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To analyse the sound absorption characteristics of banana mat

M Jayakumari[1], R Divya[2]
[1] Assistant Professor, Department of Textiles and Apparel Design, Bharathiar University, Coimbatore, Tamil Nadu, India
[2] Assistant Professor, Department of Costume Design and Fashion, PSG College of Arts and Science, Coimbatore, Tamil Nadu, India

Abstract
The study therefore aims in developing of multifunctional finishes using banana fiber reinforced with synthetic polymers. The polymers and fibers used for the study were procured and processed before the use. The procured banana fibers were pre-treated with various concentration of sodium hydroxide for removing the components that hinder is activity. In India, many of the natural lignocellulosic fibres are considered as low value fibres useful only for manufacturing industrial ropes and fabrics for packaging. Banana is one such natural lignocellulosic natural fibre.

Keywords: natural fibres, finishes, sound proof

Introduction

Industrial textiles are subgroup of a wider category of technical textiles, which mainly involve those textile products used in the course of manufacturing operations or which are incorporated into industrial products such as electrical components and industrial appliances. In recent years there has been significant interest in the use of natural fibres as potential reinforcement for both organic and inorganic matrices (Idicula, Malhotra, Joseph and Thomas, 2005). Before the advent of man-made fibres, in particular glass fibre, natural fibres of both vegetable and mineral origin were the only reinforcement available for fibre-reinforced composite materials. The use of fibres like flax, hemp, jute or sisal in this industry so far is small since availability of a durable semi-finished product with constant quality is often a problem. Recent research and development have shown that these aspects can be improved considerably. Knowing that natural fibres are cheap and have a better stiffness per weight than glass, which results in lighter components, the grown interest in natural fibres is clear. The environmental impact is smaller since the natural fibre can be thermally recycled and fibres come from a renewable resource (Sapuan, Leenie, Harimi and Beng, 2006).

Banana fiber which obtained from the pseudo-stem of banana plant is a lingo-cellulosic bast fiber with relatively good mechanical properties and it has good specific strength properties comparable to those of conventional material. Banana fibers have high strength, light weight, smaller elongation, fire resistance quality, strong moisture absorption quality, great potentialities and biodegradability. Banana fiber has recognized for apparels and home furnishings. These fibers can be explored to develop various technical textiles which are the need of the hour. Therefore, banana fibers are chosen for this study and various properties of the developed composites are explored (Kumar, Choudhary, Mishra and Varma, 2008).

This work focuses on the absorption of bio based materials. The materials and structures using sound absorption material to reduce ambient noise received much attention. Noise absorbing materials absorb unwanted sound by dissipating sound wave energy when it passes through and also by converting some of the energy into heat, making them very useful for the control of noise. Noise control is a major factor in the planning, design, and construction of transportation corridors. Architects, acoustical engineers and transportation planners are searching for creative ways to eliminate or greatly reduce noise levels.

Objectives

1. To extract the fibers from Banana pseudo-stem and pre-treat them.
2. To analyze the characteristics of banana fiber
3. To develop various polymeric composites and reinforce banana nonwoven fabric
4. To explore the ability of the developed polymeric composite reinforced banana nonwoven fabrics in sound proofing and develop an acoustic material
5. To evaluate the acoustic property using impedance tube method
6. To explore the ability of the developed polymeric composite reinforced banana nonwoven fabrics in sound proofing and develop an acoustic material
7. To evaluate the acoustic property using impedance tube method

Methodology

Materials

- Natural fibers (Banana)
- Synthetic fibers (Polyester fabric, Polyurethane and Polypropylene)
- Natural rubber latex

Banana Fibre

- The Banana fiber is collected from Ecostar unit, TNAU, Coimbatore, India.

Banana Type

- Fiber bundles extracted from matured green husk or brown husks, with average length of between 36mm to 119mm. Decorticators or D1 machines produce fiber bundles.

Natural Rubber Latex

Rubber exhibits unique physical and chemical properties. Rubber's stress-strain behavior exhibits the Mullins effect, the Payne effect, and is often modeled as hyper elastic. Latex is the stable dispersion (emulsion) of polymer micro particles in a aqueous medium. Latexes may be natural or synthetic. The word is also used to refer to natural latex rubber; particularly for non-vulcanized rubber.

