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A Review on Non Traditional Sound Absorbers

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Abstract

Use of alternative materials for noise control applications has been given more importance since past two decades. As alternative materials are identified based on their availability, cost, internal structure and environment friendliness it is likely to found application of green materials for manufacturing sound absorbers in past few years. Review on research of materials like industrial tea leaf fiber waste, coir fiber, jute fibre, date palm fibre, coconut coir fibre, kapok fibre, inorganic polymeric foam, sheep wool, waste paper, textile waste, cotton fibre and rubber granulate, arenga pinnata, wood wool cement boards, oil palm empty fruit bunch fibres, coal bottom ash and rice husk grains for application in sound absorption is described with chronological sequence. The manufacturing parameters, methods and sound absorption of materials from literature are illustrated in this work. It can be observed that potential of these green materials can be utilized for noise control application. Besides these materials there is scope for research scholars to come with new materials as alternative over the conventional ones.

Key Words:Noise; Acoustics; Sound Absorption; Natural Fibres; Waste Materials.

1 INTRODUCTION

The increased level of noise in environment is becoming a significant source of pollution. It can harm both the physical and mental health of many people who are exposed to unwanted noise for prolonged periods. Noise reduction techniques and materials are therefore becoming of increasing importance. It is essential to attain lower noise level limits to avoid harmful effects of noise on human health. When it is concerned about consequences of noise in the workplace and in the living space, it has led to the amendment of the WalshHealy act of 1969. This act created the first set of nationwide occupational noise regulations (occupational safety and health administration, 1983).Federal government of USA broadened this standard for majority of companies from USA. Similar regulations were adopted by most of the countries across world. Indian Noise regulation and control rules, 2000 has specified noise level limits for the different areas. To maintain these standard most of the companies adopted different vibration and noise control techniques.

A general noise system [1] consists of three components viz. source, path and receiver. Before selecting the noise control method, it is essential to understand the most appropriate place for controlling the noise. Noise can be controlled at source, path or at the receiver. There are two modes of noise control viz. active mode and passive mode. Generally passive mode is preferred as it does not require external power source to control the noise level. In passive mode noise is controlled by sound absorption, reflection and diffusion. Noise control by absorption is achieved by using the porous materials. Commonly used materials are mineral wool or glass wool, synthetic fibers and foams. These Sound absorbing materials are more often used at source or at receiver to lower the sound level by sound absorption.

Recently there is increase in the use of green materials [2] for sound absorption. Natural fibres are good alternatives to synthetic sound absorbers due to their acoustic and thermal performances without any adverse effect on the nature and human health. Recycled materials can even be regarded as a sustainable alternative. Alternative green sound absorbers are cheaper and less harmful to environment. Performances of such materials are evaluated by using ISO or ASTM standards and different mathematical models. This review paper aims to present the recent research work on development of sound absorbers from alternative materials and help to produce a scope for new innovations from current ideas.

2 NON-TRADITIONAL MATERIALS

For the application at the different ends of life technologies help us to get rid of unwanted or waste materials by their disposal or reuse. Sezgin Ersory et. al.[5] focused on the use of tea leaf fibre waste for manufacturing of sound absorbers. As tea leaf fibre is waste, hygienic, eco-friendly and biodegradable in nature it can prove good alternative over the conventional sound absorbing materials. The objective of work describes the use of ASTM E 1050-98 international standard for computing the sound absorption of tea leaf fibre (TLF). Impedance tube with two microphone method and tube diameter 29mm are used with frequency range 500Hz to 6300Hz. Sample are made from Woven cotton cloth (WCC) and polyester and poly propylene based nonwoven fibre (PNF) materials which are widely used in auto industry. Specimens with different thickness range of 10mm, 20mm and 30mm are prepared in this work and Sound absorption of PNF and TLF is compared with each other with or without backing of WCC. Results showed that TLF sample of 10mm with backing of WCC give average sound absorption 0.7 for frequency range between 3500-6300Hz. TLF samples of 20mm with backing of WCC give average sound absorption of 0.6 for frequency range between 500-3500Hz. TLF sample of 30mm thickness with backing gives sound absorption average 0.75 for frequency range between 500-3500Hz. This work suggests us that tea leaf waste fibre can be used as an option to conventional sound absorbing materials.

