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INVESTIGATION OF SOUND LOSS POTENTIAL OF NATURAL FIBERS AND THEIR COMPOSITIONS

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ABSTRACT

Natural fibers are porous in nature which is useful feature for sound absorption. Natural materials are ecofriendly and less harmful. Natural fibers have potential to play important role in acoustic treatments at various sensitive areas like hospitals, classroom, research laboratories, libraries, residential areas and offices. Experiments were conducted on natural fibers to understand its sound loss potential. The present paper also discusses method of sample preparation for the different compositions. Bagasse, Rice husk, Rice straw, Wood dust was tested to measure their sound loss potential. The test setup used for estimating the sound loss potential consisted of an emitter and receiver. Tests were conducted by measuring the sound level at receiver without any obstruction and readings were repeated by placing the sample in between. The difference of the two reading estimated the sound loss for that sample. The sound absorption coefficient for each case was estimated and compared with other similar materials reported in the literature. It was observed that sample made by combinations of rice husk, rice straw and wood dust gave considerable improvement in the performance. The present article discusses the sample preparation method, test setup used and results observed for different natural fibers. The present paper also gives results of compositions of different natural materials under investigation. Maximum sound absorption coefficient of the order of 0.29 was observed for Rice straw and Composition of Rice Straw and Wood dust sample.

Keywords: natural fibers, sound loss, sound absorption coefficient, bagasse, rice husk, rice straw, wood dust.

INTRODUCTION

Noise is one of the important sources of environmental pollution. The increase in noise pollution is result of rapid industrialization, vehicular traffic, trains, airplanes etc. which has adverse effect on human health. The technological development across the globe has many advantages for improving quality of life but it has certain side effects on human health, according to the recently estimated statistical data revealed that percentage of population was suffering from (53%) headaches, (36%) high blood pressure, (40%) anxiety, (36%) hearing disabilities, (15%) cardiovascular diseases, (67%) irritability and (61%) insomnia (Al Rahman *et al*., 2013). In order to overcome the problem of noise specially at sensitive areas such as hospitals, scientific laboratories, classrooms, residential areas and offices etc. acoustic treatment is essential so that the people occupying sensitive areas are not prone to pollution resulting due to sound emitted from various sources. Porous materials are widely used for noise control, which have high potential of sound absorption. These materials are categorized as porous foam or fibrous medium. Fibrous medium used for preparing sound absorbers are glass or rock wool which has high acoustic absorption properties. Foam is made from polyurethane. Foam has internal voids which traps the sound energy thus acts as good acoustic absorbing mediums (Wang and Torng, 2011). This technique used for noise control is known as passive noise control method which uses materials like glass wool, polyurethane foam, asbestos etc. (Elwaleed *et al*., 2014). These materials are expensive, flammable, non-biodegradable and harmful to society (Fatima and Mohanty, 2011). Hence it is important to investigate natural fibers to replace synthetic materials for sound absorption which have benefit of being easily

available, low cost, recyclable, eco-friendly. Natural fibers have been receiving increased attention for applications in the field of acoustics. A variety of natural fibers are already being considered for commercial utilization in building and construction applications. Natural fibers are generally categorized as vegetable fibers, stalk or wood fibers, bast or skin fibers, leaf fibers, seed fibers and fruit fibers (Berardi and Iannce, 2015). Some of naturals fibers which has scope for applications are reeds, bagasse, cattail, corncob, cotton, date palm, durian, oil palm fiber, pineapple leaves, rice, sansevieria fiber, sunflower, straw bale etc. (Asdrubali *et al*., 2015). The theoretical methods are based on physical considerations of sound propagation in materials, more complex independent variables such as tortuosity and porosity limits their use in practical applications (Oliva and Hongiston, 2013). There are several methods for measuring acoustic absorption that are normally carried out in impedance tubes with a loudspeaker and several microphones at low frequencies (Tao *et al*., 2015). Some of the textile based sound absorbing materials have good acoustical absorbing properties and flexibility of applications. Several authors have successfully predicted absorption coefficients for the textile sound absorbing materials based on geometrical parameters (Pieren and Heutschi, 2015). Coconut coir fiber is widely used natural fiber for insulation and acoustic applications. Coconut coir fiber is prepared using combinations of latex and other additives with the coir fiber. Coir fiber with perforated plates on outer surface was utilized for enhancing sound absorption (Fouladi *et al*., 2010). Use of Vegetable fiber like hemp has been reported for green building materials. Hemp concrete was made using different binders for utilizing the porosity which significantly enhanced the sound absorption

