Use of Locally Available Agro Waste Materials for Development of Sound Insulation Panels

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ABSTRACT

Any unpleasant sound is referred to as noise. Incompatible with rest, work, play, or sleep, it is unwanted inthis sense. Noise does not linger in the environment for a verylong time, in contrast to other types of pollution like air, water, and toxic compounds. When it comes to causing disturbance and hearing loss, its effects are instantaneous, but they build over time. The ability of a building to block out sound is a crucial design factor. The majority of synthetic materials used today to make noise insulators, such as petroleum-based gels or synthetic rubber, are used in their production. Acoustic plaster, glass, or mineral wool tiles, etc.are materials that are typically utilized for sound insulation. In addition to being costly, these materials also harm the environment in a substantial way. This work deals with the efforts to fabricate low-cost sound absorbing panels from bagasse and rice straw and assess their performance for sound insulation application. Sound insulation panels were prepared with rice straw and bagasse in the ratios 1:1 and 1:2. The sound absorption coefficient was measured using the impedance tube test. Acoustic behavior was determined using reverberation room test. Physical properties of panels were determined using compressive strength test, moisture absorption test and thickness swelling test. The findings show that the samples of ratio 1:1 have better sound absorbing performance and physical properties. This study shows that the acoustic properties and physical properties of panels made with rice straw and bagasse in the ratio 1:1 can be an environment friendly and economical method of manufacturing sound insulation panels.

Keywords: Sound Absorption, Acoustic property, Sound Insulation

1 Introduction

It is apparent that excessive noise negatively affects our physical and mental health, hence it makes sense to conduct a technical review of noisy technologies. In other words, noise has evolved into one of the environmental elements that industry focuses a significant amount of its efforts and concerns on. It is commonly recognized that operating airports creates conflicts of interest related to noise. In recent years, the industry has made substantial use of passive materials to reduce noise. Natural or recycled acoustical sustainable materials are frequently a good substitute for conventional synthetic materials. A proper investigation of these materials' sustainability through life cycle assessment processes must be done in order to determine whether their manufacture has a lower environmental impact than conventional ones. Natural materials like flax or recycled cellulose fibres have an airborne sound insulation quality compared to that of rock or glass wool. Numerous natural materials (such as cork or recycled rubber layers or fibres like bamboo, kenaf or coco) exhibit good sound-absorbing qualities. Additionally, these materials have strong thermal insulation qualities, are frequently lightweight, and are safe for use around people.

Additionally, a lot of these materials are already offered in the market at reasonable pricing. Techniques for reducing noise can be roughly divided into passive and active categories. While active methods include altering the acoustic field or reducing source strength in order to achieve noise reduction, passive controls entail reducing the emitted noise via energy absorption. Only low frequencies are used for active noise control. Active noise control is challenging to accomplish at medium and high frequencies due to various

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sound propagation characteristics. The primary goal of active sound control is to reduce noise more effectively at low frequencies. At higher frequencies, typical solutions are used, and they rely on the use of the materials' absorbing capabilities. As passive media, the absorbing materials disperse energy and convert it to heat to reduce noise. The frequency of the sound waves determines how much sound is absorbed. To absorb high frequency sound, the materials used must be hollow and porous. All building materials must meet certain acoustic requirements in order to absorb, reflect or transmit sound. The sound absorption coefficient, which is typically measured at frequencies of 250 Hz, 500 Hz, 1000 Hz, and 2000 Hz, is used to designate acoustic materials. These numbers can be used to compare the general level of sound level reduction achieved by commercial acoustic materials. When a room is coated with hollow plates, the sound absorption coefficient at low frequencies is excellent. By increasing the surface density of the materials and the number of air flow obstructions, the absorption coefficient can be increased. In this paper, a review of the literature on the application of acoustic absorbers in noise reduction is presented.

2 Literature Review

Four acoustic panels measuring 0.5 m x 0.5 m and 0.012 m thick were made in the study by Ismail *et al.* [1] using varied mix ratios. For sample 1, 25% of coconut coir powder was combined with 75% of shredded waste papers, and for sample 2, 50% of both materials were used. For sample 3, a mixture of 75% coconut coir powder and 25% shredded waste paper was used, and for sample 4, 100% coconut coir powder was used. The absorption coefficient of the panels was evaluated in accordance with ISO 354:1985 guidelines and in a reverberation chamber. Compared to samples 2, 3, and 4, sample 1 had the maximum absorption coefficient, according to the findings of the study carried out.

