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Studies on the Physico-Mechanical Properties of Jute Reinforced Acoustic Panels to Ascertain Diversified Uses

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ABSTRACT

Noise industry is a major cause of fatigue, irritation, decreased productivity and occupational accidents. Dangerous to hear continuous exposure to 90dB or above. One of the main methods of noise control is to place sound absorbing barriers (made of jute) between the source and the subject. The goal of this study is to study the acoustic properties of biodegradable and easily disposable natural fiber jute and compound it for noise reduction in household appliances, automotive and architectural applications. The effect of the type of fabric and the number of layers of different non-woven fabrics have been studied in indigenously made tools. Nonwoven fabrics show higher noise reduction than woven fabrics. The fabric is assessed by placing the fabric 8 cm from the sound source and the receiver decibel meter (R) 16 cm on the same side. It can be observed that randomly laid jute samples reduce the maximum noise among all the samples tested. As the number of layers of nonwoven fabric increases, the noise reduction through the sample increases initially but after most it remains almost unchanged.

KEYWORDS: *Jute composites, Noise reduction, Surface effect, Sound absorption, Sound transmission, Random laid.*

INTRODUCTION

Increasing use of electrical and mechanical appliances at home and industries has created a concern for noise pollution created by them. Urbanization and heavy growth of construction work in every neighborhood further emphasize the need of new technologies for noise reduction. Noise created by different machines can be controlled either by suppressing the noise generating factors or by using the noise proofing materials which help to reduce the acoustic wave's energy by blocking or absorption. Traditionally, noise is controlled by using expensive and non-bio-degradable sound absorbing materials such as glass wool, polymer foams, fabric filler and polymer fibres, posing an additional harm to the environment. As alternate, natural fibres like jute, cotton, flax, ramie, sisal and hemp obtained from renewable resource can be used as a cheap, biodegradable and recyclable sound absorbing materials. Although composites made of jute fibre/felt with other fibres are being used for various applications in automotive industry, construction, building sectors, furniture etc. yet jutes application as a sound absorbing/blocking material have to be explored as a solution for noise reduction problem.

Basics of Sound

A person perceives sound as any vibration of the eardrum in the audible frequency range as a result of an increasing change in air pressure in the ear. A change in pressure above and below atmospheric pressure is called sound pressure and is measured in units of Pascal (Pa).The number of pressure variations per second is called the frequency of sound, which is measured in cycles per second, which is called Hertz (Hz). A young person with normal hearing can perceive sound in the frequency range of about 20 - 20,000 Hz, which is defined as the normal audible frequency range. The reciprocal period of a pure vowel frequency is called. A period is defined as the time required for a complete cycle of sinusoidal tone and is measured in seconds. Speed of sound is the rate at which a sound wave propagates through a given medium and depends on the elasticity and density of that medium. For all practical purposes, the speed of sound in air depends only on the absolute temperature, which directly affects its concentration. At room temperature and ideal atmospheric pressure, the speed of sound in air is 343 m/s. Wavelength is defined as the distance of a pure vowel wave travel in a full time and is denoted by the Greek letter lambda (λ). The wavelength of a pure vowel is equal to the speed of sound divided by the frequency of pure vowel f c =. Knowledge of tonal wavelengths is often used in the design of noise reduction elements to interrupt or mimic offensive tones or sounds.

Sound Absorptive Materials

Substances that reduce the sound energy of a sound wave when it passes through it due to the phenomenon of wave absorption are called sound absorbing substances. These are usually used to soften a closed volume acoustic environment by reducing the amplitude of the reflected wave. Absorbents are usually resistant in nature, either fibrous, porous or, in some cases, reactive resonators. Classic examples of resistant materials are nonwoven, fibrous glass, mineral wool, felt and foam. Resonators include hollow core masonry blocks, sintered metal and so on. Most of these products provide some amount of absorption at almost all frequencies and performance at low frequencies usually increases with increasing material thickness.Perforated components used for noise control are generally classified as fibrous medium or perforated foam. Fibrous media are usually made of glass, rock wool or polyester fiber and have high sound absorption. Sometimes fire-resistant fibers are also used to make verbal products. Often noise barriers are confused with sound absorbing materials. Materials that generally provide good absorption are weak barriers. Unlike barrier and damp materials, the mass of the material does not directly affect the absorbent efficacy. Materials derived from synthetic fibers, such as mineral wool, are commonly used for heat and sound insulation because of their good performance and low cost (2).