capacity (Gle *et al*., 2011). Sound absorption of tea-leaf-fiber was studied with sample thickness of 20 and 30 mm for frequency ranges of 500-3200 and 500-2400 Hz respectively. Tea-leaf-fiber is good alternative for conventional materials due to its remarkable sound attenuation (Ersoy and Küçük, 2009). Coconut coir fiber has been used for construction of acoustic absorbing panel with help of perforated plates. These acoustic panels were tested for estimating acoustic absorption coefficient (Zulkifli *et al*., 2010). Acoustic absorbers were prepared utilizing sugarcane fibers as sustainable alternative over synthetic materials and the results shown were considerable (Putra *et al*., 2013).

There are certain natural fibers which have scarcely been tested or reported. The present paper presents tests results such natural material. Sound absorption potentials are decided on the basis of noise reduction levels obtained using samples made by natural fibers and combinations of materials. A sound loss measurement test setup was used for measuring the sound loss potential of prepared samples.

Sample Preparation

Materials used in the present work are mainly agricultural wastes which are easily available and ecofriendly. Rice husk, bagasse or cane fiber, and rice straw and wood fiber samples were prepared for investigation. Raw fibers were processed to make sample for testing of the materials. Following are the important steps employed in sample preparation.

Fiber chopping process

Raw micro porous materials from natural fiber were cut using chopping machine to prepare small uniform pieces of fiber filaments.

Fiber extraction process

The chopped materials were refined by separating the impurities present in it so that only natural raw material goes into sample preparation.

Sample preparation

A mould of desired sample size (110×120×20 mm) was used for sample preparation to have constant sample thickness. Fiber filaments were blended with binder uniformly in the mould. Rubber synthetic R505 was used as adhesive. Prepared sample were kept under 90 kg f weight for 48 h and then solar dried for moisture removal for 72 h. Figures 1 to 4 gives the samples prepared from Wood Dust, Rice husk, Rice straw and Bagasse respectively.

Compositions of different materials were prepared by using adhesive to glue two individual samples. Compositions of natural fibers were also tested and results of the same are presented. Attention was paid during sample preparation to ensure samples of exactly same geometry, with same pressure applied and constant solar drying period. The constant pressure applied during the sample preparation ensured uniform internal structure in each case.

Figure-1. Wood dust.

Figure-2. Rice husk.

Figure-3. Rice straw.

Figure-4. Bagasse.

Experimental Test Setup

Test setup (Box size 800×150×140 mm and Internal cross section dimensions to accommodate sample 110×120 mm) used for experimentation was standard sound loss test setup as shown in Figure-5 used for study of sound loss by different materials specimens prepared. Setup consists of sound source, sound receiver, closed wooden box and dB meter for measurement of sound at receiver end. The source and the receiver were placed 600 mm apart equally spaced from the center of the box and at an height of 70 mm. Source spectrum was varied in the frequency range of 125 to 1500 Hz. Samples were tested with two different sound levels emitted from source (70 and 74 dB). Tests were conducted for 30 min for each sample at each sound level. Total testing time for each sample at two different sound levels was 1 h. Three readings at a time interval of 10 min were recorded. Average reading for each source sound level has been reported to minimize error in measurement. To avoid flanking noise from surrounding interference in the measurement, the box was insulated using foam on inner walls and all the tests were conducted in the laboratory past midnight when all the other interfering noise are absent.

