
Investigation of Acoustic Material Properties of Neem Wood Powder and Glass Wool Materials

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Abstract: **-**The specimens of neem wood and waste wood powder were prepared in a constant 35 mm diameter but with various thickness values ranging from 25 to 35 mm for testing. The material was initially mixed to produce coarse fibres and then processed in a grinding machine to produce fine fibres. Two samples sample specimen's diameters of 35 mm and thickness (45 mm and 80 mm) were prepared by glass wool. The sample specimens test was conducted by using two microphones-transfer function method. By using Alfa-X software we obtain parameters by providing real part and imaginary part readings of respective samples. the randomly distributed glass fibers create a porous structure that effectively traps and dissipates sound energy. This results in a high Sound Absorption Coefficient (SAC), indicating significant sound absorption capability. The porous nature of the Neem wood powder structure allows sound waves to penetrate and get trapped within the material, reducing sound reflections. The specific Sound Absorption Coefficient (SAC) values will depend on the characteristics of the wood powder used.

Keywords*: Neem wood, Wood powder, Sound Absorption Coefficient, Porosity, Acoustic.*

1. Introduction

In recent years, due to the rapid development of transport, industrialisation and urbanisation noise pollution has increased, leading to the introduction of heart diseases, annoyances and loss of concentration, which hurt human health. Therefore, by using b natural and waste materials, the priority is to regulate and control sound. Effective solutions to these problems can be provided by the use of active noise-absorbent materials. Porosity materials and resonant materials are available for trade. In many applications that fall within the category of resonant materials, perforated panels and membrane absorbers are applied to absorb sounds.

The fundamental principle of sound absorption referred to above is based on an internal resonant effect, which endears these materials with effective absorbability in particular at low frequency range. These materials are particularly notable for their ability to perform at lower frequencies, despite their efficiency in a large frequency band. Porous materials, which contribute to their overall sound absorption characteristics, are characterised by several channels and holes facilitating the absorption of sound waves into the material.

Sound energy is lost through thermal and fluid losses due to internal friction in the materials. For porous materials, this fundamental principle allows them to function effectively in a wide range of frequencies. Due to their low weight and ease of handling, porous materials have proven to be an excellent sound absorption option for construction and transport applications. Porous materials can be classified into synthetic and natural materials. A majority of natural materials are made up of fibrous substances, characterised by many channels and pathways among fibres which allow sound absorption to be achieved effectively.

Technological advancements have led to the emergence of large, noisy systems in various industries, including vehicle manufacturing, construction, environmental protection, and equipment production. Consequently, there is an increasing demand for sound-absorbent materials that are both effective and economical to maintain human acoustic comfort amidst these developments. Sound absorption is central to addressing this requirement.

The absorption coefficient is crucial for evaluating a material's ability to absorb sound and its effectiveness in blocking sound transmission. It quantifies how much sound energy a material can absorb, thereby determining the extent of sound dampening versus reflection or transmission. Consequently, to mitigate the effects of intense and loud systems on acoustic comfort in different industries, it is vital to create materials that absorb noise efficiently and cost-effectively.

When sound interacts with a material, its absorption properties dictate whether the sound energy is absorbed or reflected. Commonly used porous synthetic materials in room acoustics include rock wool, glass wool, polyurethane, and polyester. These materials, often derived from petrochemicals, tend to be costly to manufacture. With rising environmental consciousness and health concerns regarding conventional materials, the emphasis on natural alternatives has grown. Such materials are distinguished by their renewable sources, reduced environmental pollution in production, and low embodied energy.

The sound absorption qualities of natural materials remain somewhat elusive. These materials require high porosity to effectively absorb sound, which enables the sound to enter their matrix and dissipate.

The common use of costly, environmentally hazardous synthetic materials like rock wool, glass wool, or polyester for room acoustic absorption is shifting towards natural materials. These natural alternatives are gaining popularity due to their renewable sources, minimal environmental impact during production, and low embodied energy. The increasing interest in naturally occurring fibers for acoustic applications is due to their competitive advantages such as low density, favorable mechanical properties, ease of processing, high stability, negligible health risks, widespread availability, cost-effectiveness, and a smaller environmental footprint in manufacturing. Porous absorbing materials are typically categorized based on their microstructures into cellular, fibrous, or granular types. Specifically, fibrous materials are identified as either organic or synthetic.