- Mineral wool (glass) : 27%
- Mineral wool (stone): 30%
- Foam plastics: 40%
- Other materials: 3%.

These ingredients, although widely used, can be harmful to human health if their fibers are inhaled, as they can lie in the alveoli of the lungs and cause skin irritation. Therefore such materials must be adequately covered when in direct contact with air. Moreover they can pulverize and are not resistant to water, oil and chemical agents and this does not make their application suitable for absorbing sound barriers. In recent years, there has been a growing focus on natural fibers as an alternative to synthetics, to combine high acoustic and thermal performance with minimal impact on the environment and human health. Natural fibers have very low toxicity and their production process can contribute to environmental protection. Recycled materials, such as recycled plastic fibers and recycled rubber mats, may even be considered a sustainable alternative, as they contribute to lower waste generation and raw material use. However, it is important to evaluate the "sustainability" of natural or recycled materials and to verify the total energy consumption in the production process.

Sound Insulation

Noise insulation is required to eliminate the sound path of a receiver from a source to reduce unwanted external noise in an apartment of a building, or inside a concert hall. Heavy materials such as concrete continue to be the best material for sound insulation which will double the unit area per wall and improve its insulation by about 6dB. Good insulation can be achieved with much less mass by using double leaf partition (two separate independent walls).

Types of Acoustical Effects

Sound is the sensation of sound waves. (Disruption / pressure setup setup in a medium). Unpleasant, unwanted, annoying words are generally considered as noise and it is a highly subjective feeling. Basically sound propagation is the molecular transfer of kinetic energy. Workplace and environmental noise pollution is a significant threat to human comfort. There are various ways to reduce noise and they can be grouped by passive and active means.

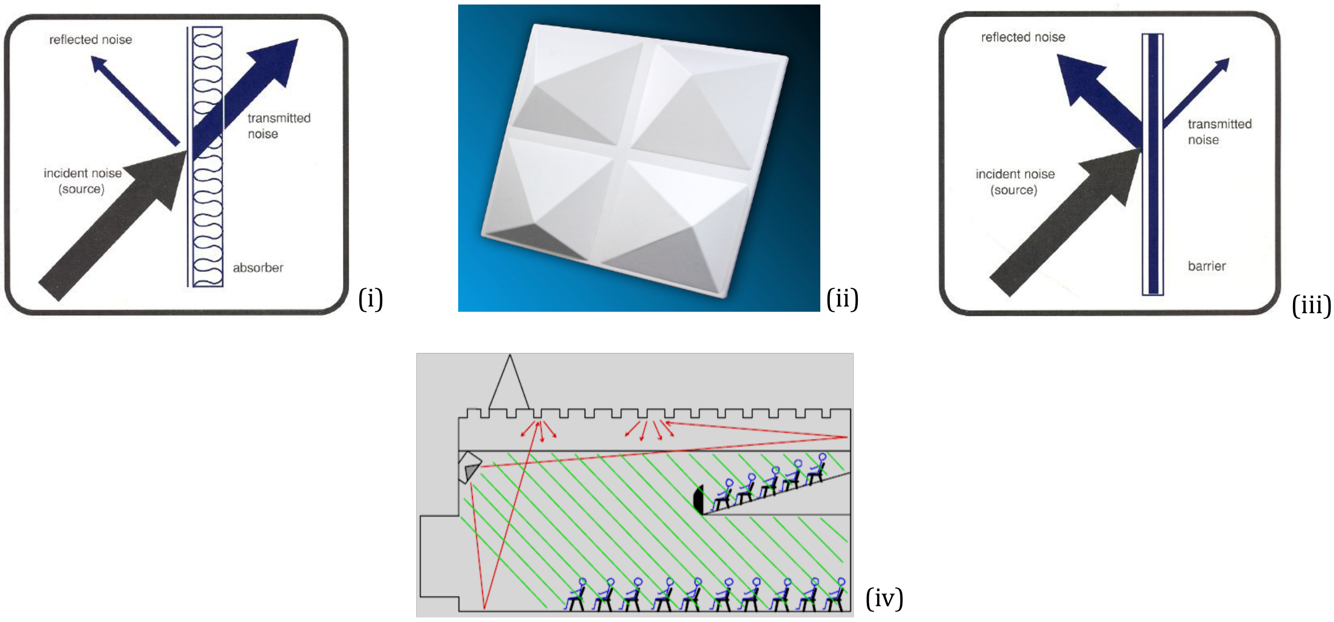


Fig.1. (i) Sound Absorbers (ii) Sound Diffusers (iii) Noise Barriers (iv) Sound Reflectors