The sound proof box consists of two chambers containing a. Sound emitter and b. Sound receiver. Initial test is conducted inside the closed box without any barrier between source and receiver. Next the prepared sample is placed as a barrier and the box is closed again. The difference between the first and second reading (i.e., with and without barrier) gives the sound loss by using the prepared natural fiber. Following procedure elaborates the method employed for testing the specimens.

Procedure for Testing of Specimens (Figure-6):

a) Switch ON the dB meter and Sound Source to first sound level (70 dB)
b) Closing the door of the wooden box and recording the direct reading on dB meter without using any sound absorbing material specimen in between the source and receiver
c) Opening the box door and keeping the specimen as barrier between the source and receiver and closing the box
d) Recording the indirect reading while using specimen as barrier in between the source and receiver
e) Repeating the procedure for different sample specimens

Figure-5. Photograph of the test set up.
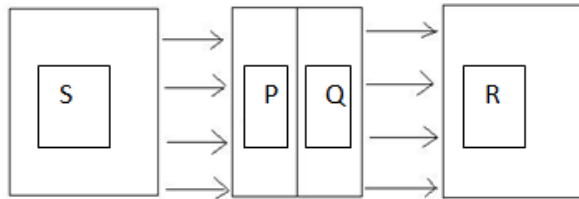
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Figure-6. Method employed for measuring the sound loss with samples placed in between source and emitter. (S) Sound source with variable Sound Level from70-74 dB on either side of specimen, (P) Base material used in combination having 20 mm thickness (Q) Different material as per combinations having 20 mm thickness (R) Sound Receiver/dB meter having range of 20-120 dB for measuring the sound level.

Experimental tests conducted on samples

The tests were conducted with two different sound levels viz. 70 and 74 dB. Tests were also conducted on composites by joining samples of two different materials but thickness in each case (single base material as well as composites of different materials) kept 40 mm constant for original sample as well as compositions to understand effect of pure natural fiber vis-à-vis its composites. Following tables and graphs give the results obtained from various tests carried out based on the procedure described above:

- Initial Sound Level (dB)*-Readings obtained without any sound barrier in between sound source and receiver
- Final Sound Level (dB)**- Reading obtained by using sound barrier in between the sound source and receiver

Table-1 indicates maximum Sound loss of 20 and 18 dB for the two levels respectively during the tests conducted in case of test samples prepared from of composite of Rice Husk and Rice Straw.

Table-2 indicates maximum Sound loss of 20 and 18 dB for the two sound levels respectively during the tests conducted in case of test samples prepared from composite of Bagasse and Rice Straw.

Table-3 indicates maximum Sound loss of 22 and 20 dB for the two sound intensities respectively in case of test conducted on sample prepared from pure Rice Straw.

Table-4 indicates maximum Sound loss of 22 and 20 dB for the two sound levels respectively during the tests conducted in case of test conducted on samples prepared from Composite of Wood dust and Rice Straw.

Table-1. Sound loss results from tests conducted on Rice Husk based compositions.

	Source sound level 1			Source sound level 2		
	-----------------------------------			--------------------------------		
	Initial*	**Final***	**Absorbed**	**Initial***	**Final***	**Absorbed**
	sound level	Sound level	Sound level	Sound level	Sound level	Sound level
Specimen	(dB) (X)	(dB) (X)	(dB) (X-Y)	(dB) (X)	(dB) (X)	(dB)(X-Y)
Wood dust	70	50	20	74	56	18
Wood dust+Rice Husk	70	50	20	74	56	18
Wood dust +Bagasse	70	50	20	74	54	20
Wood dust +Rice Straw	70	48	22	74	54	20

Table-2. Sound loss results from tests conducted on Bagasse based compositions.