Natural fibres can be derived from a variety of sources, including vegetables, such as hemp and wood, animal fibres, such as wool and fur felt, or mineral fibres, such as asbestos. On the other hand, synthetic fibres can be made from mineral or polymer-based materials such as fiberglass, glass wool and plastic fibre etc. examples of which are: Within the category of vegetable fibers, there are several subtypes: stalk or wood fibers (for instance, wheat and rice straw, softwood, or hardwood), bast fibers or skin fibers (including flax, jute, industrial hemp, ramie, rattan, and soybean), leaf fibers (like sisal, palm, and agave), seed fibers (such as cotton and kapok), and fruit fibers (for example, coconut).

In structures that are less uniform than synthetic porous materials, microscopic examination reveals the irregular shape and formation of natural fibres. For theoretical models which attempt to estimate the actual absorption behaviour of nature's materials, there is a significant challenge in terms of structure asymmetry. The study mainly covers vegetable fibers that have been subjected to compression and are then formed into sound insulation samples. This paper specifically looks at unprocessed raw natural fibres, in contrast to the usual practice of applying binders for creating panels and blocks from fibre. Only compression ensured that the material remained stable, without any binders in it.

The present study builds upon recent research conducted by the authors to evaluate the sound absorption characteristics of both natural and synthetic fibers. Specifically, it focuses on developing models to predict the acoustic behavior of these fibers beyond mere laboratory tests. The objective is to formulate equations that can predict the acoustic performance of organic fibers, offering a systematic methodology and diminishing the dependency on empirical assessments often required for heterogeneous natural fibers.

Natural fibres are attractive because of their easy processing, high stability, occupational health advantages, low fogging behaviour, abundant availability, cost-effectiveness and reduced environmental footprint during the production process. Furthermore, research suggests that during the plant growth phase vegetable fibres are capable of contributing positively to the environment through CO2 capture and storage.

The high flammability of natural materials is the main challenge for their use in acoustic applications, and moisture absorption. To be practically used in construction and structural applications, future studies and research on reducing the flammability of natural materials need to be further developed. To achieve a composite material with good strength and sound absorption capacity for structural applications such as acoustic panels, building applications, acoustic enclosures etc., work should be further developed with a variety of resins.

The scope of this study is to compile the current work on natural sound-absorbing material as well as composites of waste material. This review is arranged in 4 categories:

- The mechanism for absorbing sound.
- Sound absorption characteristics of various materials, in comparison to synthetic materials:
- Acoustical performance is influenced by material properties, along with test parameters.
- Testing standards primarily the mechanism of porous sound absorption materials are explained. In further part advancement in the research of natural and waste material for acoustic application and testing standards is discussed.

Natural sound-absorbing material

In the acoustic field, natural materials have a very important role to play. Natural materials are increasingly used due to their biodegradability characteristics and low cost, as the properties of natural materials make it possible to design a material for acoustic applications. Variations in composition, porosity, thickness and other properties may alter the performance of natural materials within a sound field. The internal porosity of natural fibers makes them suitable for sound absorption, so many natural fiber materials are used in the acoustic field because they provide greater airflow resistance.

Synthetic Sound absorbing materials

Synthetic materials are particularly crucial in the field of acoustics for their sound absorption capabilities. Sound absorption involves transforming sound energy into heat, thereby diminishing the reflection of noise waves from surfaces. Controlling and minimizing sound reflection is vital for enhancing sound quality and is targeted in various acoustic applications to lower noise levels and create a more agreeable environment. Synthetic materials, in comparison to natural ones, provide several benefits for sound absorption, which underscores their significance in acoustics.

