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Study on thermo-acoustic insulating property of biocomposite

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Non biodegradability in environment, sophisticated method of fabrication and economical soundness of synthetic fibers makes its alternative source for preparation of other composite from environmentally eco friendly materials. Many bio-based agricultural waste materials having very low environmental impact can be used in different scientific applications than manmade synthetic materials. Sugarcane is a renewable, natural agricultural resource which can be use in many products for major scientific applications after extraction of juice. Ultrasonically determined blended aqueous solution of NaOH is used for the surface modification of the dried fibres. The SEM characterization of treated fibre and the bio composite prepared from suitable composition of epoxy resin as matrix and sugarcane as filler confirm the suitability of the material for thermal, electrical and sound absorption property. Measurement of electrical and thermal conductivity of the sample indicates the insulating behavior of the sample. The dielectric constant of the material decreases with increase of log frequency indicating its energy storage performance. The presence of more porosity in network structure improves the sound absorption coefficient computed from the data obtained experimentally.

Keywords: Sugarcane bagasse, Sound absorption, Thermal conductivity, Electrical conductivity, Dielectric constant

1 Introduction

The issue of environmental pollution and its relation with global warming have encouraged the scientists and engineers to develop new technologies or materials which are more favorable and supportive to nature[1,2]. Recently, synthetic composite materials developed from various synthetic fibers like foams, rubber, glass-wool, polyester are hazardous to human health, disruptive at workplaces and harmful for the environment[3]. Thus instead of these manmade fibers, natural fibers which are cheaper, easily available, biodegradable, porous in nature and poses lower health risk are should be used for various scientific applications[4]. Over last three decades composite materials which have multifunctional system properties have been dominant emerging materials. The composite made from jute, coir, sisal, ramie, bamboo, banana and sugarcane are the current challenge to develop several innovative materials. Sugarcane is abundantly available in India and after extraction of its juice the bagasse can be utilized for the development of various composite materials[5]. It is chemically composed of cellulose (35%), hemicelluloses (25%), lignin (22%) and ash (22%). Due to lignin content it can be considered as more durable compared to other natural fibres. After cultivation and extraction of juice these wastes even if unable to use as cattle food and burned to clear the field for the next crop. Thus some efforts have also been done for utilization of the fibers that extracted from the baggage. The extracted soft fibers may very weak, but when it is coupled with epoxy resin, then the formation of biocomposite material is physically very tough. This is because of development of close chain between epoxy resin and sugar cane fibres[6-11]. The objective of this paper is to present research development in the area of sound absorption of natural fiber composites combined with some polymer materials. The effective physical parameters for enhancing the low frequency absorption in the materials are also highlighted in the current work. The scientific mechanisms behind the sound absorption, thermal and electrical insulations were discussed in terms of interaction of wave with material structure. In addition, the suitability of waste material can be turned to green technological material for different applications were highlighted for sustainable management of waste materials.

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2 Materials and Methodology

By using conventional mixture juice extractor all the juices were separated from the sugarcane. After extraction of juice the left residue known as baggage which can be used as the bagasse fibres. The soft core part was removed to get the rind. These rinds were cut across the length in such a way that the cutting portions should be free from the nodes. The extracted fibres were now kept in hot water at 90 ºC for 1 h to remove the sugar traces. The samples were dried under the sunlight for 24 h. Then the fibres were chemically treated with 1N solution of NaOH under atmospheric pressure in order to remove the surface impurities[12]. It breaks the network of hydrogen bond and increases the surface roughness of the fibre which provides better mechanical strength, improves lustre, dimensional stability and elasticity of the fibre[13-15]. In order to normalize the pH, the raw fibres were washed with distilled water so that it can remove the excess concentration of NaOH and lignin from the materials. Then the small pieces of fibres were kept in an oven at 60 ºC for one day to remove the moisture. The small pieces of fibre were now grinded and by the help of test sieve of 30 meshes the crushed parts of the bagasse were converted in to 150 µm size. The bagasse dusts were kept in air tight polythene to avoid moisture absorption prior to compounding. For the fabrication of sample both epoxy and baggage fibre dusts were weighed separately. The epoxy and hardener were mixed together with 10:1 ratio and stirred properly to demolish the air voids. A metallic mould of dimension of diameter 29 mm and thickness 1.4 mm was taken whose bottom was spread by plastic releasing agent and applied silicon spray for the easily removal of the composite. By calculating the proper weight percentage of fibre dust and epoxy polymers as per Eq.1 are mixed together and stirred for 30 min. The mixture was poured into the metallic mould and pressed with heavy loads. After 24 h the sample was removed from the mould, wiped with the tissue paper and kept in air tight polythene packets. The whole methodology and preparation of samples are schematically represented by Fig. 1 and Fig. 2.

