluated with the frequency of 400 to 4000 Hz at a distance of 25cm, 50 cm, 75 cm respectively. The fabric was evaluated up to 6 layers; it is inferred that the sound reduction increased with increase in layers of fabric at a maximum frequency of 4000 Hz.

3.4.5. Sound insulation of Sample C

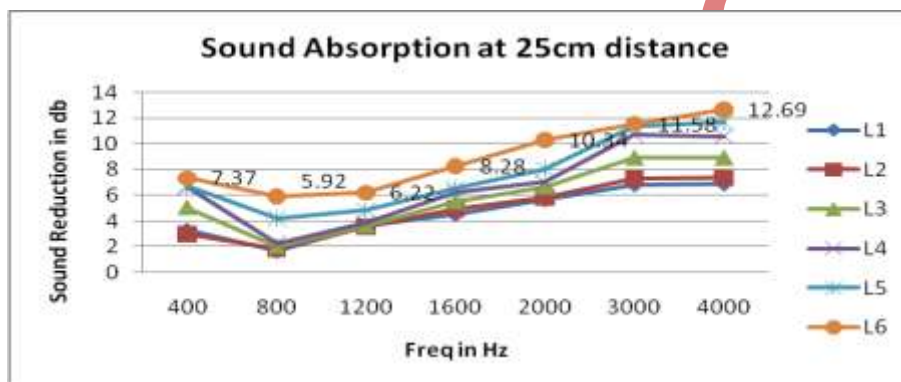


Fig. 14 Sound absorption of sample C at 25 cm distance

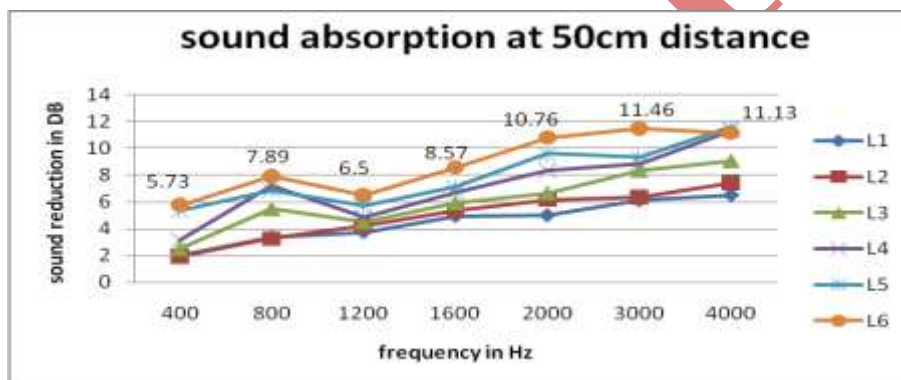


Fig. 15 Sound absorption of sample C at 50 cm distance

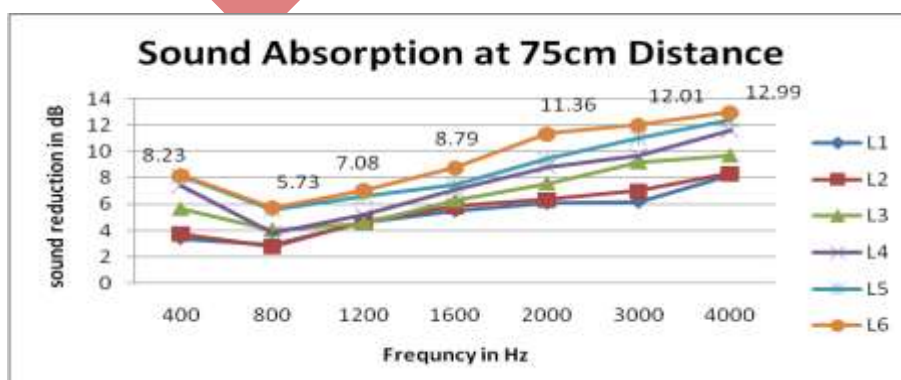
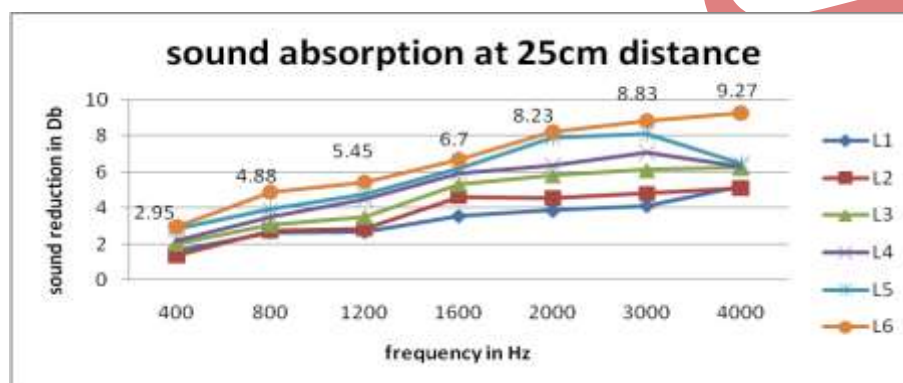
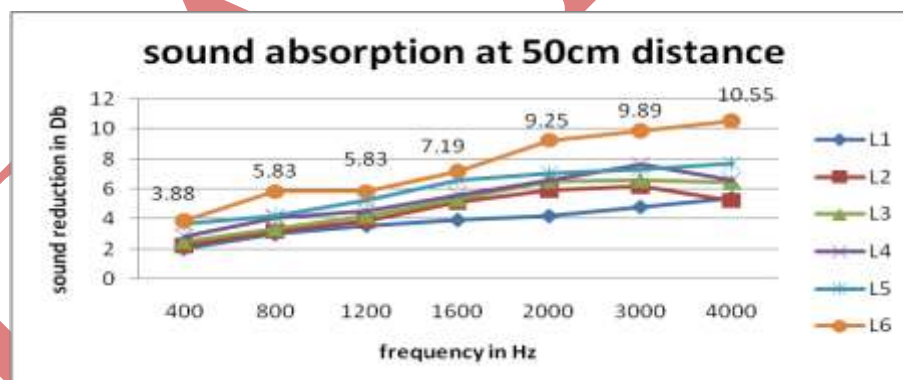