2. Literature Survey

A method has been developed for the measurement of acoustic tortuosity and porosity in rigid porous materials. This method is based on the principles of existing ultrasonic techniques, but it's specifically adapted to thick samples of materials such as grains, pores and fibers with an approximate length of 1 mm by employing sound waves. The measurements shall be made using laser-generated waves of sound. The method can estimate the valid frequency range of each material based on predictions from a cell model and assumptions regarding the onset of large scattering. In cases where the scattering does not interfere, the effectiveness of the method can be demonstrated by the fact that the onset of significant scattering occurs at a frequency well beyond the upper limit of the pulse bandwidth. In addition to its suitability for large samples, the method does not require a specific set of measurements with samples and simple calculations to distinguish between tortuosity and porosity. In principle, to determine the characteristic length, the method may also be used [1].

Many researchers study the effects of various parameters on material sound absorption capacity. Different natural materials, waste materials composite and their acoustic performance with significant parameters are discussed in this review. In summary, the evolution of natural materials as acoustic materials has been described briefly by many researchers and some issues need to be resolved such as high flammability, moisture absorption, and manufacture reduction in thickness. Unfolding the above issues embellishes the utility of natural material for practical application [2].

An impedance tube and a model which takes into account the interaction of an acoustical wave with regular media have been used to investigate the sound properties of periodically formed materials manufactured by additive manufacturing. Broadband Acoustic properties similar to those found in porous materials are demonstrated by structures with regular acoustical characteristics made using additive processes. It is possible to create structures with enhanced absorption capacity by adjusting the printing parameters, including the lattice and filament diameter. Using a smaller filament diameter, decreasing lattice parameters and changing the orientation of printing filament can achieve greater absorption. The influence of tortuosity and resistance to airflow is reduced as the lattice parameters increase [3].

This paper initiates with an experimental exploration of sound absorption coefficients' behaviour due to the influence of backing walls on various composite materials. These composites consist of waste constituents like rubber particles, polypropylene, crushed plastic, wood flour, jute, and cord fabrics, which find use in standard construction materials such as plasterboard, polystyrene, and OSB. The experiments took place with the tube's end within an anechoic chamber. This study analyses the effect of the backing cavity on the acoustic performance of the samples, particularly regarding sound absorption. Consequently, when a rigid backing is employed at the tube's end, the absorption coefficient values we report are less than those from standard measurements. Introducing a single layer atop the backing plate enhances the noise absorption of the produced sample [7].

The research indicates that samples containing textile fibers, such as jute and cord fabrics, exhibit superior sound absorption qualities within the tested frequency range. This finding holds significant implications for environmental and human health. Notably, the acoustic absorption properties of plasterboard, when compared to those with polystyrene backing, are improved by the addition of a single layer of any recycled waste material, regardless of its thickness. When using OSB as the foundational material, a comparable pattern is observed in thin samples. It is the density, rather than the thickness, of the backing material that has a more pronounced effect on the sound absorption capabilities of these samples [4].

Sound absorption coefficients, particularly in the upper and lower frequency ranges, were observed during experiments on samples of naturally occurring fibres. The inherent inhomogeneity of natural fibres and the difficulty in developing prediction models for their behaviour are reinforced by significant standard deviations observed from airflow resistance measurements. The significant differences in the results obtained suggest a need to reduce the direct measurement of material properties and encourage the consideration of models that can predict behaviour with low variables. To do so, the study used an inverse optimization method for the calculation of coefficients that best describe acoustic impedance and propagation constants in a variety of natural fibres [8].

The study used an optimization technique to create laws which reduced errors in the determinations and forecasts for different fibres. This implies that a robust test of the validity of theoretical calculations was facilitated by the use of data from 11 one-third-octave bands. Finally, the paper provides a set of coefficients which are essential for the laws which model the acoustic behaviour of different fibres. The development of simple prediction models, and the ensuing feasibility to incorporate these models in replication software, have been considered necessary as an acknowledgement of the importance of encouraging wider use of naturally occurring fibers for efficient absorption applications. This development will allow acoustic software to incorporate naturally occurring materials in their Standard Library, expanding the range of materials available for noise absorption purposes [5].

This study evaluates the performance of bagasse derived from natural fibers. Three bagasse samples were prepared and analyzed, each with a different thickness. Systematic variations in operating parameters were employed to determine the bagasse's airflow resistance and acoustic absorption coefficient. A comprehensive experimental and theoretical investigation was conducted to assess the material's sound properties. The findings indicated a high acoustic absorption coefficient, ranging from 0.7 to 0.8 across various frequencies, showcasing its sound absorption capability [6].