$$\text{Fiber wt\%} = \left(\frac{\text{Weight of the fiber}}{\text{Weight of the polymer} + \text{Weight of the fiber}} \right) \times 100 \quad \ldots (1)$$

3 Characterization of Sample

The morphological behavior of the sample was analyzed by HITACHI SU 3500 Scanning Electron SEM. Figure 3(a) shows the SEM of untreated bagasse fibre containing bundles of fibrils with wax and other impurities which can reduce the bonding of fibre and polymer. Figure 3(b) indicates alkali treated bagasse fibre in which the distribution of fibrils in more surface area and provides more space for the bonding with superior mechanical strength.

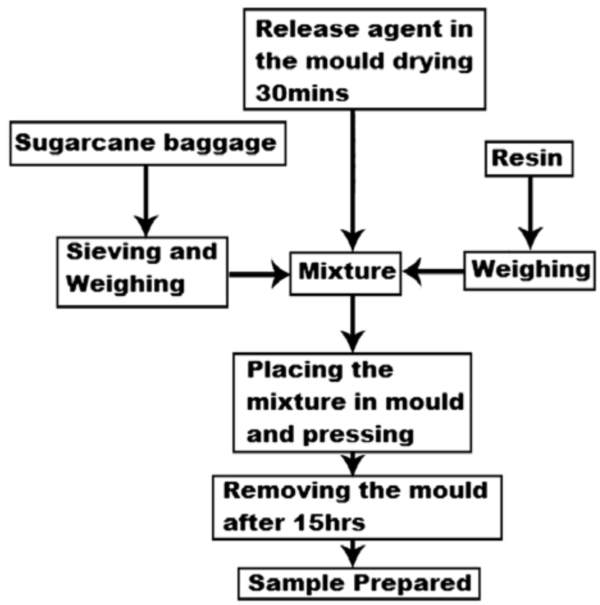

Fig. 1 — Steps for synthesis of sample.

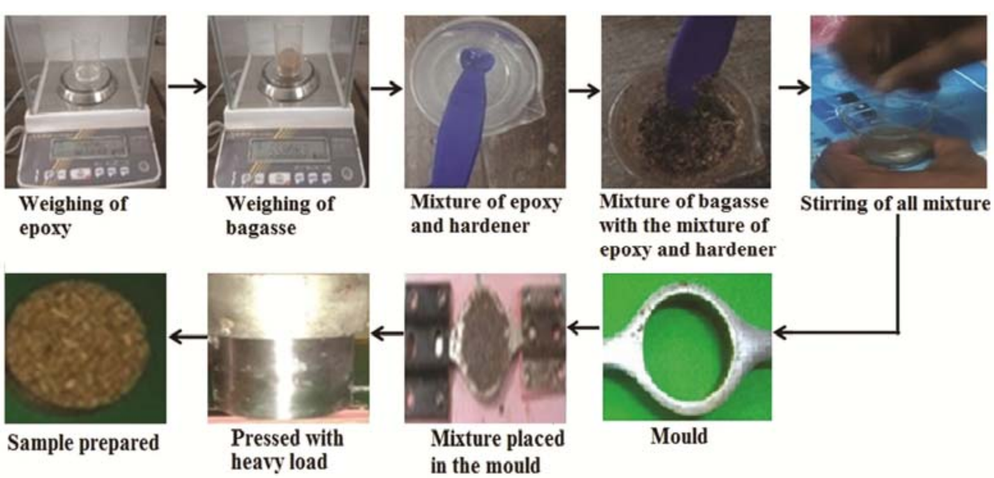

Fig. 2 — Preparation of sample in laboratory.