The physical, mechanical, and acoustic absorption coefficients of insulating boards manufactured of bagasse were examined by Hoseini *et al.* [2]. In order to create homogenous as well as three-layered insulating boards, urea formaldehyde and melamine urea formaldehyde were employed as resins. The findings showed that while resin type didn't significantly change physical or mechanical qualities, it did have an impact on sound absorption coefficients. Date palm tree leaves were found to be thermally stable up to 213 degrees Celsius, according to a study by Nuhait *et al.* on date palm tree leaves and wheat straw fibres for thermal and acoustic insulation in buildings. For hybrid bound boards, three-point bending tests were also carried out. The findings of their research suggested that such new bonded fibre boards may be used.

The use of pineapple leaf fibres as an alternative natural acoustic material was studied by Putra *et al.* [3]. To examine their influence on the sound absorption properties, various densities and thicknesses of fabricated samples made from raw pineapple leaf fibres were used. Based on ISO 10534-2, a measurement of the normal incidence sound absorption coefficient in an impedance tube was made. A study found that by adjusting the fibre densities or adding an air gap behind the samples, pineapple leaf fibres could obtain an average sound absorption coefficient of 0.9 above 1 kHz. Additionally, it was shown that the performance of the sound absorption was comparable to that of synthetic polyurethane foam and commercial rock wool fibres.

The surface morphology of widely accessible agricultural products such coconut husks, banana pseudo stems, and sugarcane husks were examined by Dave *et al.* [4] for their potential as thermal and acoustic insulators. Using the procedures outlined by the American Society for Testing Materials, fibre pads were built and evaluated for noise reduction coefficients, thermal insulating performance, water absorption capacity, and flame tolerance. Agricultural materials were imaged analytically using scanning electron microscopy (SEM). For coconut husks, banana pseudo stems, and sugarcane husk pads, the noise reduction coefficients were 0.80 dB and 0.92 dB, 0.75 dB and 0.78 dB, and 0.50 dB and 0.35 dB, respectively, at 800 Hz and 440 Hz. The most effective at absorbing water and having a high 56% flame tolerance were coconut

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husk pads.

3 Scope and Objective of the Study

Noise has definite consequences on human health and is dangerous for the environment in the modern world. Usually,to control noise disturbances, expensive sound absorption materials are used. The building industry still makes considerable use of synthetic materials as acoustic absorbers. These non-biodegradable materials considerably increase carbon dioxide levels, which has the consequence of causing global warming. They also pollute the ecosystem. Natural materials are gaining a lot of attention as alternatives to synthetic ones. There are more applications where sustainable, renewable materials are being used [5]. To create a sound-absorbing panel, natural waste products like rice straw and bagasse were chosen. The RB 1 and RB 2 combinations of rice straw and bagasse in the ratios of 1:1 and 1:2 respectively, were adopted. The study's main goal was to evaluate the sound absorption, moisture absorption, and strength characteristics of sound absorption panels constructed of organic waste materials including bagasse and rice straw. The sound absorption coefficient was computed using the impedance tube test. The acoustic behaviour was evaluated using the reverberation chamber test. The physical properties of the panels were assessed using compressive strength testing, moisture absorption testing, and thickness swelling testing.

4 Materials

Following materials were used for the study.

4.1 Rice straw

During harvest, rice straw is removed together with the rice grains and is either heaped or strewn out on the field depending on whether it was harvested manually or by machines. And after harvest, the majority is either burned on-site, added to the soil, or used largely for the subsequent crop. The biochemical makeup of wheat and rice straws is similar to that of an agricultural-based lignocellulose residue, with an average content of 15- 20% lignin, 30-45% cellulose, and a few trace amounts of minor organic compounds. While rice straw is low in nitrogen, it is quite heavy in inorganic substances, often known as ash. Figure 1 depicts the rice straw that was used in the investigation.

Figure 1: *Rice Straw*

4.2 Bagasse

A major agricultural waste and byproduct of the sugar industry is bagasse, which comes from sugar cane waste. After the sugarcane is crushed, a dry, pulpy, fibrous residue is left behind. It serves as a biofuel for the generation of heat, energy, and electricity as well as pulp production and the fabrication of building materials. Figure 2 depicts the bagasse utilized for the investigation.