The natural rubber latex is purchased with the properties of Viscosity cps (sp 2/60) 20 – 100, TSC (%) 60.0 – 61.5, Alkalinity (%) 0.65 – 0.8, Mechanical stability 650 Seconds min, pH 10.5 – 11.5.

Polyester fabric, Polyurethane and Polypropylene

Polyester fabric, polyurethane and polypropylene woven cloth is purchased from Pollachi (12 Gauge hessian cloth), that is layered on the Banana latex mats.

Flow Chart – Methodology

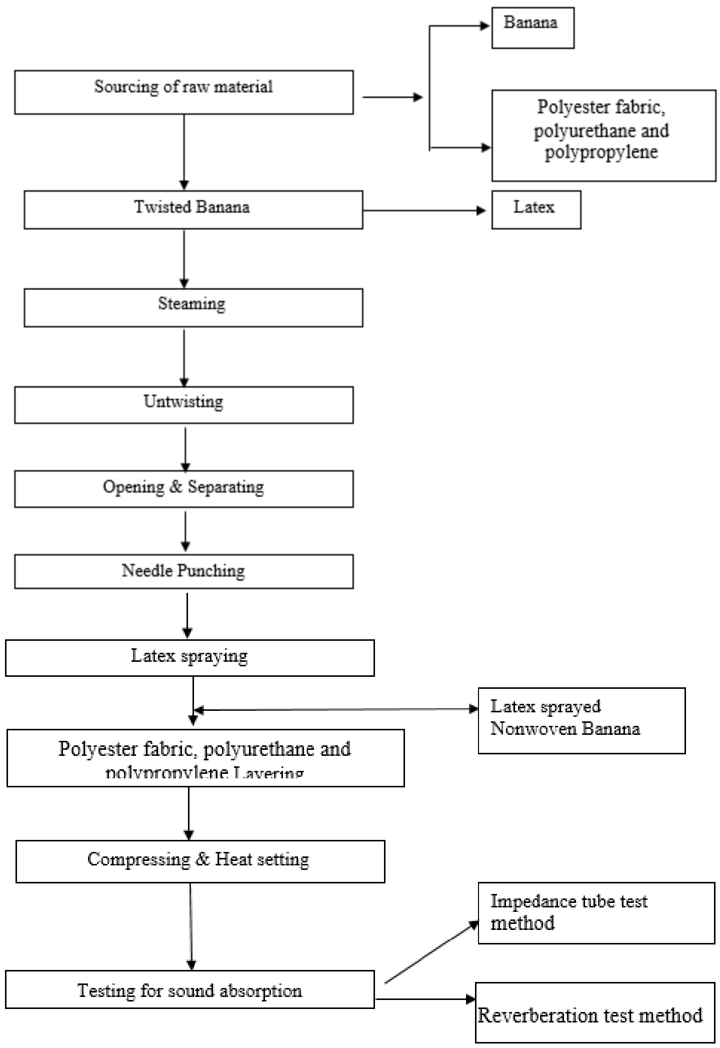

Fig 1: Flowchart

The Figure 6.1 explains the methodology of producing the hybrid nonwoven structure. Banana fibers were sourced as twisted ropes and subjected to dry in a drying chamber to remove its moisture content. The dried twisted Banana fibres were then machined in an untwisting chamber which removes the twist and sends it to a pin typed opening roller. These well opened fibres were directed to the web forming unit in order to convert the lose fibres into a batt. After which the web was passed through the needle punching machine. The fiber was punched at the rate of about 240 strokes per min on a needle board of width 2.2m and with a needle density of 5 needles per square inch. The natural rubber polymer latex which acts as the bonding agent was uniformly sprayed over the needle punched Banana mat using an automatic spray gun. For the samples which needed polyester fabric, polyurethane and polypropylene coverings, the backing was done at this stage and then the mats were thermally bonded in a hot press at 110^0 C ± 2^0 C for 5 minutes and cooled under ambient conditions.