Passive media reduces noise by dissipating energy and converting heat into heat, whereas in the process of noise reduction of active media requires the application of external energy. In practical applications textiles are often employed as sound absorbers, for example, textile interior parts of automobiles or room carpets that are used to absorb sound energy. The absorbent material in these applications is mounted directly on an acoustic hard surface. The textile can then be considered as a porous medium and its sound absorption properties depend on its thickness.

Recently, the subject of noise has received increasing amount of attention to the scientists, technologists and public as a whole. There is ample evidence showing that the high noise levels cause sleep disturbance, hearing loss, decrease in productivity/learning ability/scholastic performance, and increase in stress related hormones and blood pressure. Therefore, unwanted and uncontrolled noise should be reduced using noise barriers and noise absorbers. Properly designed textile materials may be considered as noise control elements in a wide range of applications, including wall claddings acoustic barriers and acoustic ceilings [1].

The sound reduction between two spaces is dependent on all of the elements of the structure separating them. The sound pressure waves cause the fibres or particles to vibrate. These movements are so small that they are not normally visible. This vibration liberates tiny amount of heat due to the friction and thus absorbed sound energy is converted to potential and heat energy. Common porous absorbers include carpet, draperies, spray-applied cellulose, aerated plaster, fibrous mineral wool and glass fibre, open cell foam and felted or cast porous ceiling tile. The air inside the pores acts as damper. The most effective way to increase damping is through the use of a viscous interlayer such as soundproofing mat. Bending waves, excited by the incident sound, because shear strains within the viscous interlayer material. Because the interlayer has inherently high damping, the bending eaves are transformed into heat energy. The mass law predicts that the transmission loss will increase by approximately 6 dB for doubling of the surface mass using thicker material or denser material [2].

A numerical method of calculating acoustic performance of nonwovens has been proposed in a study [3] and the noise absorption coefficient of fibre webs is shown as a function of their thickness and porosity. It has been shown [4] that the absorption coefficient is higher for the nonwoven having more fine fibres. The use of nonwoven is increasing rapidly in the automobile industry due to its sound insulation property [5]. One of the oldest applications of impregnated jute or shoddy mat is in noise damping [1,6]. The efficacy of the nonwoven materials as sound insulator has been examined by Teli et al. [7]. They observed that with the increase in frequency and area density the extent of sound reduction increases by the nonwoven while with the increase in air permeability, it decreases.

Needle-punched nonwoven with jute and its blend may be used as sound insulator and absorber. However, the information regarding this is found to be scanty. Detailed study and proper quantification of various jute and jute blends is necessary for their use as sound absorbent/ insulator. Keeping this in mind, in the present study an attempt has been made to investigate the sound reduction by various specially tailored jute, polyester, polypropylene and jute:polypropylene blended needle-punched nonwovens.

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 jute) between the source and the different is one of the main methods of noise control. Hard, rigid, materials like concrete and brick have almost no sound absorption. Other building materials (lightweight plaster walls, windows and different panels or floors on studs) work as membrane absorbers and contribute significantly to the low-frequency absorption. Carpet, velour fabric and heavy curtain show good acoustic property [8]. Textile materials are used in many sound insulation applications in interior design products (panels and upholstery), automotive insulation (carpet, trunk liners and roof paneling) and machine sound insulation (duct liner and trunk). Acoustical wall panels made from 100% polyester (60% PET-recycled fibre and 40% PET-virgin fibre), are recyclable and provide great sound absorption [9]. Acoustic ceilings made of fiberglass, mineral fiber, wood, or metal control the sound quality by absorption and diffusion of sound eaves. In automobiles textile materials are used to enhance comfort, thermal insulation, cabin air filters, safety and sound insulation. Skill weavers have developed lightweight, translucent curtain materials known as "sound quenching curtain"., which are excellent in absorbing sound. With a gap of 15 cm between curtain and wall, it can absorb up to five times more sound than typical lightweight curtains [10] Nonwoven absorbent materials especially recycled materials have low production costs, low specific gravity and are aesthetically appealing.