Figure 2: *Bagasse*

4.3 Adhesive

Polyvinyl acetate having boiling point of 112°C was used as adhesive for the fabrication of panels.

5 Preparation of Moulds and Fabrication of Panels

Two different moulds were prepared from GI sheets. A square mould of size 150 mm x150 x mm 10mm was made from GI steel for panel preparation. A circular mould of diameter 46.90mm was made from GI steel for conducting tube impedance test. The details of moulds are shown in fig.3.

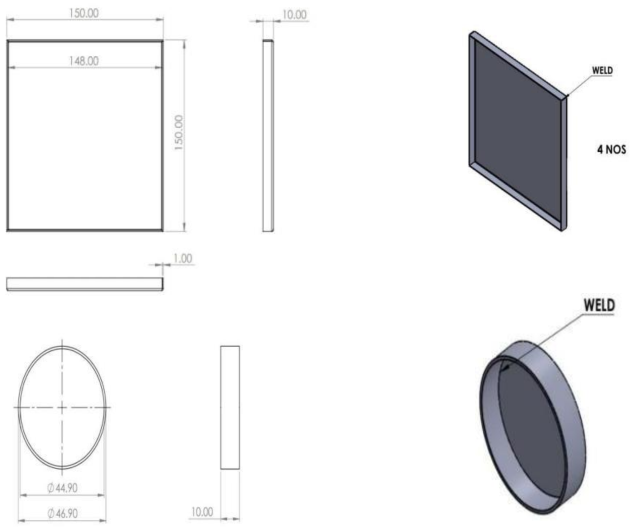

Figure 3: *(a) Mould for square panel (b) Mould for tube impedance test*

Using cotton cloth, the moulds were washed and dried, and then grease or oil was added to the exterior. Agro waste components were blended with adhesives at the appropriate mix ratio to attain the desired consistency. The mixture was then poured into the mould, spread out evenly, and tamped to remove any air pockets. For 24 hours, the panels were left in the mould unattended. After 24 hours, the panels were taken out of the mould and exposed to sunshine for an additional 48 hours.

6 Test On Panels

Tests have been conducted in order to investigate and optimize the performance of rice straw and bagasse for sound insulation. The test procedures were categorized into two. The tests were conducted to determine the sound absorption characteristics and to determine the physical characteristics.

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6.1 Impedance Tube Test

To calculate the sound absorption coefficient, impedance measurements were run. A marble cutter was used to carve the panel into a circle with a 10 cm diameter. After that, the sample was placed inside an impedance tube device. Software called PULSE LABVIEW was used to calculate the sound absorption coefficient. A graph showing the sound absorption coefficient versus frequency was created from the tube impedance test results. According to ASTM E-1050, the impedance tube was used toevaluate the frequency-dependent normal incidence absorption coefficient. Two microphones were used to measure the sound pressure levels at two points x_1,x_2 that were close to the sample. Sound pressure at each point is expressed as,

$$P_1 = P_0 e^{-jkx1} + \mathrm{R} P_0 e^{jkx1} \quad (1)$$

$$P_2 = P_0 e^{-jkx2} + \mathrm{R} P_0 e^{jkx2} \quad (2)$$

Where P_0 is the pressure amplitude, k is wave number The sound absorption coefficient is calculated as,

$$a = 1 - |R|^2 \quad (3)$$

where reflection coefficient R is obtained as,

$$R = \left(\frac{H_{12} - e^{jk\Delta x}}{e^{-jk\Delta x} - H_{12}}\right) e^{-j2kx1} \quad (4)$$

Where $\Delta x = x_1 - x_2$ (5)

The complex transfer function of sound pressure H_{12} is derived as

$$H_{12} = \frac{e^{-jkx1} + \mathrm{R} e^{jkx1}}{e^{-jkx2} + \mathrm{R} e^{jkx2}} \quad (6)$$

The test setup is shown in fig.4(a) and (b)