Further analyses investigated the effects of sample thickness and air gap, yielding positive outcomes. A strong correlation between the calculated and measured values was confirmed by comparing the results with theoretical data from existing literature.

The current research activities main objectives are set out in the following order.

Evaluate acoustic properties: Porosity, Airflow resistivity, and Tortuosity are key factors in assessing the material's sound absorption capabilities.

- Porosity refers to the proportion of air within a porous material to its total volume.
- Airflow resistivity characterizes the resistance of a porous material's framework to steady-state airflow.
- Tortuosity is the ratio of the actual path length travelled through a material to the linear path length within that material.

3. Methodology & specimen Preparation

The material and method required to prepare the specimen are as follows.

- Glass wool Specimen
- Neem wood powder Specimen
- Waste wood powder

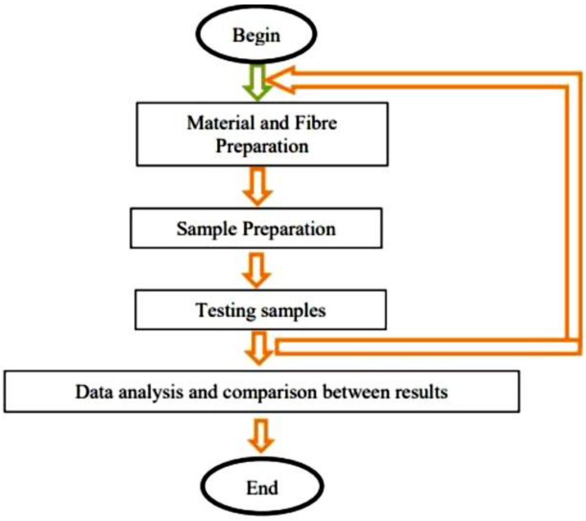

Figure 1. Flow chart

Sample Specimen preparation

To assess the acoustic properties of two materials, namely natural and synthetic, we have carried out a work to compare their respective results. The preparation process of material and fibers can vary depending on the specific type of material or fiber used, we used wood powder as a natural material and glass wool as a synthetic material. The processes involved in the preparation of these materials are given below.

The specimens of neem wood and waste wood powder were prepared in a constant 35 mm diameter but with various thickness values ranging from 25 to 35 mm for testing. The material was initially mixed to produce coarse fibres and then processed in a grinding machine to produce fine fibres. The resulting waste wood powder finer fibers were sifted through strainers. Then, to achieve the desired density and thickness, fibers were formed into samples through moulds that applied external pressure. For specimen preparation, Maida starch has been used as a binding material. To eliminate moisture, all samples have been sun dried.

Figure 2. Neem Wood Powder Specimens (D=35 mm, t=25mm/35mm).

Two samples sample specimen's diameters of 35 mm and thickness (45 mm and 80 mm) were prepared by glass wool. This process involved a tight press and constant folding of glass wool, as it was 35 mm in diameter. To obtain the shape, it must have been attached to a thread or any appropriate form of tube.

Figure 3. Glass Wool Specimens (D=35mm, t=45mm/80mm).

4. Experimental work, Data analysis and Comparison results

The sample specimens test was conducted by using two microphones-transfer function method.

- The circular shape specimen of 35mm constant diameter, 25mm and 35mm thickness for Neem wood & waste wood powder specimens and 45mm and 80mm thickness for glass wool specimens, placed inside the impedance tube machine for testing.
- The impedance tube is utilized to measure sound frequencies. The test adhered to the ASTM E1050-98 standard, which specifies the use of an impedance tube.
- The two microphones used for the test had to be calibrated using a sound calibrator from the speaker for 114dB.
- Calibration was performed to evaluate the gauge frequency values' acoustic absorption ranging from 0 to 1.
- Before initiating the experiment, additional necessary resources were interconnected. After positioning the sample within the tube, the piston should be carefully extended outward to align the sample with the tube's edge, ensuring the material's outer surface does not surpass the tube's edge.
- A frequency of 500Hz to 4500Hz has been set for the tube. Using Audacity software, the audio waves detected were converted into a digital signal.
- The output of the results was saved in graph form using MATLAB software.