Sample Preparation

Table 1 and 2 shows the design specification and specifications of the samples. Figure 1, 2 and 3 shows the nonwoven Banana mat samples with 10 mm thickness.

Table 1: Design specification

Density (g/decim^3)	**90**	**110**	**130**
Latex%	19	22	25
Covering material (polyester fabric, polyurethane and polypropylene)	Without	Single side	Double sided

Table 2: Sample Specification

Samples	Density(g /decim^3)	Late x%	polyester fabric, polyurethane and polypropylene covering
S1	110	19	-
S2	90	19	-
S3	130	19	-
S4	110	22	Single side
S5	110	25	Single side
S6	110	22	Double side
S7	110	25	Double side
S8	110	22	-
S9	110	25	-

Fig 1: Nonwoven Banana sample without polyester fabric, polyurethane and polypropylene layering

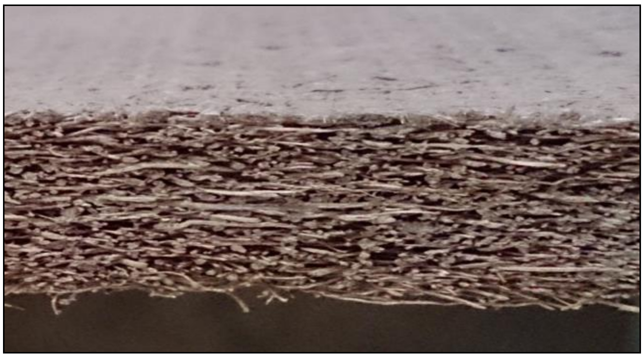

Fig 2: Nonwoven Banana sample with single side polyester fabric, polyurethane and polypropylene

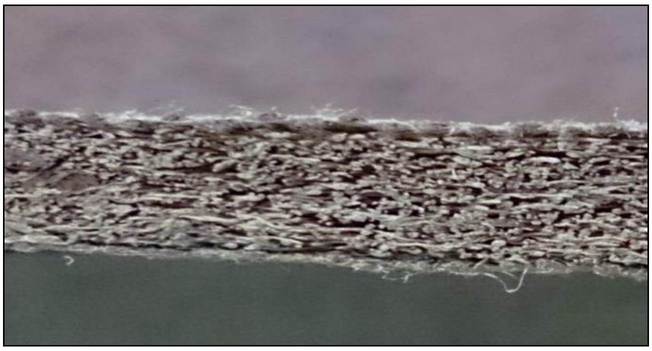

Fig 3: Nonwoven Banana sample with double side polyester fabric, polyurethane and polypropylene layering

Test Methods

Impedance Tube Test

The acoustic properties of the produced Banana mats were measured by means of impedance tube type 2716-C. Measurements are based on the two-microphone transfer-function method according to ISO 10534–2 and ASTM E1050–98 international standards. The impedance tube is a hollow cylinder with a sound source at one end and a test sample holder at the other. Microphone ports are mounted at two locations along the wall of the tube as shown in the Figure 4.

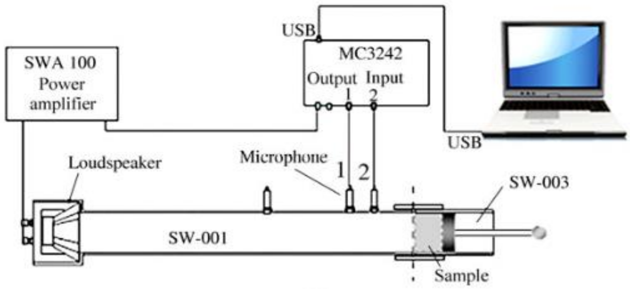

Fig 4: Schematic diagram of acoustical material testing system

Reverberation Time Test Method

The equipment set up shown in Figure 6.6 can be used to obtain reverberation decays. A wide band sound signal is amplified and used to measure the reverberation time.