	Source sound level 1			Source sound level 2		
	--------------------------------			--------------------------------		
	Initial*	**Final***	**Absorbed**	**Initial***	**Final***	**Absorbed**
	sound level	Sound level	Sound level	Sound level	Sound level	Sound level
Specimen	(dB) (X)	(dB) (X)	(dB) (X-Y)	(dB) (X)	(dB) (X)	(dB)(X-Y)
Bagasse	70	54	16	74	58	16
Bagasse +Rice Husk	70	54	16	74	59	15
Bagasse+Rice Straw	70	50	20	74	56	18
Bagasse +Wood dust	70	51	19	74	56	18

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Table-3. Sound loss results from tests conducted on Rice Straw based Compositions.

Specimen	Source sound level 1			Source sound level 2		
	Initial*	Final**	Absorbed	Initial*	Final**	Absorbed
	sound level	Sound level	Sound level	Sound level	Sound level	Sound level
	(dB) (X)	(dB) (X)	(dB) (X-Y)	(dB) (X)	(dB) (X)	(dB)(X-Y)
Rice Straw	70	48	22	74	54	20
Rice Straw +Rice Husk	70	51	19	74	54	20
Rice Straw+Bagasse	70	53	17	74	55	19
Rice Straw +Wood dust	70	50	20	74	59	15

Table-4. Sound loss results from tests conducted on Wood Dust based Compositions.

Specimen	Source sound level 1			Source sound level 2		
	Initial*	Final**	Absorbed	Initial*	Final**	Absorbed
	sound level	Sound level	Sound level	Sound level	Sound level	Sound level
	(dB) (X)	(dB) (X)	(dB) (X-Y)	(dB) (X)	(dB) (X)	(dB)(X-Y)
Wood dust	70	50	20	74	56	18
Wood dust+Rice Husk	70	50	20	74	56	18
Wood dust +Bagasse	70	50	20	74	54	20
Wood dust +Rice Straw	70	48	22	74	54	20

RESULTS AND DISCUSSIONS

Graphs of investigation on different combinations of materials and their Sound loss levels at two distinct sound levels emitted (70 and 74 dB) are plotted below for the sound level measure at the receiver with various tests samples and there composites prepared and placed as barrier between the sound source and emitter.

Figure-7 shows the sound level decrements for different combinations form 55 to 48 dB with reference to direct reading without barrier for sound level of 70 dB. Similarly Figure-8 shows decrement from 61 to 54 dB with reference to direct sound level of 74 dB.

Tables 5 and 6 give the sound absorption coefficient from literature and from the current tests conducted respectively.

The sound absorption coefficients for materials tested in the present work can be compared with natural fibers reported in literature for frequency range between 125 to 1500 Hz. Above results are in the range of 2 to 15% as compared to the reference values in literature.

Figure-9 shows Sound absorption coefficient for Rice straw and Composition of Rice straw and Wood dust were maximum and around 0.29.

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Table-5. Acoustic absorption coefficient from literature for natural and synthetic materials.

Material (Specimen)	Thickness (mm)	Sound absorption coefficient (avg)	Note
Glass fibers wool	25	0.23	Specimen tested for
(Wang and Torng, 2011)			specific density
Date palm fiber	10-30	0.13	Specimen tested for
(Elwaleed *et al.*, 2014)			different compression ratios
Jute Composite material	25	0.53	Latex jute composites
(Fatima and Mohanty, 2011)			are used for test
Recycled PET	10	0.09	Recycled polyethylene
(Asdrubali *et al.*, 2015)			fiber was tested as alternative
Double layer wood fiber	25	0.25	Multiple layer of wood fiber
(Oliva and Hongiston, 2013)			were used for better results
Coconut Coir Fiber	20	0.28	Materials used
(Zulkifli *et al.*, 2010)			with perforated plates
Sugarcane wasted fiber	15	0.21	Measured for fiber and
(Putra *et al.*, 2013)			binder composition of 70:30

Note- Sound absorption coefficients mentioned in the table above are average values for the low frequency range of the source i.e., 125 to 2500 Hz

Table-6. Acoustic absorption coefficients for different test specimens and material combinations obtained from tests conducted in present work.