Further it was observed that the fibre surfaces are filled with large number of pores which confirm that removal of impurities with delignified surface. This increases the reaction sites on the fibre surface for bonding with polymer matrix. Since natural fibres are multicellular structure, bundles of individual cells are bonded by natural polymers, such as lignin and pectin[16]. The empty cavity in samples is known as lumen and exists in the cell unit of biofibers. The presence of this lumen decreases bulk density of the fibers. Though the treatment of alkali causes degradation and decomposition of dissolved polysaccharides but excess treatment may cause the loss of carbon in form of carbon dioxide[17] for which an optimum blend of aqueous alkali should be used for better surface morphology[18]. Figure 3(c) shows SEM of sugarcane baggage with epoxy polymer composite which indicates the presence of porosity embedded with strong bonding of polymer matrix. The presence of these pores acts like acoustic and thermal insulators[19]. The elemental dispersive spectrum (EDS) analysis confirms the presence of different element present in sugarcane bagasse to their own critical ionization energy and its own excitation depth. The most elemental observed in sugarcane bagasse-epoxy composite are observed well below 3 keV and some others up to 7 keV. The presence of Al and Si with carbon and oxygen elements shows broadest and tallest peak when compared to all other elemental composition. Most of the minerals are observed within 3 keV ranges which indicate that the minerals present are in lower energy range. The higher peak in the spectrum, the more concentrated is the element in the specimen as shown in Fig. 4.

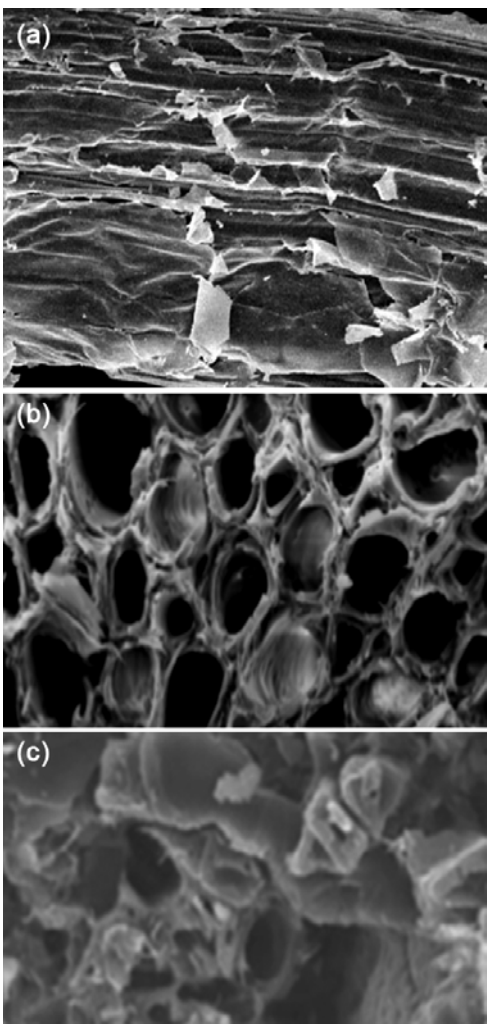

Fig. 3 — (a) SEM of untreated bagasse fibre, (b) SEM of treated bagasse fibre and (c) SEM of sugarcane bagasse composite.

4 Experimental

4.1 Sound absorption measurement

For the measurement of sound absorption coefficient the sample was placed at one end of a cylindrical tube and a microphone was placed at the other end which was connected to the computer as shown in Fig. 5. The instrument measured the sound pressure in decibel and indicated sound absorption coefficient by EXTECH software.

4.2 Measurement of insulation property

Both thermal and electrical conductivity of the sample were measured by Lee's apparatus and the arrangement for electrical conductivity as shown in Fig. 5(b) and Fig. 5(c). For measurement of electrical conductivity the sample was placed between two copper plates whose one end was fitted to the negative terminal of 12 V battery and other was fitted to a digital multimeter. By short circuiting, fixed resistance was calculate[20].

4.3 Dielectric measurement

HP impedance analyzer E4980A was used for the measurement of dielectric properties of the composite

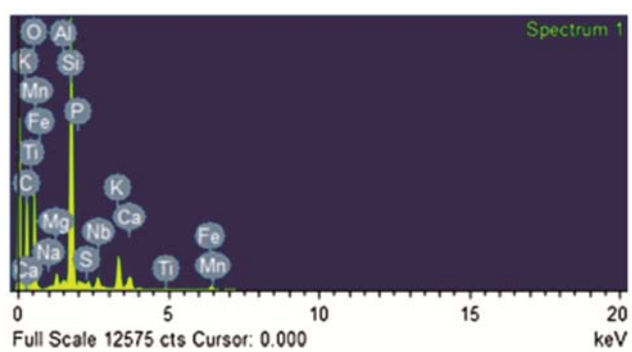

Fig. 4 — EDS analysis of sugarcane bagasse composite.

material. The sugar cane baggage fibre composites were analyzed by using two contacting metal electrode method in the frequency range 1 kHz – 1 MHz with ASTM D150-11 standard.