An unidirectional microphone is positioned on tripod, usually at ear height for a listening room, or microphone height for a room used for recording The smaller the microphone capsule, generally the less its directional effects. Some larger capsule microphones (e.g., 1-in-diameter diaphragms) can be fitted with random incidence correctors, but using a smaller microphone (e.g., 1/2-in-diameter diaphragm) is preferred for more uniform sensitivity to sound arriving from all angles.

Audacity software is used to measure the RT60. Here, there are two methods were adopted to measuring reverberation time 1) balloon burst method 2) impulse frequency generation method. In the case of first method balloon is used for source, in the second method small loud speaker is used as a source. in second method only we can measure the RT 60 in different frequencies. In balloon burst method at fraction of second the decay time was measured and it contain all frequencies.

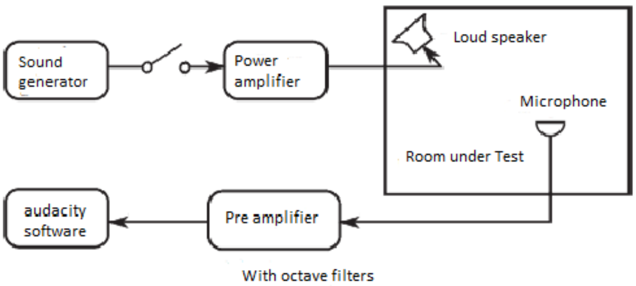

Fig 5: Equipment configuration for measuring the reverberation time of an enclosure

Results and Discussions

Effect of Density on Absorption Coefficient

The Figure 6.7 and Table 6.3 shows the sound absorption coefficient at different frequencies of the developed samples with densities: 90,110 and 130 g / decim^3 respectively. It is observed that all the tested nonwoven mats have low sound absorption coefficient (equal or lower than 0.09) in low frequencies (100-400 Hz) and high sound absorption coefficient up to 0.76 for S3, 0.71 for S1 and 0.63 for S2 at high frequencies (2000 -6300 Hz). The above graph clearly shows that there is a dominant influence of the density on the sound absorption in all frequency as the density of the material is proven to be directly proportional to it's sound absorption which is expected to last upto a certain limit (Sapuan, Leenie, Harimi and Beng, 2006). This might be due to change of properties like increased air flow resistance, small pore size, more tortuous path and more contact area for sound to get dampened at high densities (Abdul Hakim Abdullah, Afiqah Azharia, Farrahshaida Mohd Salleh, 2015).

The linear equation of S1 is Y = 0.000X + 0.024 with R^2 value of 0.957, S2 is Y =0.000X + 0.012 with R^2 value of 0.978 and S3 is Y = 0.000X + 0.050 with R^2 value of 0.931.the sound absorbing performance of S1, S2 and S3 shows good correlation.