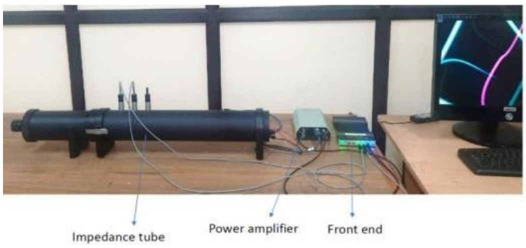

Figure 4 (a): *Test setup for impedance tube test*

Figure 4 (b): *Test setup with panel*

6.2 Reverberation Room Test

An exclusive acoustic testing space called a reverberation chamber was used to house the sample panels. Different frequencies of waves enter the surface of the material from various directions with the same probability, and the change in reverberation time determines how well the sound is absorbed.[6] Reverberation sound absorption coefficient is the name given to the sound absorption coefficient that was obtained. A bluetooth speaker was set to its loudest setting. The audio tone generator (400Hz, 800Hz) used to create the sound provided constant sound frequency and volume throughout. Through a bluetooth connection, the speaker was joined to a smartphone that continuously produced sound. Above the test box, a decibel meter was positioned. The reading appeared on decibel meter was recorded.

The test set up for reverberation test is shown in fig.5. Fig 6 shows the test setup without and with panel.

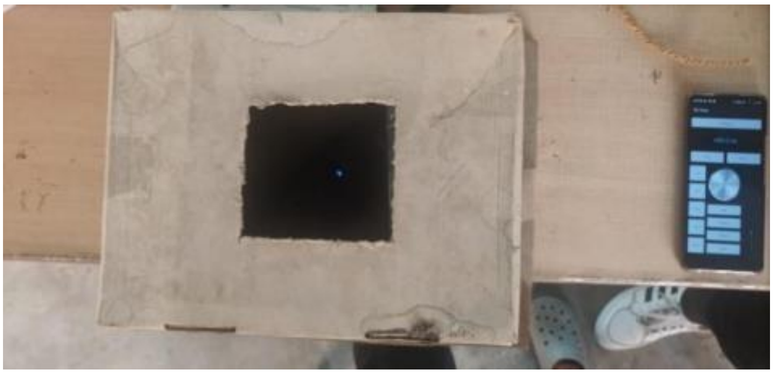

Figure 5: *Reverberation Chamber*

Figure 6: *Test Setup without and with panel*

6.3 Moisture Absorption Test

The samples were dried in an oven at a specific temperature and time for the moisture absorption test,after which they were placed in a desiccator to cool. The specimens were weighed as soon as it was cooled.The panels were then submerged in water for 24 hours at 23°C. The moisture absorption of each of the panels were determined.

6.4 Thickness Swelling Test

The key indicator of the dimensional stability of wood composite panel materials is often the thickness swell determined using the water soak method in accordance with ASTM D 570. Here, the thickness of dry panels was measured. The panel was then submerged in water for a whole day. The thickness of the soaked panel was tested and recorded after 24 hours [7]. The soaked specimens RB1 and RB2 kept for thickness swelling test is shown in Fig.7.

Thickness swelling of RB 1

Thickness swelling of RB 2

Figure 7: *Thickness Swelling test of samples*

6.5 Compressive Strength Test

Mechanical test measuring the maximum amount of compressive load the panels can bear before fracturing was measured as per IS 516:1959. The maximum load applied to the specimens of maximum surface area (49cm^2) was recorded. The appearance of the specimen for any unusual features in the type of failure was also observed. Test set up and sample tested are shown in fig.8.

Figure 8: *Test setup and specimen failed in compression.*

7 Results And Discussion

7.1 Tube Impedance Test

Fig.9 represents the graph showing sound absorption coefficient vs frequency. It was observed that the sample RB 1 showed sound absorption coefficient of 0.45 at 800 Hz. Whereas for RB 2 at 800 Hz the sound absorption coefficient measured was 0.27. The difference in the results may be due to the porosity of the materials used as porosity of materials play an important role on sound absorption coefficient. If the porosity of material is more, then its absorption coefficient will be at its peak [8]. However, as frequency increases the absorption coefficient shows a drop [9]. Sound absorption coefficient of most absorbers turns to drop after reaching the peak. This may be due to the resonance phenomena.