When we go further for finding out the new alternate materials it is observed that the coconut coir fibre is another option for utilizing its sound absorbing characteristics as discussed by Mohammad Hosseini Fouladi [6] et. al. The wet coir fibre samples are made using appropriate mixture with the binder as well as use of manual press machine for applying binding force on the mixture. Coir fibre had absorption coefficient of 0.8 at frequency greater than 1300Hz with 20mm thickness but increase in the thickness improved sound absorption up to 0.8 at minimum frequency of 578 Hz with 45mm thickness of samples. Two methodologies were adopted for acoustic analysis of coir fibre; Delany-Bazley model and Allard-Biot model. These two methodologies contain use of porous material except Allard- Biot model as it contain porous with mixture of air and frame (elastic). The work gives importance to alteration of mass, thickness, and fibre diameter of each sample as it determines the flow resistivity and porosity of material. Bulk density and diameter of sample both are helpful to determined flow resistivity of material. If there is certain increase in bulk density then flow resistivity also increases considerably. Because of high flow resistivity the sound absorption coefficient of sample increases. The Allard technique has the advantage that it can show pattern effect as well as resonance very well, but it has complicated formulation and works only with industrial fibre. In case of Delany-Bazley method which is suitable for overall acoustic behaviour and it was simpler to apply without modifying any different relations. Finally it is understood that Allard-Biot model is based on wave transmission and Delany-Bazley model based on empirical equations. Results from these methodologies are compared with the experimental results. This approach helps us to utilize the coconut coir fibre for achieving objective of cost effective sound absorbing materials.

These consequent researches on natural materials tend us to identify and use the available natural materials for application in acoustics. The approach for the application of jute as sound absorbing materials is discussed by S Fatima [7] et. al. They have manufactured sound absorber using jute fibre with alkali treated and used natural rubber latexas binding agent. Normal incidence sound absorbption of jute felt composite is measured by using impedance tube test setup. Certain physical properties like flow resistivity, porosity, tortuosity and characteristic lengths of the jute fiber were investigated. It is suggested that Jute shows more significant properties than glass fibre. Jute as natural sound absorber emerged as economical and green alternative for noise control for application in household appliances like dishwasher, vacuum cleaner and cloth drier. It has also found its application in noise control among the automotive applications such as in engine partition, car door panels, in roofing's and floorings. It can be even utilized in building applications like partitions, roofings and ceilings.

Comparison between the acoustical properties of two natural fibre provide more details on the effect due to porous structures of fibres on the sound absorption of materials as mentioned in the work by Lamyaa Abd Al Rahman [8] et. al. Objective of work involves the use of Date Palm Fibre (DPF) and Coconut Coir Fibre (CCF). These two micro porous fibres can be used as good alternative acoustic materials over existing materials. Acoustic Absorption Coefficient (AAC) for samples thickness range 10mm-40mm and density variation between 90-160 Kg/m^3 with reference to frequency range of 1000Hz- 5000Hz was found. Comparison of AAC values for DPF and CCF sample were carried with respect to their bulk densities and sample thickness. It was observed that DPF samples showed the comparable AAC for lower and higher frequencies but poor at medium frequencies. CCF samples showed comparable AAC at medium frequencies and poor at lower and high frequencies. Further study showed reason of variation in AAC of DPF and CCF sample due to fibre diameter. It was observed that samples prepared from DPF were having small fibre diameter compared to CCF thus it showed better AAC values at low and high frequencies. Change fibre diameter causes change in the bulk density of the material. Natural fibre seems to give better absorption due to increased bulk density.

Work of Hai-fan Xiang [9] et.al. describes the use of kapok fibre for its sound absorption properties. Objective of work is theoretical modeling and experimental validation of acoustical performance of natural kapok fibres. Modified Delany and Bazely model had been adopted to calculate the sound absorption coefficient. Normal incidence sound absorption was measured by SW 466 Impedance tube by transfer function method. Effect of hollow structure, bulk density, thickness fibre length, fibre orientation on the sound absorption properties are taken into consideration in this work. Kapok fibres have good acoustical damping properties due to its hollow structure and hence can be used in noise reduction field.