5 Results and Discussion

The microstructure analysis of the sugarcane bagasse and its polymer blended composite encompass a numerous pores throughout the composites which are arranged in closed network like structure. Sound-absorbing materials absorb most of the sound energy striking them and reflect very little. However, materials that have a high value of sound absorption coefficient are usually porous[21]. Figure 6 shows the propagation of sound with a constant frequency with and without sound absorbing material. The presence of material drops the intensity of sound (d) nearly 12 dB confirms that blockage of sound energy within the material.

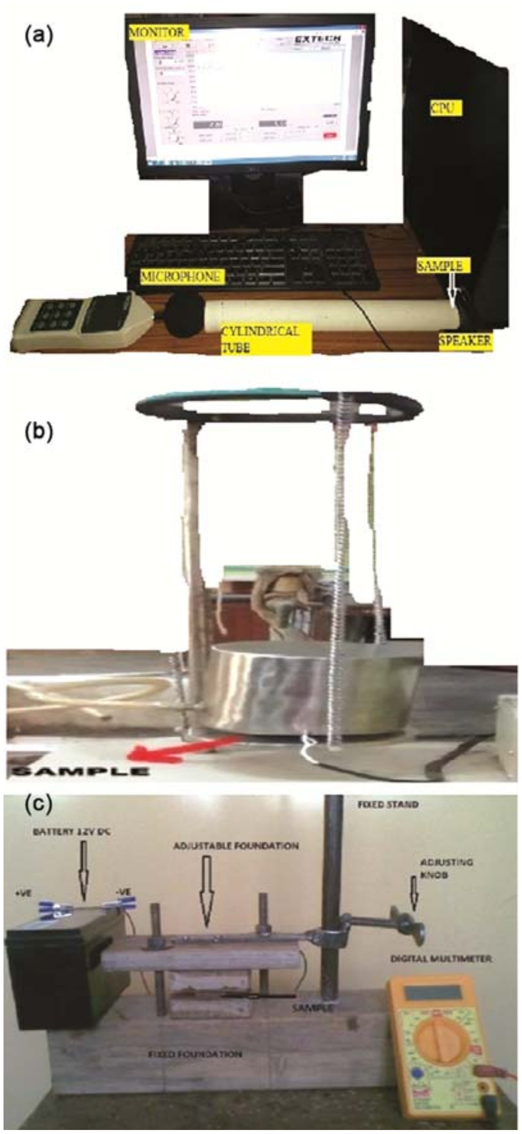

Fig. 5 — (a) Experimental arrangement for sound absorption measurement, (b) for thermal conductivity measurement and (c) electrical conductivity measurement.

This dropping in intensity of sound are used to calculate the absorption coefficient using the following Eq. (2):

$$\alpha = 1 - 10^{-(\frac{d}{20})} \quad \ldots (2)$$

where α is absorption coefficient and d is drop in intensity of sound in decibel. This dropping of sound energy through the surfaces of the material is affected by geometrical and other parameters of the materials like thickness of the porous layer, air voids or surface porosity, air flow resistance per unit length, tortuosity, coarseness of the aggregate mix, etc. The result shows that the sound absorption coefficient increases with increase in frequency from 500 Hz to 3000 Hz as shown in Fig. 7.

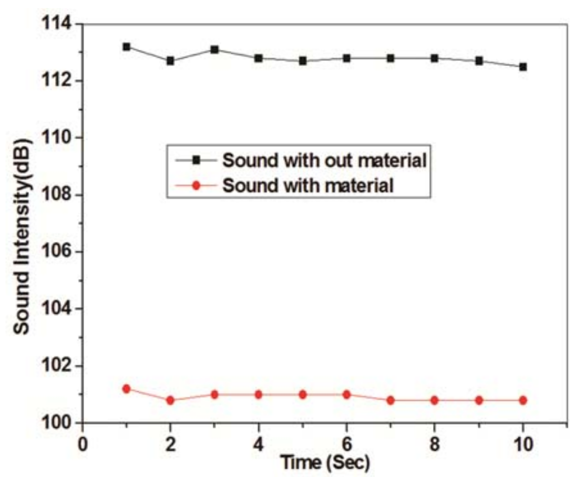

Fig. 6 — Propagation of sound wave without and with material with constant frequency for different time.