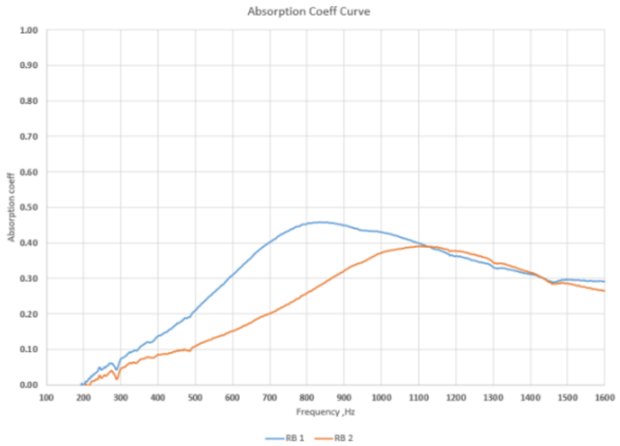

Figure 9: *Absorption coefficient vs. Frequency*

7.2 Reverberation Room Test

Sound absorption panels have been tested in reverberation chamber conforming to ISO 354 standards. The room was designed to represent the real situation to investigate maximum effect of noise. The test results are presented in table 1.

Table 1: *Reverberation Room Test Details*

Frequency	Panel ID	Average value of Sound produced without panel (dB)	Average value of Sound produced with panel (dB)
400Hz	RB 1	105.5	83.5
	RB 2	105.5	87.6
800Hz	RB 1	103	89.2
	RB 2	103	91.5

It was observed that when frequency was 400 Hz, the RB 1 panels produced a decibel drop of 22 dB and RB 2 panels produced a decibel drop of 17.9 dB. Similarly, when frequency was 800 Hz, the RB 1 panel produced a decibel drop of 13.8 dB and RB 2 panels produced a decibel drop of 11.5 dB.

7.3 Moisture Absorption of Sound Insulation Panels

The percentage moisture absorption is indicated in table 2. The results indicate that the panels of combination RB 1 showed an average moisture content of 8.27% and panels of combination RB 2 shows an average moisture content of 11.4%. Since the rice straw and bagasse are in equal amount the moisture absorption is less, whereas in the other casethe rice straw and bagasse are in different proportion so the moisture content was greater.

Table 2: *Moisture Absorption Test Details*

Panel ID	Initial Weight(W1) g	Final Weight(W2) g	% moisture absorption
RB 1- 1	8.46	7.76	8.27
RB 1-2	8.45	7.75	8.28
RB 1-3	8.46	7.76	8.27
RB 2-1	7.78	6.85	11.95
RB 2-2	7.79	6.86	11.93
RB2-3	7.77	6.84	11.96

The moisture content is inversely proportional to the density in the case of natural fiber composite [10]. A lower density yields higher porosity, spaces and voids. The porous structure of bagasse contributes to the

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increased moisture absorption of RB 2 panel.

7.4 Thickness Swelling Test

Thickness swelling test was conducted to determine the changes in dimensional stability of the panel. The thickness of the panels after 24 hours immersion in distilled water is tabulated in table 3.

Table 3: *Thickness Swelling Test Details*

Panel ID	Thickness of drypanel (mm)	Thickness aftersoaking (mm)
RB 1- 1	9	10
RB 1-2	8.99	10
RB 1-3	9	10.01
RB 2-1	9	10
RB 2-2	9	9.98
RB2-3	8.97	9.74

The test results shows that the initial thickness of RB 1 panels before soaking was 9mm. The thickness after soaking in water for 24 hours was around 10mm. Similarly, for RB 2 panels the initial thickness before soaking in water was 9mm and after soaking in the water for 24 hours its thickness changed into 9.90 mm.

7.5 Compressive Strength Test of Sound Insulation Panel

The compressive strength test results of RB1 and RB2 panels are presented in table 4.

Table 4: *Compressive Strength Test Details*

Panel ID	Load	Avg. compressive strength (N/mm^2)
RB 1- 1	8.2	1.67
RB 1-2	8.3	
RB 1-3	8.1	
RB 2-1	6.8	1.38
RB 2-2	6.9	
RB2-3	6.8	

Based on the test results obtained it can be concluded that RB 1 exhibited more compressive strength when compared to RB2 panels. RB 2 comprised of rice straw and bagasse in the ratio 1:2. The reduction in compressive strength of RB2 panels may be due to the more porous structure of bagasse [11, 12].