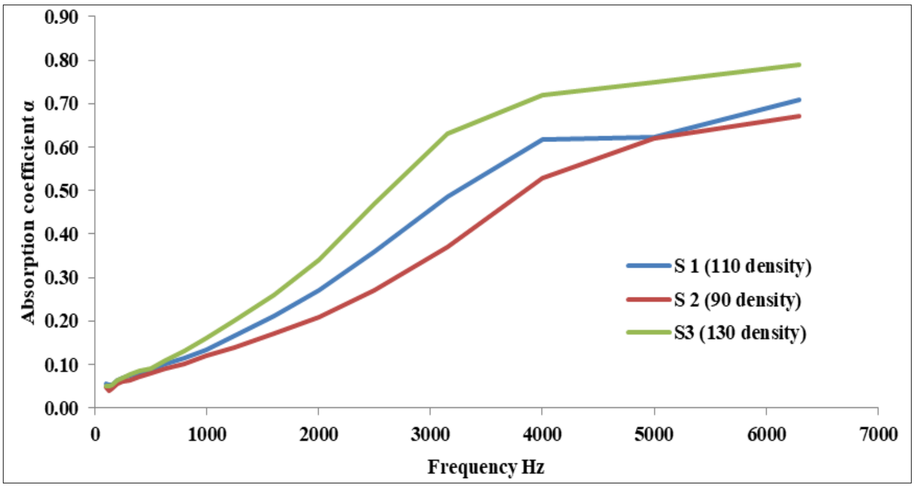

Fig 6: Influence of density on absorption coefficient

Effect of Latex% on Sound Absorption

Table 3: Influence of density on absorption coefficient

S.No.	Samples	Frequency Hz	absorption coefficient
1	S1 (90 density)	150	0.03
2		1000	0.08
3		2000	0.24
4		3000	0.32
5		4000	0.52
6		5000	0.58
7		6000	0.62
8		7000	0.63
1	S1 (110 density)	150	0.06
2		1000	0.10
3		2000	0.26
4		3000	0.42
5		4000	0.56
6		5000	0.60
7		6000	0.65
8		7000	0.69
1	S1 (130 density)	150	0.08
2		1000	0.16
3		2000	0.56
4		3000	0.63
5		4000	0.68
6		5000	0.60
7		6000	0.71
8		7000	0.78

Table 4: Influence of latex percentage on absorption coefficient

S.No.	Samples	Frequency Hz	absorption coefficient
1	S1 (19% Latex)	150	0.04
2		1000	0.12
3		2000	0.27
4		3000	0.49
5		4000	0.62
6		5000	0.60
7		6000	0.60
8		6500	0.72

1	S8 (22% Latex)	150	0.06
2		1000	0.15
3		2000	0.29
4		3000	0.53
5		4000	0.68
6		5000	0.64
7		6000	0.62
8		7000	0.61
1	S9 (25% Latex)	150	0.06
2		1000	0.16
3		2000	0.28
4		3000	0.51
5		4000	0.68
6		5000	0.66
7		6000	0.64
8		7000	0.62

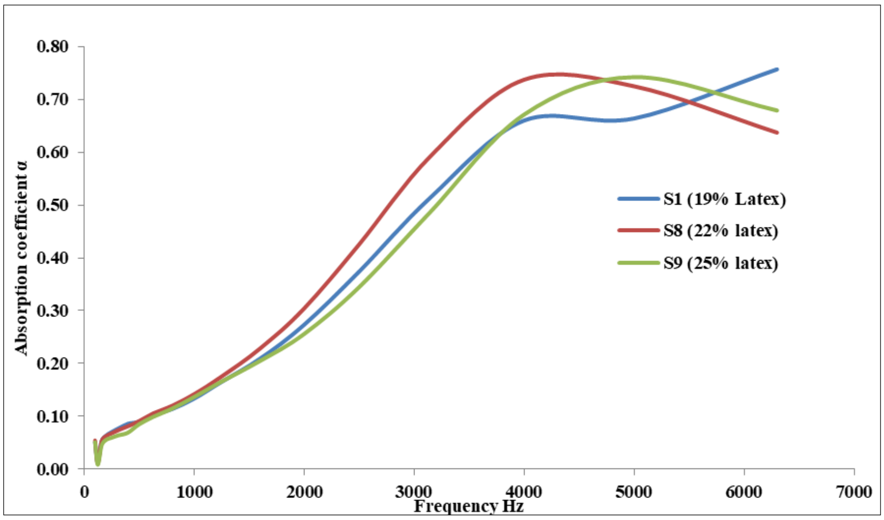

Fig 7: Influence of latex percentage on absorption coefficient

From the Figure 6.8 and Table 6.4, it is observed that 22% latex coated sample S8 shows better absorption coefficient than S1 and S9 in the mid-high frequency range (1000-4000 Hz), due to the possession of high volume fraction of amorphous regions in the latex, after which the trend declines.. The α value of sample S9 with 25% latex is observed to be shifting lower due to over cross linking of the latex polymer with Banana resulting to the formation of a thin film which blocked the pores (Mohapatra, Mishra and Sutar, 2010; Nilza, Jústiz-Smith, Junior Virgo, Vernon and Buchanan, 2008).