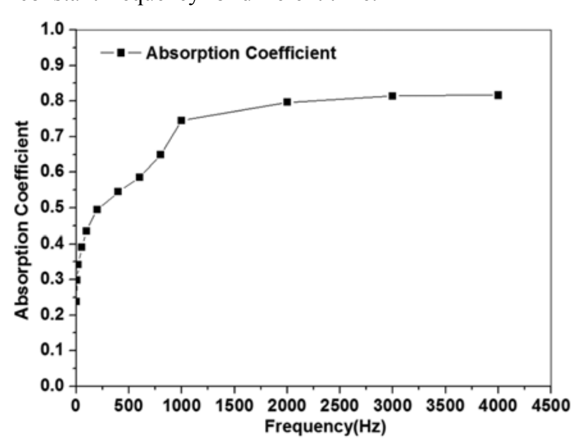

Fig. 7 — Frequency versus absorption coefficient of material.

The maximum values of sound absorption coefficient of samples are observed between 2500 to 3000 Hz frequencies. This absorption of sound can be explained by the fact that when a porous material is exposed to incident sound waves, the air molecules at the surface of the material and within the pores of the material are forced to vibrate and, in doing so, lose some of their original energy. This is because of the energy of the air molecules is converted into heat due to thermal and viscous losses at the walls of the interior pores and tunnels within the material. At low frequencies, these changes are isothermal, while at high frequencies, they are adiabatic. In fibrous materials, much of the energy can also be absorbed by scattering from the fibers and by the vibration caused in the individual fibers. The fibers of the material rub together under the influence of the sound waves[22]. The sound absorption mechanism in bulk granular materials is quite similar to that in rigid porous materials where the solid structure can be regarded as ideally rigid and stationary. Then the sound absorption is produced by the viscosity of the air contained inside the interconnecting voids that separate the granules. At low and mid frequencies, the solid structure interacts with the bulk of the gas through an isothermal heat transfer process. In addition, scattering from the granules also influence the absorption of sound energy inside the material. A good absorption material is one whose absorption coefficient (α) value equal to 1 or close to 1 and an absorption plateau at this value at a wider frequency range. The result is 0.80 to 0.85 which shows that the materials is a class- B type sound absorbing material as per stanadard SR EN ISO 11654, 2002. The coefficient of thermal conductivity of the sample goes on decreasing with increase of weight percentage of fibrous material as shown in Fig. 8. This may attributed due to fact that periodic compression and rarefaction of the sound energy is accompanied by changes in temperature.

At low frequencies, there is sufficient time for heat to be exchanged and a flow of heat energy occurs. This mechanism is enhanced by the large surface to volume ratio in the pores and the relatively high heat conductivity of the fibres at low frequencies. The oscillating pressure acting at the material causes the air molecules to oscillate in the pores at the frequency of the excitation and get damped due to increase in density of the medium. This result in sound energy being dissipated as heat due to friction losses between the fibre particles that occurs at high frequencies. Further, for electrical conductivity measurement when the material is soaked with water and kept in between the two conducting plates the material becomes polarized creating a number of dipole and increases the electrical conductivity of 10^{-5} order which is very low as shown in Fig. 9. This indicates that the material has low electrical conductivity and can act as an electrical insulator[23].

The interaction of high sound energy with the material produces a large number of dipole due to dielectric polarization, ionic polarization and electronic polarization.