Work has been carried on Inorganic Polymeric Foam as a sound absorbing and insulating material by Tu-Cheng Hung [10] et. al. in which they had manufactured inorganic polymeric foam due to their additional advantages such as inexpensive, fire resistant, energy saving and eco-friendly. Objective of this work is to manufacture the Inorganic polymeric foam (IPF) specimen using the metakaolin powder and blast furnace slag as raw materials. Meytakaolin powder consisting Silicon dioxide and aluminum trioxide and blast furnace slag of Calcium oxide and silicon dioxide. Binder paste was prepared using the water, AE and silicate modulus. Mixture of the raw materials, binder, alkaline activating solution and formed bubble were poured and stirred into a tank. These mixtures were cured for different curing times to get different foam densities. Foam with densities 0.4, 0.6, 0.8 and 1.0 g/cm3 were cut in the specimen size of diameter 4 cm and 6cm thick. Normal incidence Sound absorption of the respective specimens is found using the 2 microphone impedance tube method of ASTM E1050-98. Test on the specimens is carried out for frequency range of 100Hz to 4000Hz. Sound absorption of the different specimens compared with respect densities and frequency. It was observed that the sound absorption increases as the density of specimen decreases from 1.0 to 0.4 regardless to frequency. Similarly as the relative density decreases from 0.4 to 0.2 sound absorption increases respectively. It can be seen that there is a scope to use the furnace waste material form manufacturing of sound absorber which can considerably save cost and give better option for the reuse of waste materials for acoustic applications.

As date palm fibres gives good sound absorbing properties, it is essential to control the physical parameters to get optimum sound absorption coefficient. Therefore A K Elwaleed [11] et. al. considered the effect of change in compression of the physical properties of materials which ultimately provides the desired results. Objective work is to experiment and investigate how the compression impacts the sound absorption characteristics of date palm fibre. Average diameter of the date palm fibre is measured as 0.408 mm and average density of about 919 kg/m3. The sample specimens from the fibre are manufactured using set of plastic molds. These moulds are manufactured in different sizes with equivalent diameter to the impedance tube diameter for low and high frequency measurements on the test setup. Samples with 100mm diameter are used to find out sound absorption at low frequency range of about 0 to1000Hz. Samples having the diameter 28mm are used for the measurement with frequency range between 1000Hz to 5000Hz.

Graphs of normal sound absorption with respect to frequency are obtained using the computer interface and the impedance tube. The value of uncompressed sample of 30mm found to be small at low frequency range, increasing as increase in frequency to give a significant peak. When the sample is compress to 23mm thickness with compression rate of 1.3 which results in slight decreasing sound absorption for frequency 1500 Hz and 2500 Hz. Comparing to the overall performance of the sample with compression rate 2.5 to sample with compression rate 1.3 is found to be small for the respective frequency range. Results for the samples with compression rate of 1.3 are found to be better as the physical parameters are optimized. Therefore for the sample with compression rate of 2.5 the decrease in sound absorption coefficient could be accredited mainly to that the large variation of the flow shows an overall lower performance compared with the compression rate of 1.3. Therefore there was limitation for the compression rate beyond which the sound absorption coefficient is decreased due to air flow resistivity. Simulation to describe the sound absorption of the panels with and without modified flow resistivity has been done using the Delany and Bazley model. Observation from the work describes that the results from the panels with modified flow resistivity are quiet trending with the results from the experiment.

Study on the coconut coir fibre for utilizing it sound absorbing ability gave rise to improve by different means, also by use of micro perforated panel of different materials and varying percentage of the perforations helped to know more about increasing the flexibility for application of coir fibre as sound absorber. As discussed by M T Fadzlita [12] et. al. objective is to use the perforated zinc sheet plates to improve sound absorbing coefficient and two types of perforation plates (6.92% and 19.23%) were combined with coir fibre. Perforated plates were made of 1mm thick zinc sheet. If high percentage of perforation is present then higher the sound absorption coefficient. The plates are divided into two types as per perforation percentage. The sound absorption coefficient for a two groups achieved peak value like 0.73, but 6.92% group shows high percentage of sound absorption coefficient as compared to group second which is having 19.23% of perforation peaking at up to 2000Hz. Significant thing is that above 2000Hz frequency range both group shows low sound absorption coefficient. Finally perforated plate with coir fiber showed evident sound absorption coefficient peak at low frequency range but decreases with high frequency range. Another work on Sheep Wool for sustainable architecture by Daniela Bosia [13] et.al.wherein they used the recycled sheep wool to make a specimen due to their additional advantage such as easy availability, inexpensive, biodegradable, and environmental. The test specimen panel used to measure sound absorption coefficient had 12m2 areas with 50 mm thickness and 130 kg/m3 density. The specimen was tested within the frequency range 100 to 5000 Hz. The sound absorption coefficient was found by using reverberation room at National Institute of Meteorological research by comparing the reverberation time with and without specimen in the condition air temperature 16, relative humidity 39, pressure 1005 KPa. It was found that sounds absorption coefficient increased with increasing in frequency for given specimen. As it shows a good performance at low and high frequencies like glass and rock wood with same density it can be used as alternative for sound absorption.