Fig. 16 Sound absorption of sample C at 75 cm distance

Fig. 14, 15, 16 shows the sound absorption property of sample C (50/50 Hollow Polyester/Polyester) non-woven fabric with 82gsm, which is evaluated with the frequency of 400 to 4000 Hz at a distance of 25cm, 50 cm, 75 cm respectively. The fabric was evaluated up to 6 layers; it is inferred that the sound reduction increased with increase in layers of fabric at a maximum frequency of 4000 Hz.

3.4.6. Sound insulation of Sample C1

**Fig. 17 Sound absorption of sample C1 at 25 cm distance****Fig. 18 Sound absorption of sample C1 at 50 cm distance**

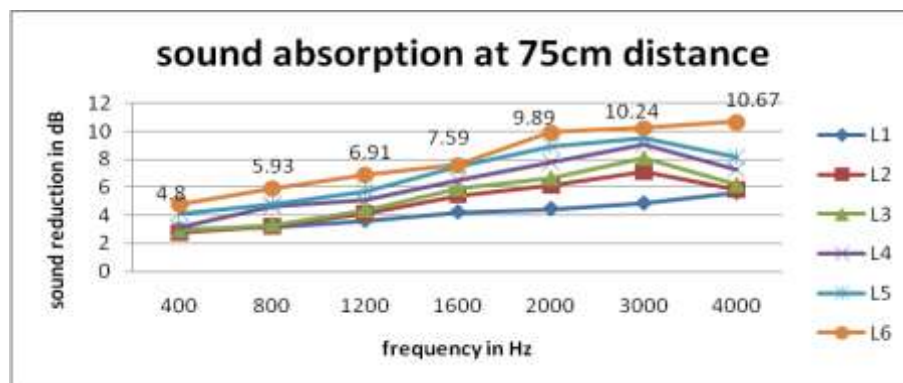


Fig. 19 Sound absorption of sample C1 at 75 cm distance

Fig. 17, 18, 19 shows the sound absorption property of sample C1 (50/50 Hollow Polyester/Polyester) non-woven fabric with 52gsm, which is evaluated with the frequency of 400 to 4000 Hz at a distance of 25cm, 50 cm, 75 cm respectively. The fabric was evaluated up to 6 layers; it is inferred that the sound reduction increased with increase in layers of fabric at a maximum frequency of 4000 Hz.