The dielectric constant decreases enhancing the more dielectric loss or storage capacity of the material. The dielectric constant of epoxy blended sugarcane bagasse composite decreases with increase of log frequency as shown in Fig. 10 due to the interfacial polarization between the epoxy and

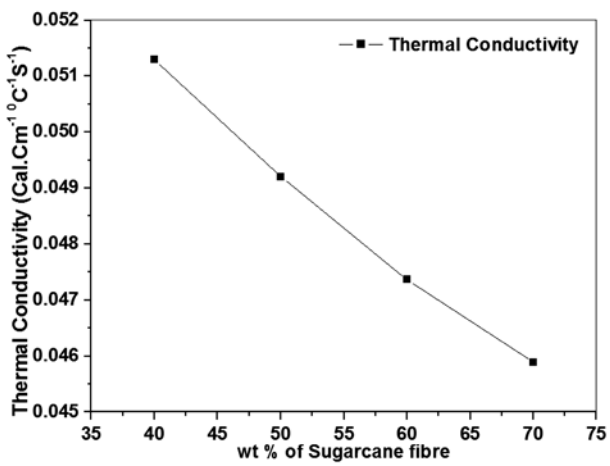

Fig. 8 — Variation of thermal conductivity of material with fibre weight percentage.

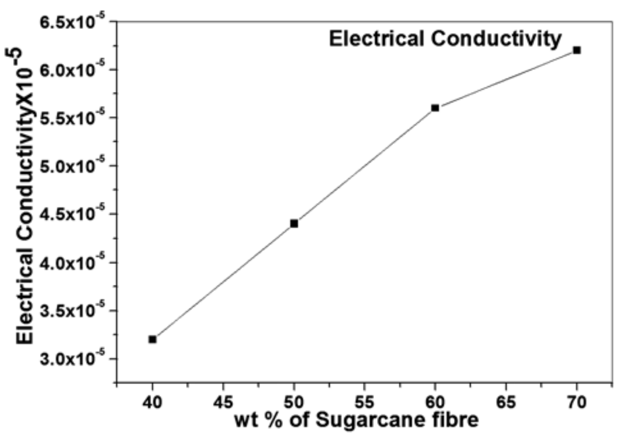

Fig. 9 — Variation of electrical conductivity of material with fibre weight percentage.

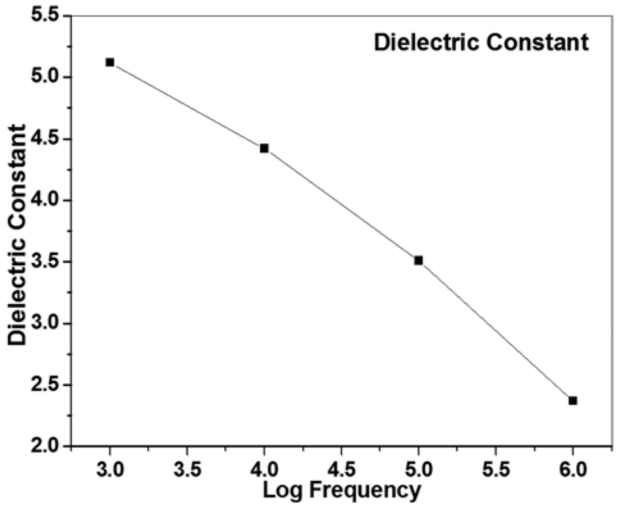

Fig. 10 — Variation of dielectric constant with frequency.

bagasse molecules. Again at higher frequencies small value of dielectric constant facilitates to absorb the electrical energy in an electric field[24].

6 Conclusions

In this paper both physical and acoustical properties of sugarcane bagasse fibre have been investigated. The result of this study indicates that the alkali treated sugarcane baggage reinforced composites are very light in weight, tough, exhibits good insulating, dielectric and noise reduction properties. The alkali treatment modifies the properties of natural fiber. Due to this there is an increase in interface adhesion between the fibre and matrix. The SEM analysis of the raw, treated and composite material explains support for the sound absorption property of the material and explains the basic scientific mechanism for sound absorption. At very low frequencies the material has low sound absorption capacity and above 1000 Hz it increases rapidly. The sound absorption coefficient is 0.80 which can be categorized into class-B sound absorbing material as per the standard data. Thus it can be utilized in high frequency sound generating sources to minimize the intensity. The presence of more pores in the surface of the composites facilitates the reduction of thermal conductivity and electrical conductivity. The sound propagation and sound absorption coefficient strengthen the acoustic performance of the synthesized material. The dielectric loss of material indicates that it may have good microwave absorbing property. Thus sugar cane bagasse is a kind of agricultural waste product can be considered as potential replacement of manmade synthetic fibres for the fabrication of composite materials which find its application not only in the field of acoustic material can also be used for thermal insulating, electrical insulating and energy storage device.

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