Specimen	Sample thickness (mm)	Sound absorption coefficient (avg)
Single material		
Rice Husk	20	0.19
Bagasse	20	0.22
Rice Straw	20	0.29
Wood Dust	20	0.26
Material combinations		
Rice Husk + Rice Straw	40	0.26
Rice Husk + Bagasse	40	0.22
Rice Husk + Wood Dust	40	0.24
Bagasse + Rice Husk	40	0.22
Bagasse + Rice Straw	40	0.26
Bagasse + Wood Dust	40	0.26
Rice Straw + Rice Husk	40	0.27
Rice Straw + Bagasse	40	0.25
Rice Straw + Wood Dust	40	0.24
Wood Dust + Rice Husk	40	0.26
Wood Dust + Bagasse	40	0.28
Wood Dust + Rice Straw	40	0.29

Note- Sound absorption coefficients mentioned in the table above are average values for the low frequency range of the source i.e., 125 to 2500 Hz by taking average of the two sound levels
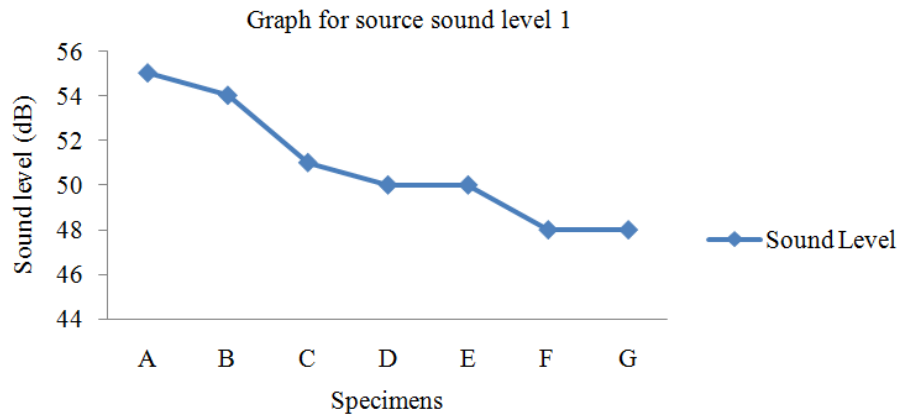
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Figure-7. For Source sound level 1 of 70 dB (40 mm thickness Specimen in each case). (A) Rice husk with 40 mm thickness by combinations of two samples of 20 mm thickness, (B) Bagasse with 40 mm thickness by combinations of two samples of 20 mm thickness, (C) Combination of Rice straw and Rice husk samples of 20 mm thickness each (total 40 mm), (D) Wood dust with 40 mm thickness by combinations of two samples of 20 mm thickness, (E) Combination of Bagasse and Rice Straw samples of 20 mm thickness each (total 40 mm), (F) Rice Straw with 40 mm thickness by combinations of two samples of 20 mm thickness, (G) Combination of wood dust and Rice Straw samples of 20 mm thickness each (total 40 mm).
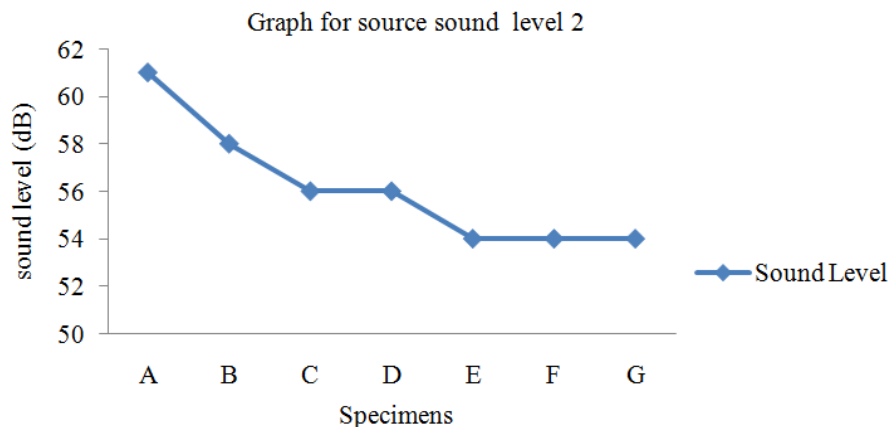