3.4.7. Sound reduction based on GSM of the samples

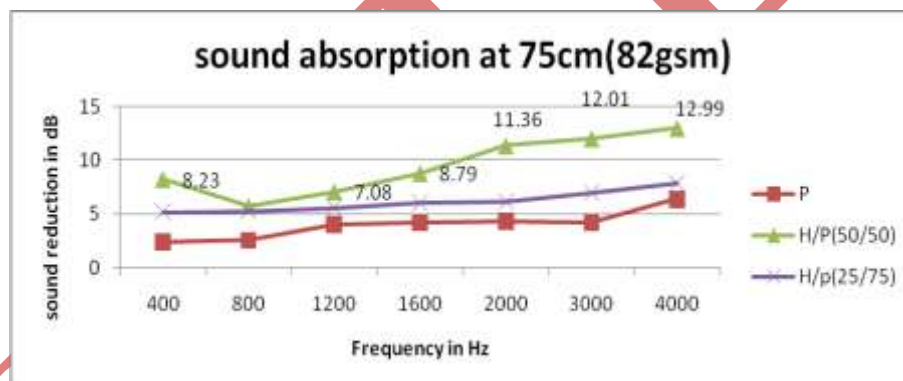


Fig. 20 Sound reduction of samples (A, B, C) at 75 cm distance

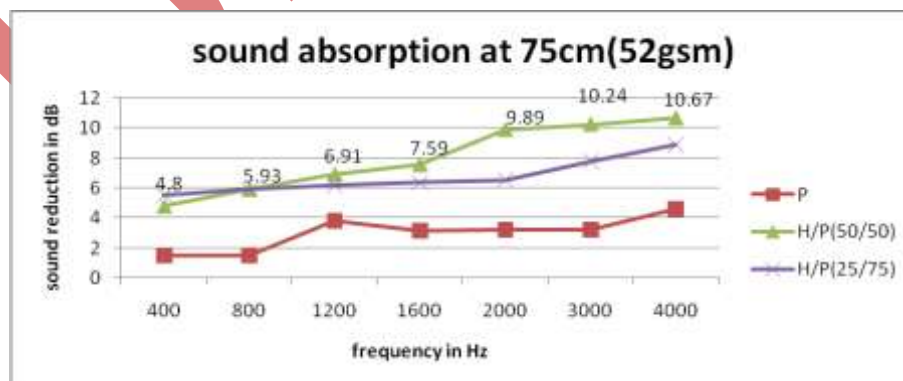


Fig. 21 Sound reduction of samples (A1, B1, C1) at 75 cm distance

From the Fig. 20 and Fig. 21, it is clear that sample C, C1 (50/50 hollow polyester/solid polyester) with 6 layers has the maximum sound absorption of 13dB and 11.5dB 4000Hz respectively, when compared with other samples.

3.4.8. Sound reduction of the pleated sample C

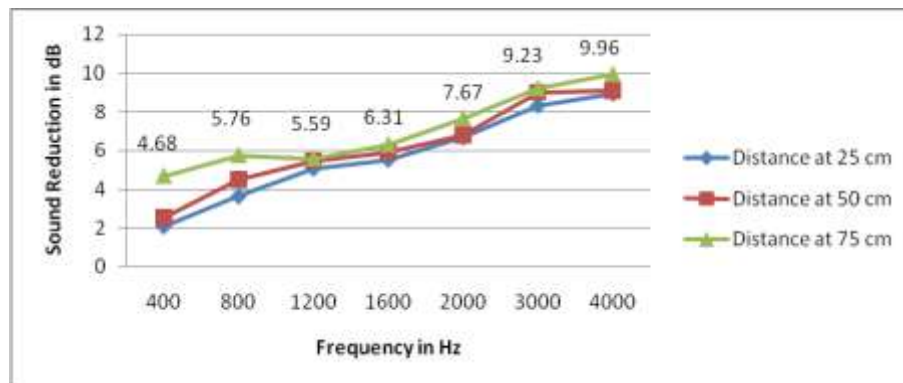


Fig. 22 Sound reduction of the pleated sample C at 75 cm distance

From Fig. 20 & 21, it was analysed that the samples C & C1 showed greater sound reduction than rest of the samples. Amongst the two samples C had higher sound absorption. Hence the sample C was pleated and tested at three different distances. It is concluded from the Fig. 22 that sample C (50/50 Hollow polyester/solid polyester) non-woven fabric with 82 GSM and with pleat has the maximum sound absorption of 9.74dB 4000 Hz at 75 cm distance.

4. CONCLUSION

The non woven fabric samples made of polyester and hollow polyester fibers of denier 6 and of three different proportions of 82 gsm and 52 gsm each, produced by spun lace technique were tested for their thickness, air permeability, thermal conductivity and sound insulation. Non woven fabric samples with higher gsm showed more thickness, which leads to lesser air permeability and higher thermal conductivity. Also Samples produced with 52 gsm showed good air permeable rate but lesser thermal conductivity.

The sound evaluation test was conducted for all the samples at three different distances and up to 6 layers. As the fabric layers and distance increased the samples showed more sound absorption i.e., leading to reduction in transfer of sound outside. Based on the gsm it was evaluated that sample C with equal proportion of polyester and hollow polyester fibers recorded the highest rate of sound absorption, and samples produced with 100% polyester fibers recorded the lowest rates. It was also found that there is direct relationship between weight per square meter and sound reduction. Similarly the pleated samples produced with high percentage of hollow fibers recorded the highest rates of sound absorption than 100% polyester fibers.

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