The polynomial equation of S1 is Y = -1E-08X^2 + 0.00X – 0.050 with R^2 value of 0.979, S8 is Y = -3E^2 + 0.000X – 0.014 with R^2 value of 0.955 and S9 is Y = - 2E - 08X^2 + 0.000X – 0.070 with R^2 value of 0.957. The model with the $R^2 \geq 0.6$ (60%) can be considered as a valid model. From the above obtained values it is evident that, nonwoven Banana mat Latex percentage has R^2 value of more than 0.8 indicating that the model is valid (Padam, Tin, Chye and Abdullah, 2014; Srinivasan, Rajendra Boopathy, Sangeetha and Vijaya Ramnath, 2014).

Effect of polyester, polyurethane and polypropylene covering material on sound absorption

Table 5: Influence of polyester fabric, polyurethane and polypropylene covering material with 22% latex on absorption coefficient

S.No.	Samples	Frequency Hz	Absorption coefficient
1	S4 (Single side)	150	0.04
2		1000	0.12
3		2000	0.27
4		3000	0.49
5		4000	0.62
6		5000	0.60
7		6000	0.60
8		6500	0.72
1	S6 (Double side)	150	0.06
2		1000	0.15
3		2000	0.29
4		3000	0.53
5		4000	0.68

6		5000	0.64
7		6000	0.62
8		7000	0.61
1	S8 (No covering)	150	0.06
2		1000	0.16
3		2000	0.28
4		3000	0.51
5		4000	0.68
6		5000	0.66
7		6000	0.64
8		7000	0.62

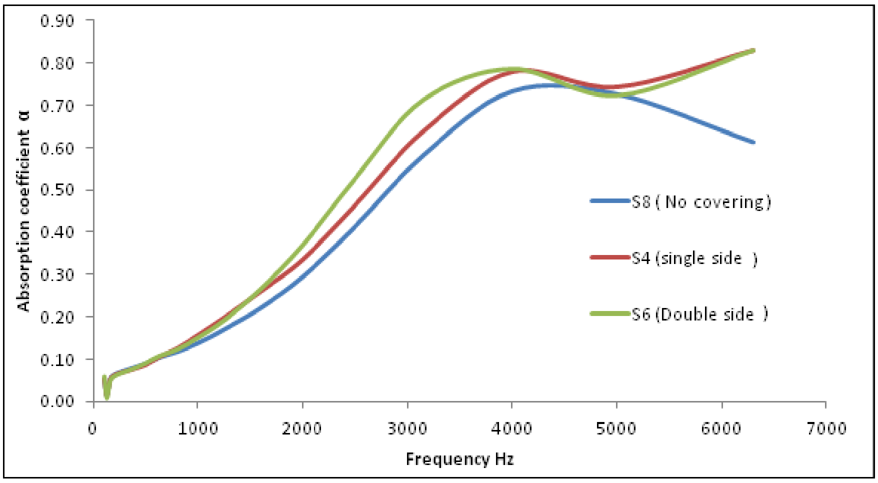

Fig 8: Influence of polyester fabric, polyurethane and polypropylene covering material with 22% latex on absorption coefficient

The acoustic properties of the nonwoven hybrid structure with polyester fabric, polyurethane and polypropylene coverings were compared as shown in the Figure 6.9, Table 6.5 and Figure 6.10, Table 6.6. It is observed that the samples with double side polyester fabric, polyurethane and polypropylene covering perform better in terms of sound absorption values. This was an effect of increase in the surface pores and the volume fraction of amorphous regions on the surface. 25% Latex with double sided polyester fabric, polyurethane and polypropylene covering shows slightly higher absorption coefficient values (0.85 – 0.97) than 22% latex with double sided polyester fabric, polyurethane and polypropylene covering (0.8). The probability of the polyester fabric, polyurethane and polypropylene covering to act as a perforated panel might have influenced this result (Pathak, Mandavgane and Kulkarni, 2016; Guimarães, Wypych, Saul, Ramos and Satyanarayana, 2010).