An Effort is made to use fabric curtains [14] instead of bulky panels for the sound absorbing applications as discussed in the work wherein an approach of utilizing the lightweight multilayer fabric curtains are used as sound absorber. The values of sound absorption of these curtains are predicted using the equivalent circuit method. These curtains comprises of multiple layers of porous fabric sheets arranged parallel and separated by well-defined air gaps.

For the validation of measurement of 24 lightweight woven fabric curtain methods such as impedance transfer method (ITM), equivalent circuit method (ECM), and transfer matrix method is adopted. Equivalent circuit method is more suitable for use as the ECM can be used for the modeling of materials having the air cavities. Normal incidence absorption coefficient measured for the each fabric manifest good conformity with mean value and standard deviation of 0.01 $\pm$0.05. It has been observed that magnitude of energy absorbed by the curtains which were placed in the diffuse field of a room are in similar order of the amount of sound absorption by curtains mounted in front of the walls.

Use of recycled material panels for the application in building material can prove to be good sustainable alternative. Objective of the work of Cinzia Buratti [16] et. al. is to utilize wool, recycled paper and nonwoven polyester fabric as sound absorbing materials and explore their good acoustic behavior. These materials contribute to low production cost and are similar to the traditional porous materials. Three samples were made with diameter 29mm and three same samples with varying diameter of 100mm where made. The first sample is made of waste paper glued and pressed of 10mm thick. Second sample is made with combination of layers of textile fibre and waste paper glued with each other having a thickness of 18mm. Third one contained two layer glued wool and the waste paper with thickness of 50 mm. Sound absorption coefficients of Samples made is tested with the help of impedance tube. Impedance tube having two microphone of standard ISO10534-2 with diameter 29mm and another tube of same standard but of diameter 100mm were used for performing the test. These sound absorption materials were scrutinized to get the improved acoustic performance of lecture room with the help of simulation software. The obtained reading was the compared with the traditional panels. Both the panels were applied on the ceilings of the lecture hall by comparing the obtained reading it was observed that the both traditional material and waste material had same absorption coefficient.

Some acoustical properties of few conventional material can improved by combining them with use of waste materials which significantly reduces the cost in material and provides us another option for reducing the dependency on the existing materials. The work on Improved sound absorption properties of polyurethane foam mixed with textile waste [17] gives knowledge of how the sound absorption properties will increasing by using textile waste mixing with polyurethane foam. Propelling liquid isocyantepolyol mixture gives polyurethane foam with blow agent as catalyst is a rigid product but forms composite matrix with textile waste. Her polyamide 15%, polyacril 40%, 40% modal are the materials used for improving acoustic properties of polyurethane foam. For making composite matrix polyol, catalyst stabilizing agent, flame retardants are used. Impedance tube method is used to get the sound absorption coefficient with the help of two microphones transfer function and measuring acoustic parameters in different frequency range is done using Bruel and kjaer tube kit. The result shows that SAC of composite material as the weight percentage of textile waste increases the density of material also increases. Here Noise reduction coefficient of material (NRC) is maximum for 60% RPF (60% rigid polyurethane foam and 40% textile waste) is 0.0593 also having maximum sound absorption coefficient. While there 100 RPF have half NRC of 60 RPF in the frequency range of 1400-3100 Hz. also 75 RPF having best SAA of 0.86 at 1000Hz.