8 Conclusion

Studies were conducted on panels made of agro waste materials such as rice straw and bagasse to check the sound absorption, strength, dimensional stability etc. Tests were conducted on panels made of rice straw and bagasse mixed in proportions 1:1 (RB 1) and 1:2(RB 2). The following conclusions were obtained.

1. From the Impedance tube test, sound absorptioncoefficient of RB 1 panels was obtained as 0.45.For good sound absorption, sound absorption coefficient should be between 0.3 to 0.7.
2. From the compressive strength test conducted on samples, RB 1 panels exhibited more compressive strength than RB2 panels.
3. Based on the results of moisture absorption test, RB 1 panels had a moisture content of 8.27% compared to 11.95 % moisture content of RB 2 panels. RB 2 panels are more porous due to the increased content of bagasse.
4. In the thickness swelling test, RB 1 panels absorbed more water compared to RB2.
5. Based on the reverberation room test result, when subjected to 400Hz frequency RB 1 panels produced a decibel drop of 22 dB and RB 2 panels produced a decibel drop of 17.9 db. Similarly, when tested at 800 Hz frequency RB 1panels produced a decibel drop of 13.8 dB. RB 2panels produced a decibel drop

of 11.5 dB.

This study demonstrates how sound insulation panels manufactured from rice straw and bagasse in suitable ratio can have favourable acoustic and physical qualities, making them a cost-effective and environmentally responsible option.

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References

[1] Ismail, F. Z., M. N. Rahmat, and N. M. Ishak. "Sustainable Absorption Panels from Agricultural Wastes." In MATEC Web of Conferences, vol. 15, p. 01035. EDP Sciences, 2014.

[2] Fouladi, Mohammad Hosseini, Mohd Jailani Mohd Nor, Md Ayub, and Zulkarnain Ali Leman. "Utilization of coir fiber in multilayer acousticabsorption panel." Applied Acoustics 71, no. 3,2010, pp 241-249

[3] Putra, Azma, Khai Hee Or, Mohd Zulkefli Selamat, Mohd Jailani Mohd Nor, Muhamad Haziq Hassan, and Iwan Prasetiyo. "Sound absorption of extracted pineapple-leaf fibres." Applied Acoustics 136, 2018, pp 9-15.

[4] Mercado, Ricky Dave T., Romnick M. Ureta, and Reynan Jay D. Templo. "The potential of selected agricultural wastes fibers as acoustic absorber and thermal insulator based on their surface morphology via scanning electron microscopy." World News of Natural Sciences 20 ,2018,pp 129-147.

[5] Madurwar, Mangesh V., Rahul V. Ralegaonkar, and Sachin A. Mandavgane. "Application of agro-waste for sustainable construction materials: A review." Construction and Building materials 38,2013, pp872-878.

[6] Asdrubali, Francesco, Francesco D'Alessandro, and Samuele Schiavoni. "A review of unconventional sustainable building insulation materials." Sustainable Materials and Technologies 4,2015, pp 1-17.

[7] Pickering, Kim L., MG Aruan Efendy, and Tan Minh Le. "A review ofrecent developments in natural fibre composites and their mechanical performance." Composites Part A: Applied Science and Manufacturing 83,2016, pp 98-112

[8] Taban, Ebrahim, Somayeh Amininasab, Parham Soltani, Umberto Berardi, Debelo Dugasa Abdi, and Seyed Ehsan Samaei. "Use of date palm waste fibers as sound absorption material." Journal of Building Engineering 41,2021, pp 102752.

[9] Rahimah, A. H., and A. A. Tajul. "The potential of agriculture waste material for noise insulator application toward green design and material.", International Journal of Civil & Environmental Engineering IJCEE-IJENS Vol:10 No: 05.

[10] Balador, Zahra, Morten Gjerde, Nigel Isaacs, and Marzieh Imani. "Thermal and acoustic building insulations from agricultural wastes." Handbook of Ecomaterials,2018, pp 1-20.

[11] Balan, A., and N. Shivasankaran. "Noise control using waste materialsreinforced composites." LJRS 19, no. 2,2019, pp 47-52.

[12] Azimi, M. "Noise reduction in buildings using sound absorbing materials." Journal of Architectural Engineering Technology 6, no. 2,2017, pp 1-2.