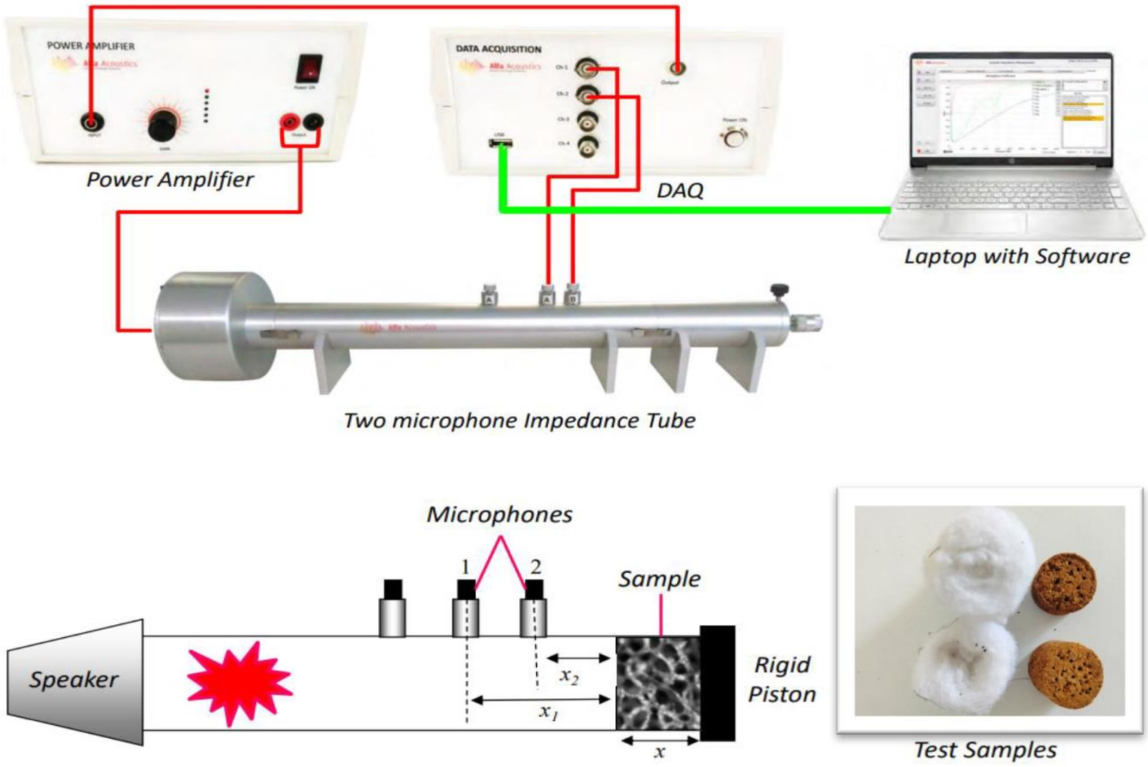

Figure 4. Impedance Tube experimental setup.

Data Analysis and Comparison Results

Table 1. Acoustic absorption measurements for Neem wood powder specimen.

Material	Density	Thickness	Frequency [Hz]								
Neem wood powder	Kg/m3	M	500	1000	1500	2000	2500	3000	3500	4000	4500
	220	0.025	0.679	0.516	0.457	0.476	0.484	0.483	0.486	0.499	0.524
		0.035	0.474	0.660	0.429	0.382	0.409	0.435	0.459	0.478	0.495