Generally natural fibres have good internal voids and porous which enhances the effect on the sound absorption by these fibres which can be future improved by introducing the composite method as discussed in the work on Acoustic Absorption of Natural Fiber Composite [18]. It shows that the natural fibre cannot compete with synthetic material because the having moisture contents, thicker diameter, lower fatigue quality, but when we remove moisture from it will decrease the property of sound absorption. For this particular reason granular material are used. For making the composite material first is Natural fibre composite method and second is pre-treatment of natural fibre in with alkaline method is used. Natural fibre replaces Fibre glass, wool and glass wool by coir, corn, paddy, sisal, and banana. Another thing is fibro granular composite in which granular material mixed with natural rubber and polymer fibre matrix forms fibro granular composite. Orientation of fibro granular composite helps to optimize Acoustic properties to get maximum Sound Absorption Average (SAA). The rubber granular having pores to give high porosity which increases tortousity and flow resistivity. Result describes that SAA increase by higher density, decreased diameter, increased sample layer thickness. As also diameter decreases flow resistivity increases. Rubber grain absorption increases with decrease in grain size. Alkaline treatment gives low frequency sound absorption and increases air flow resistivity. The performance of fibro granular material has been remarkable than conventional materials for noise control applications.

Composites provide a good method for manufacturing the sound absorbing materials, similar thing can be implemented in the natural sound absorbers in order to increase the performance of natural materials as discussed in the work on Acoustic Performance and physical properties of nonwoven fiber; Aregna Pinnata (Ijuk) and Natural Rubber composite [19]. This work proposed that Aregna Pinnata can be used as alternative over synthetic material. For making the sample Aregna Pinnata it is soaked in alkaline and then mixed with natural rubber as binder. Further process forms material and binder mixture samples in the ratio of 100:0,80:20,70:30,60:40 with 50mm fixed thickness sample. These samples are test on impedance tube using by ASTM E1050 two microphone methods by Delany Bazley empirical method. The result shows higher binder higher density. Porosity increases with decrease in mixture of Aregna Pinnata and rubber to ratio of 80:20 mixtures which gives more porosity and sound absorption than 100:0 and 60:40 gives less porosity. Increase in bulk density causes in flow resistivity and reduction in porosity. It gives best sound absorption at 80:20 binder mixtures of 0.98 SAA for 100Hz. Mixing natural rubber and without mixing it gives 0.9 SAA consists of 100:0 mixture for 1300Hz. The natural binding gives natural character of sound absorption of material but mixed with natural rubber gives better sound absorption.

Alteration in the physical structure of the composites results in the change in the physical properties. Alteration can be achieved by the various ways and these are applied in the exiting manufacturing method of the acoustic materials. Thus achieving appropriate balance in these alteration lead us to optimum absorption sound coefficient. But to get the desired change of physical structure it is required to find out the desired change in physical properties for which study of mathematical modelling is required. The work on Modelling and optimization of the sound absorption of wood wool cement boards [20] has objective of the improvement in sound absorbing property of wood wool cement board using the optimization. This work specially adopted on three impedance models that are Attenborough model, Johnson-Champox-Allard (JCA) model and Johnson-Champox-Allard-Lafarge (JCAL) Model. These models plays vital role in predicting the accuracy of the sound absorption coefficient of materials. They suggested the use of JCA model as it take five parameters into account for predicting the absorption value. These parameters are flow resistivity, open porosity, tortuosity, thermal and viscous characteristic lengths that are largely affect the acoustic performance of respective materials. Deviations of the all three models were compared with respect to frequencies and strand widths of material. On that basis JCA model was selected as more feasible model to forecast the values of sound absorption for the wood wool cemented material. It has also been observed that the wood wool multi-layers and air gap plays vital role in improving the sound absorption value of respective material.

Another effort for the use of natural fibre is made in the work on oil palm empty fruit bunch fibres [21] as sustainable acoustic absorber which utilized the fibre from the given material as alternative to the glass wool, stone wool, etc. The fibres are extracted from the empty fruit bunch with the help of mechanical retting process. Then the raw fibres obtained were feed into the aluminum mould and were kept under 100C temperature and 5 min of compression. Samples were made of varying thickness of 10mm and 20mm and also of diameter 33mm.The samples were made of varying density. Work implemented use of impedance tube of standard IOS 10534-2 consisting tube with diameter 33mm and two microphones. Testing was carried out by varying the density, thickness and air gap. The obtained result concluded that with the increase in the thickness of sample increases and density increases the absorption coefficient but up to certain extent at very high density the sound absorption coefficient tends to decrease. The absorption coefficient also increases with the increase in the air gap. The obtained readings was the compared with the readings of the commercial synthetic rock wool From this work it was observed that oil palm empty fruit fiber is an good alternative for glass wool, stone wool, It was found that the oil palm empty fruit bunch fibers can have absorption coefficient of 0.90 on average above 1000 Hz frequency.