High density materials, such as steel, can prevent the transmission of sound very effectively by almost total reflection of the incident sound, thus causing sound pollution. Moreover, the sheer weight and cost of steel materials render them as an inefficient sound insulating material. Currently porous materials such as nonwovens fibrous assemblies are widely used as sound absorptive materials. Nonwoven fabrics are usually manufactures directly from fibres, thus partially or completely eliminating conventional textile operations, such as drawing, roving, spinning, weaving, or knitting. The simplicity of fabric specific gravity, allows nonwovens to compete favorably with woven or knitted fabrics in terms of performance and cost in applications ranging from simple low cost replacements for more expensive textiles to high-quality textiles.

In Bangladesh very little and limited research works have been carried out in the field of jute composites for making acoustic panels or similar products. The Chemistry Division feels that research should be conducted in this prospective field of interest so that jute fibre could be more profitably utilized and jute sector shall remain viable for contributing much more to the national economy ofBangladesh. Therefore, this project has been undertaken to start-up a new dimension for jute diversification.

MATERIALS AND METHOD

Materials: Tossa Deshie jute of grade TD_3 was used for the preparation of needle –punched nonwoven fabrics.

Evaluation of Sound Insulation

Fabrication of Sound Absorption/Insulation Testing Apparatus

A simple testing apparatus has been set up to measure the permeability of sound through a jute fabric. It consists of a sound insulating box made out of thick transparent rigid plastic with removable top lid. Inside one vertical wall of this box a sound source and a decibel meter (S) are fixed. In another movable (to adjust the distance between sound source and receiver) vertical wall, a decibel meter (R) is fixed coaxially opposite to sound generator to measure the sound intensity. In between these two decibel meters, a sliding (to adjust the distance between sound source and fabric) arrangement is there to fix the fabric sample vertically. The sound intensity is controlled by an electrical panel.

Measurement of Sound Insulation

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

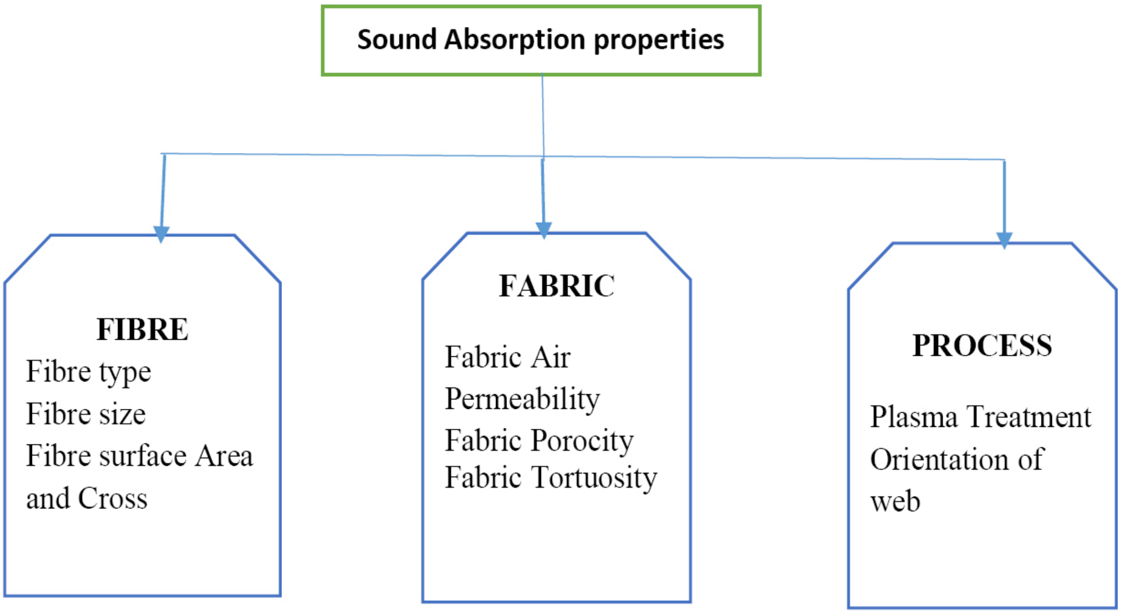
dB_F = (Decibel reduction with sample) – (Decibel reduction without sample)