Figure-8. For Source sound level 2 of 74 dB (40 mm thickness Specimen in each case). (A) Rice husk with 40 mm thickness by combinations of two samples of 20 mm thickness, (B) Bagasse with 40 mm thickness by combinations of two samples of 20 mm thickness, (C) Wood dust with 40 mm thickness by combinations of two samples of 20 mm thickness, (D) Combination of Bagasse and Rice Straw samples of 20 mm thickness each (total 40 mm), (E) Combination of Rice straw and Rice husk samples of 20 mm thickness each (total 40 mm), (F) Rice Straw with 40 mm thickness by combinations of two samples of 20 mm thickness, (G) Combination of wood dust and Rice Straw samples of 20 mm thickness each (total 40 mm).
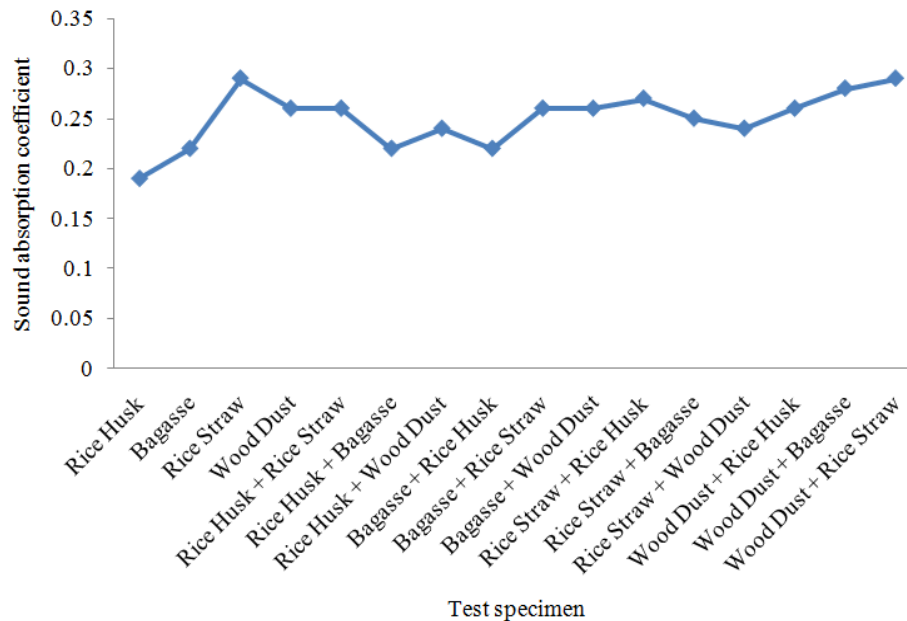
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Figure-9. Sound absorption coefficients obtained for different test specimens
for frequency range of 125 to 1500 Hz.

CONCLUSIONS

Sound absorption coefficients obtained for different materials and material compositions in this study are comparable with the values referred for different materials from literature. Specimens used in present work give remarkable sound absorption coefficients especially rice straw samples and sample made from combinations of wood dust and rice straw for the frequency range of 125 to 2500 Hz. Maximum coefficient of sound absorption was for Rice straw and Composition of Rice straw and Wood dust which was estimated to be 0.29.

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