The work Assessment of normal incidence absorption performance of sound absorbing materials [22] focuses the use different materials such as cell polyurethane foam, polystyrene, polyvinylchloride (PVC), rubber, mineral wool, carpet and glass samples with varying thickness. The efforts are done to build the impedance tube of two microphones with standard of IOS-10534.The impedance tube was made with the inner diameter of 3cm and the total length of 97.2cm. Test setup consists of 3-W loudspeaker and a pair of inch pressure field microphone from BSWA Company. To eliminate error the microphone was calibrated by BK calibrator at frequency of 1000Hz and 94 dB sound pressure. Test samples were prepared with 30mm diameter and varying thickness of 25mm and 30mm. These samples were then tested on the developed impedance tube. And it was observed that the mineral wool and carpet had the highest absorption coefficient (0.97) and the rubber sample had the lowest sound absorbing coefficient. Polystyrene sample with 25 mm thickness had the absorption coefficient higher than the same sample of 30mm. The peak absorption coefficient of 25mm glass sample was 0.36 that amount was reduced to 0.2 in the 30mm thickness. Samples such as rubber, PVC and closed cell polyurethane foam had very low absorption coefficient. The work concludes that according to results of this study the SAC can be obtained with lowest cost and highest accuracy by the made impedance tube.

Based on ideology of reusing the waste materials, similar kind of work is conducted on finding new methodology for manufacturing the multilayer acoustic absorber using the coal bottom ash [23] as discussed in this work. The materials are manufactured from coal bottom Ash (BA) from the traditional pulverized coal combustion. As per the SAC measurements in the impedance tube the intrinsic properties such as porosity, tortuosity and static airflow resistivity of material were determined. From intrinsic properties of material computer simulation were carried out in order to predict the acoustic behavior for different thicknesses, wave incident angle or multiplayer composite products. For simulation purpose SIMAM software were used and mathematical equation that describes the acoustic response of porous materials enact in software CARAM. The acoustic behavior of composite multilayer panels and the results were compared with those obtained in Reverberation room. Therefore it is observed that this technique gives accurate result of the acoustic absorption of product with the advantage of requiring small specimens of a material and decreasing the total cost of investigation.

Sound absorption by the fibro granular composite having the cylindrical grains describes the composite manufactured by combination of granular rice husk grains and coconut coir fibre [24]. These were the natural materials with low cost, inexpensive, eco-friendly and biodegradable. The single natural material didnt give the desired sound absorption coefficient so they investigate a composite made from natural materials [25]. These granular and fiber materials were mixed randomly with 50:50 ratio with different thickness 20,30,40 and 50 mm having diameter 28mm and 100mm. The necessary cohesion between materials was provided by using suitable binder with different percentage. These samples were tested within the frequency range of 0 kHz to 50 kHz. The SAC was measured by using a set of two impedance tube SCS 9020B/K ASTM E1050-98. One is high frequency and other is low frequency range of diameter 28mm and 100mm respectively. It was found that the increased in grains, samples thickness, and amount binder results in increase of sound absorption coefficient at lower frequencies. It is observed that natural composite materials with appropriate manufacturing technique will prove as good alternative of existing materials. Experimentation of the sample specimens in the research work are often conducted using the normal incidence method. The Results obtained are generally between 100Hz to 5000Hz for samples with range of thickness.

Research approach for utilizing potential of alternative materials for sound absorption since past few years is represented with summary chart as described below.