$$= (dB_S - dB_R)_{WS} - (dB_S - dB_R)_{WOS}$$

Where dB_F is the sound reduction responsible for fabric; dB_S is the sound intensity at source; dB_R the sound intensity at receiver; WS, with sample and WOS, without sample.

Factors influencing sound absorption of nonwoven materials

The efficacy of a material as a sound barrier depends on frequency of the sound wave to which material is exposed, fabric weight per unit area, air permeability of the substrate, thickness and construction. Acoustic insulation and absorption properties of nonwoven fabrics depend on fiber geometry and fibre arrangement within the fabric structure [10]. A summary of the factor s influencing sound absorption of nonwoven materials is shown in figure;



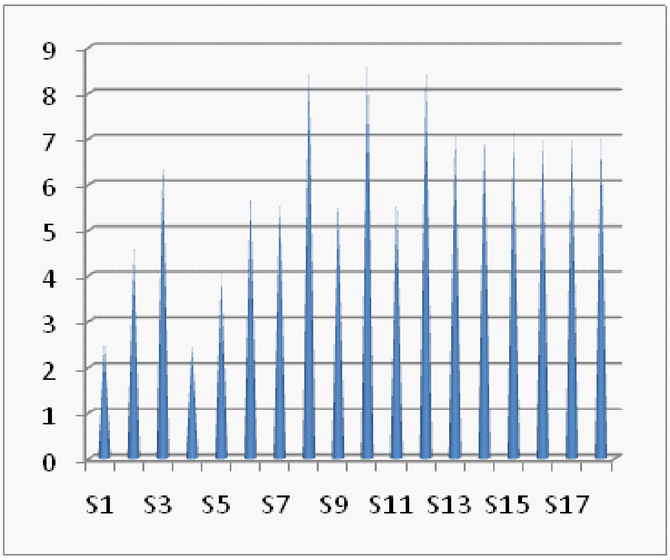
RESULT AND DISCUSSION

Table 1: Constructional details of Cross laid, parallel laid and random laid experimental Fabrics.

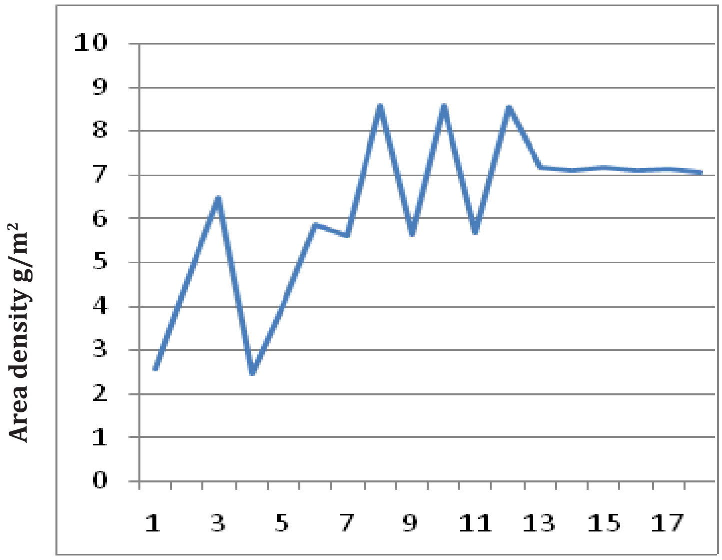
Sample No.	Fibre	Laying type	Proportion	Mass per unit area g/m^2	Fabric thickness mm	Bulk density g/cm^3
S1	Jute	Cross laid	100%	299	2.55	0.117
S2	Jute	Cross laid	100%	512	4.57	0.112
S3	Jute	Cross laid	100%	701	6.49	0.108
S4	Jute	Cross laid	100%	295	2.45	0.120
S5	Jute	Cross laid	100%	515	4.05	0.127