Table 6: Influence of polyester fabric, polyurethane and polypropylene covering material with 25% latex on absorption coefficient

S.No.	Samples	Frequency Hz	Absorption coefficient
1	S4 (Single side)	150	0.04
2		1000	0.12
3		2000	0.28
4		3000	0.57
5		4000	0.69
6		5000	0.67
7		6000	0.68
8		6500	0.69
1	S6 (Double side)	150	0.05
2		1000	0.18
3		2000	0.34
4		3000	0.79
5		4000	0.74
6		5000	0.82
7		6000	0.84
8		7000	0.85
1	S8 (No covering)	150	0.03
2		1000	0.11
3		2000	0.23
4		3000	0.44
5		4000	0.68
6		5000	0.64
7		6000	0.63
8		7000	0.61

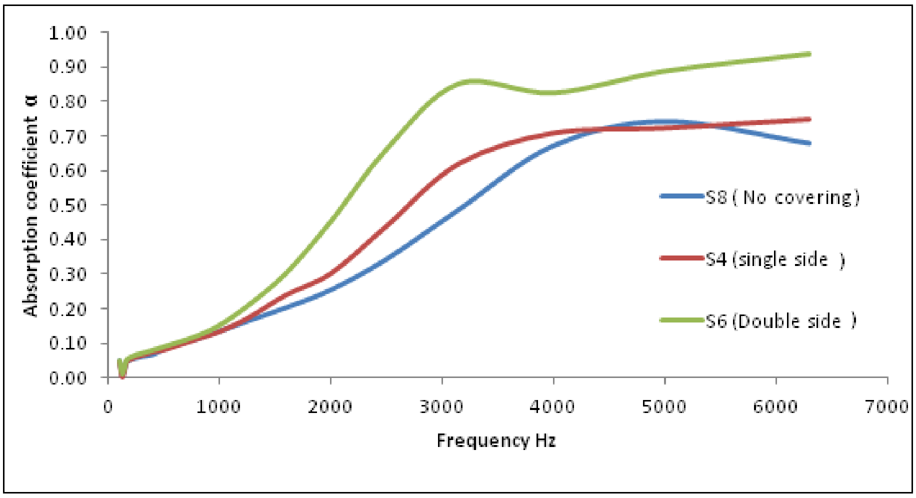

Fig 9: Influence of polyester fabric, polyurethane and polypropylene covering material with 25% latex on absorption coefficient

The polynomial equation of the S8 is Y = -3E-08X^2 + 0.000X – 0.014 with R ^{2} value of 0.955, S4 is Y = -2E-08X^2 + 0.000X - 0.082 with R ^{2} value of 0.981, S6 is Y = -1E-08X^2 + 0.000X – 0.034 with R^2 value 0.983, S9 is Y = -1E-08X^2 + 0.000X – 0.036 with R^2 0.0983, S5 is Y = -2E-0.8X^2 + 0.000X – 0.045 with R ^{2} 0.979 and S7 is Y = -3E-08X^2 + 0.000X - 0.089 with R^2 value of 0.965. The sound absorbing performance of polyester fabric, polyurethane and polypropylene covering with different latex percentage shows good correlation (Sherely Annie Paul, Abderrahim Boudenne, Laurent Ibos, Yves Candau, Kuruvilla Joseph, Sabu Thomas, 2008; Sivaraj and Rajeshkumar, 2011).

Conclusion

All the samples show higher sound absorption coefficient at higher frequency range. This trend has been followed throughout the spectrum and drastic increments are exhibited in the high frequency range (2000-6300Hz) that always contains the best values of sound absorption.

Samples with different latex%: S1 (19%), S8 (22%) and S9 (25%) were tested acoustically. The experimental test results exhibited better sound absorption coefficient for S2 at high frequency range of 1000 – 5000Hz.

The covering of polyester fabric, polyurethane and polypropylene layer cloth on the surface of the Banana matt with both sides increased the sound absorption properties significantly. For the samples with constant thickness of 10mm, double side polyester fabric, polyurethane and polypropylene covering exhibits a better sound absorption (0.94 at 6400 Hz for S7) when compared to the sample with single side polyester fabric, polyurethane and polypropylene covering and to the sample with no covering.

Generally the result indicated that the natural fibrous Banana mat hold promising properties to be used as an eco-friendly sound absorbing material for auditoriums, theatres, floor mats, home theaters and in any high sound environments.

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