TABLE I. SUMMARY OF DATA OBTAINED FROM RESEARCH WORK

Author	*Methodology adopted for analysis*	*Material as Sound Absorber*	*Controlled parameter*	*Frequency Range*	*Thickness*	*Maximum Sound Absorption α*
Sezgin Ersory et. al. 2009	ASTM E1050-98	Industrial tea leaf fibre waste	With backing of woven cotton cloth	500-2400 Hz 500-3500 Hz	20 mm 30mm	0.8 0.75
Hosseini Fouladi et. al. 2011	Delany-Bazley Model and Allard and Biot Model	Coir Fibre	Bulk density and fiber diameter	1360-5000 Hz	20 mm	0.80
S Fatima et. al. 2011	ASTM E1050-98	Jute fibre	Without Rigid metal backing	0-4000 Hz 0-4000 Hz	25.4 mm 50.8mm	0.57 0.72
Lamyaa Abd Al Rahaman et. al. 2013	ASTM E1050-98	Date palm fibre and coconut coir fibre	Density	4184.38-4575 Hz 4521.88-4906.25 Hz	20mm 40mm	0.71 0.99
Hai-Fan Xianga et. al. 2013	ASTM E1050-98	Kapok Fibre	Bulk density and Fibre length	125-4000 Hz 125-4000 Hz	20 mm 40 mm	0.465 0.598
Tu Cheng Hung et. al. 2014	ASTM E1050-98	Inorganic polymeric Foam	Density and Thickness	100-4000 Hz	60 mm	0.70
A K Elwaleed et. al. 2014	ISO 10534 - 2	Date Palm Fiber	Compression Rate	0-5000 Hz	23 mm	0.52
M T Fadzlita et. al. 2014	ISO 354 - 2013	Coir Fiber	Perforation percentage of panels	0-4000 Hz	20 mm	0.75

Daniela Bosia et. al. 2015	EN ISO 354	Sheep wool	Density and Thickness	100-5000 Hz	50 mm	0.85
Reto Pieren et. al. 2015	Equivalent circuit method	Fabric Curtain	No of layers	125-4000 Hz	200 mm	0.8
Cinzia Buratti et. al. 2016	ISO 10534 - 2	Waste Paper	Thickness	0-4000 Hz	50 mm	0.9
Ancuta-Elena Tiuc et. al. 2016	ISO 10534 - 2	Textile waste and Foam	Composition	100-3100Hz	40 mm	0.85
Hasina Mamtaz et. al. 2016	ISO 10534 - 2	Cotton Fibre and Rubber granulate	Composition	0-500 Hz	40 mm	0.74
Manthan Sambu et. al. 2016	ASTM E 1050-09	Arenga pinnata and natural rubber	composition	0-4000Hz	50mm	0.85
B Botterman et. al. 2017	JCA MODEL	Wood Wool cement boards	Air cavity	200-2500 Hz	23 mm	0.5
Khai Hee Or et. al. 2017	ISO 10534 - 2	Oil Palm Empty Fruit Bunch fibres	Density and Thickness	500-4500 Hz	20 mm	0.9
Farhad Forouhamajd et. al. 2017	ISO 10534 - 2	Carpet	thickness	0-7000Hz	25 mm	0.97
C Arenas et. al. 2017	ISO 354, CARAM software	Coal bottom ash	Open porosity and static air flow resistivity	500-5000Hz	40mm	0.93
Hasina Mamtaz et.al.	ASTM E 1050-98	Rice Husk grains	Density, Thickness	0-5000 Hz	30 mm	0.86

Note: Data in the table provides the overview on the optimum results obtained in the research work mentioned in the paper.

3 DISCUSSION

Escalation in global awareness on use of green materials for sound absorption application encouraged researchers across the globe to go for identifying these green materials. These materials so far included in the work by researchers are either natural or waste materials. Materials described in the above articles are industrial tea leaf fiber waste, coir fiber, jute fibre, date palm fibre, coconut coir fibre, kapok fibre, inorganic polymeric foam, sheep wool, waste paper, Textile waste, cotton fibre and rubber granulate, arenga pinnata, wood wool cement boards, oil palm empty fruit bunch fibres, coal bottom ash and rice husk grains for application in sound absorption. Sound absorbers made by researchers are based on the variation of the parameters such as material thickness, density, flow resistivity, fiber length, fiber diameter, open porosity; air gap and reflective backing plates etc. impact the sound absorption coefficient of the manufactured materials. Other than these there are several materials like rice husk, bamboo, sugarcane waste fibre, banana leaf fibre, etc utilized for application in sound absorption. It can be observed that there is scope for researchers to come with new material like water hyacinth, peanut shell, and waste rubber from tires, construction waste, etc which can prove to be good alternatives over the conventional sound absorbers.

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