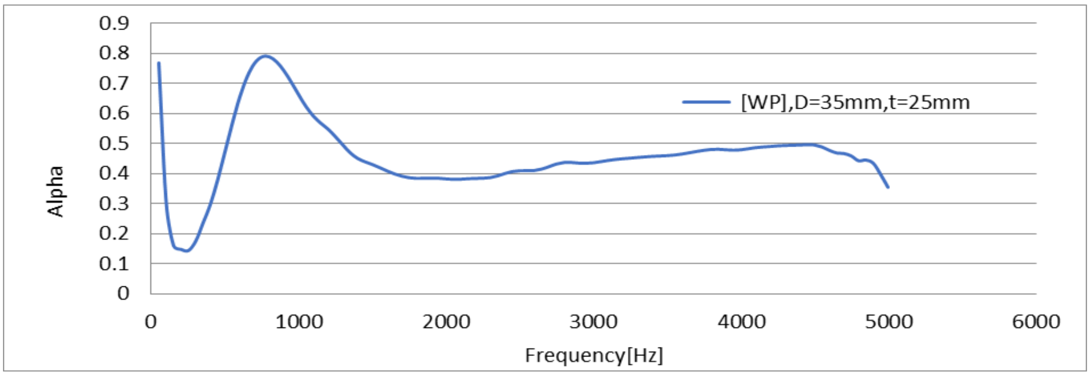

Figure 5. Graph of Neem Wood Powder Specimen of Thickness 25mm.

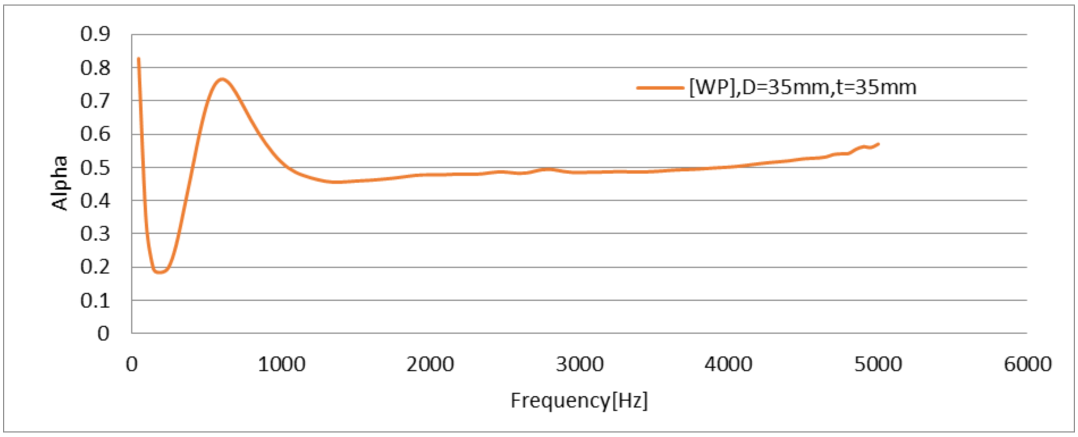

Figure 6. Graph of Neem Wood Powder Specimen of Thickness 35mm.

Table 2. Acoustic absorption measurements for Glass wool Specimen.

Material	Density	Thickness	Frequency [Hz]								
Glass wool	Kg/m3	m	500	1000	1500	2000	2500	3000	3500	4000	4500
	16	0.045	0.700	0.921	0.934	0.908	0.919	0.956	0.984	0.991	0.989
		0.08	0.683	0.781	0.854	0.8922	0.915	0.934	0.949	0.960	0.967

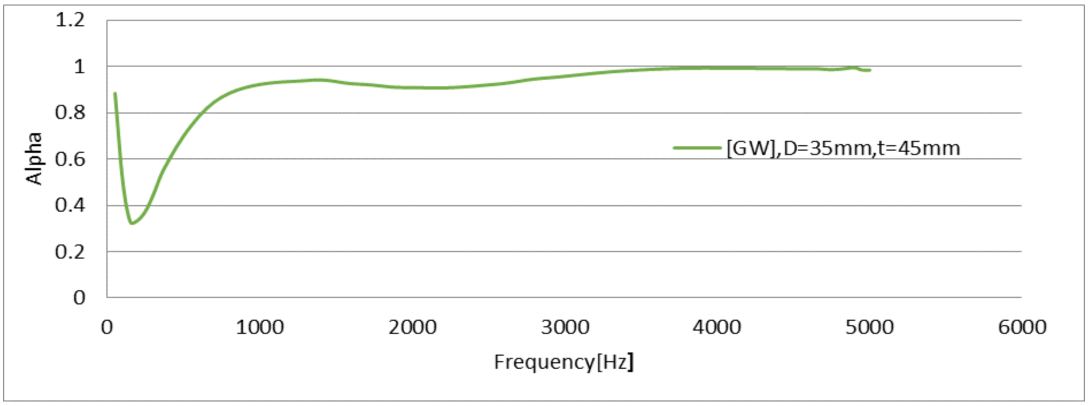

Figure 7. Graph of Glass Wool Specimen of Thickness 45mm.