S6	Jute	Cross laid	100%	701	5.85	0.119
S_7	Jute	Parallel laid	100%	706	5.60	0.126
S_8	Jute	Parallel laid	100%	910	8.58	0.121
S_9	Jute	Parallel laid	100%	699	5.65	0.124
S_{10}	Jute	Parallel laid	100%	910	8.58	0.121
S_{11}	Jute	Parallel laid	100%	697	5.67	0.123
S_{12}	Jute	Parallel laid	100%	912	8.56	0.106
S_{13}	Jute	Random laid	100%	711	7.18	0.099
S_{14}	Jute	Random laid	100%	715	7.08	0.101
S_{15}	Jute	Random laid	100%	712	7.17	0.099
S_{16}	Jute	Random laid	100%	717	7.10	0.100
S_{17}	Jute	Random laid	100%	713	7.14	0.099
S_{18}	Jute	Random laid	100%	710	7.04	0.100

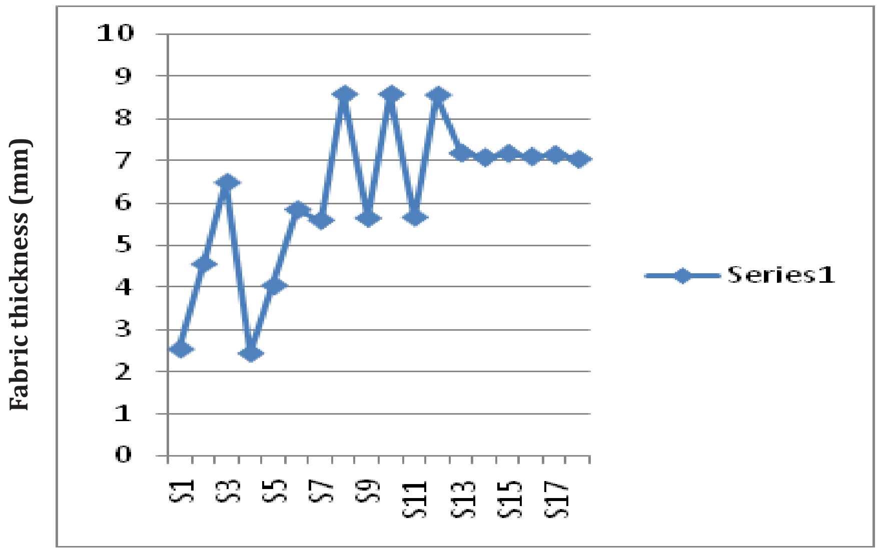
The sound reduction of 500 g/m2 fabrics made out of 100% Jute. The evaluation has been done keeping the fabric at 8 cm and receiver decibel meter (R) at 16 cm in the same side from the source of sound. It can be observed that random laid jute samples give the highest sound reduction among all the samples tested.



Different samples
Fig-1: Effect of Fabric Area density



Fabric Thickness mm Different samples
Fig-2: Effect of Fabric thickness



Different samples
Fig-3: Effect of bulk density

EFFECT OF NUMBER OF LAYERS OF FABRIC ON SOUND REDUCTION

Jute fabrics having single layer area density of 500,700 and 900 g/m2 are tested for sound insulation in single and multiple layers. With the increase in number of layers of Jute fabric, the sound reduction through the samples increases initially but after the maximum it remains almost unaltered. As the layer increases, it not only increases the area density of the combined sample but also introduces an air gap between the layers. At the maximum sound reduction, possibly all the frequencies of sound that can be absorbed or reflected by the said jute fabric are restricted and beyond that the effect of addition of layer is found inactive. In this case, the maximum reduction is achieved with 500g/m2 of 4 layers having total area density of 2000 g/m2 or 900g /m2 of 2 layers having total area density of 1800g/m2.

CONCLUSIONS

Sound reduction is observed in the following order: Random laid > Cross laid > Parallel laid. Sound reduction increases as the distance between the fabric and the sound source increases. With the increase in area density of fabric, this effect increases. It is also observed that the higher the source decibel, the lower is the sound reduction. With the increase in number of layers of jute fabric, the sound reduction through the set of fabrics increases initially but after the maximum it remains almost unaltered.

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