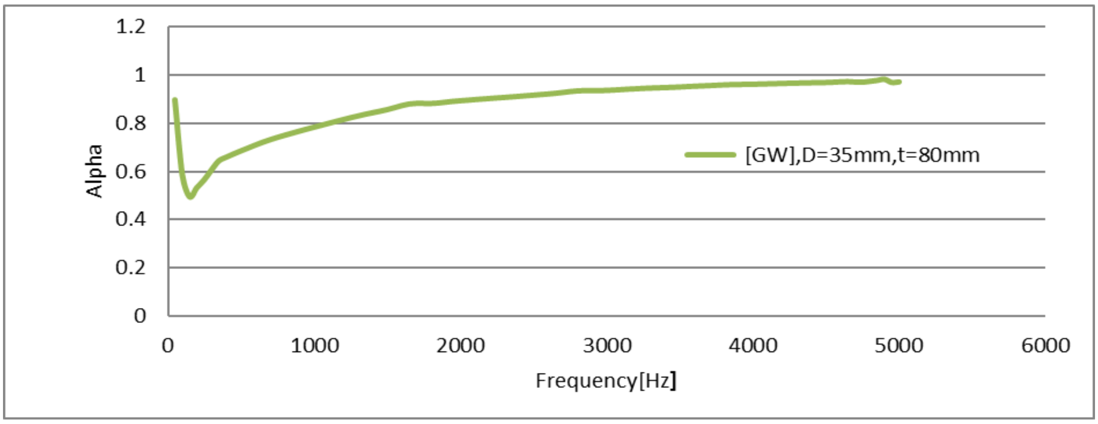

Figure 8. Graph of Glass Wool Specimen of Thickness 80mm.

Acoustic absorption measurements of Neem wood powder for different thicknesses.

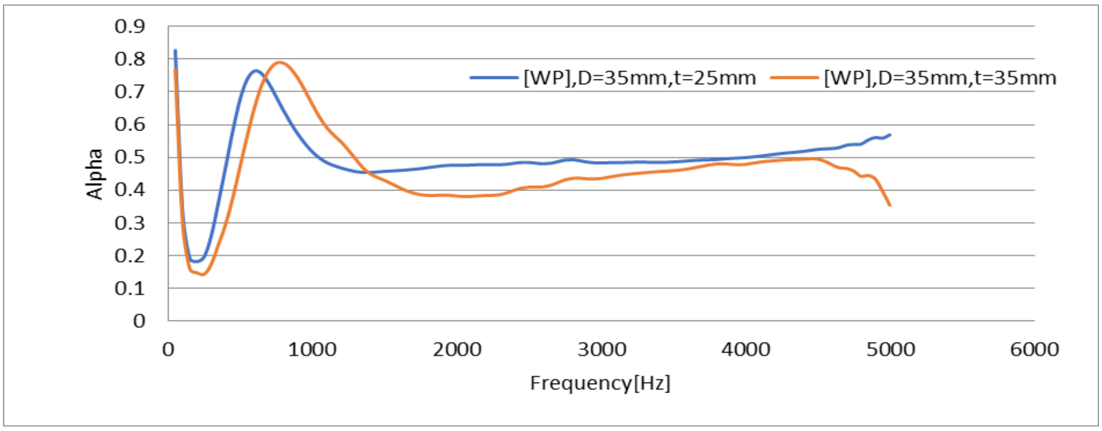

Figure 9. Graph of Neem Wood Powder Specimen (D=35mm, t=25mm/35mm).

Acoustic absorption measurements of glass wool for different thicknesses.

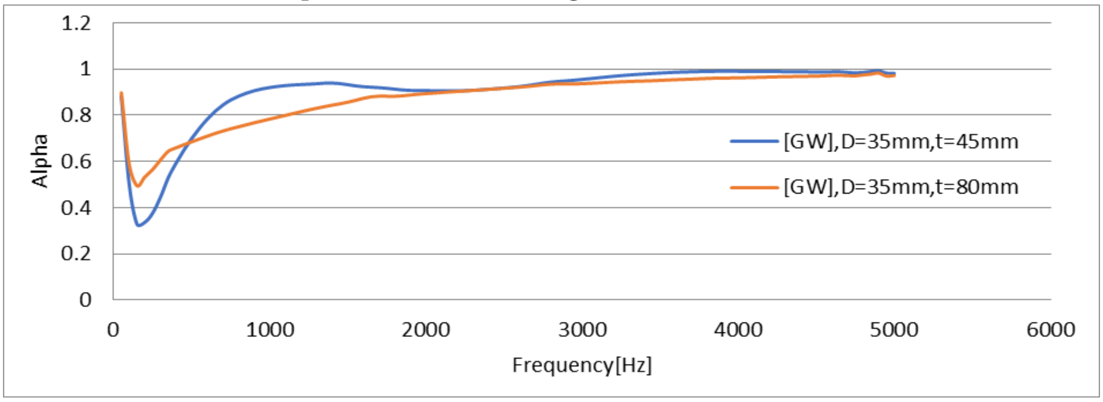

Figure 10. Graph of Glass wool Specimen of Thickness 45mm and 80mm.

Acoustic absorption measurements of Glass wool and Neem wood powder for different thicknesses.

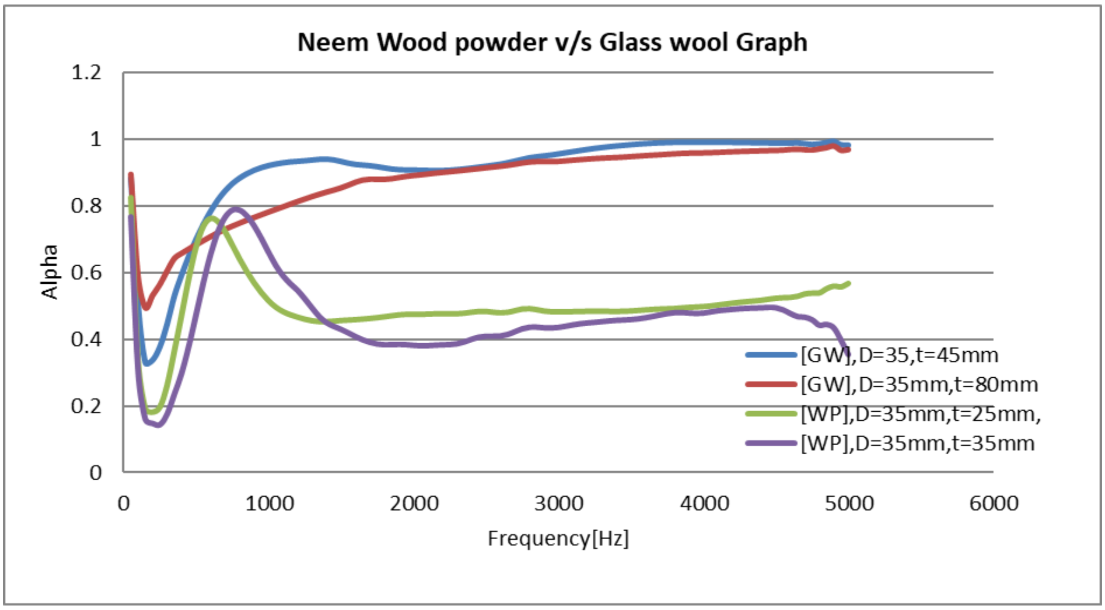

Figure 11. Graph of Neem Wood Powder and Glass Wool specimen for different thicknesses.

Porosity, Flow resistivity and Tortuosity Results.

By using Alfa-X software we can calculate these parameters by providing real part and imaginary part readings of respective samples.

Table 3 Porosity, Flow resistivity and Tortuosity results.

Neem Wood powder	t=0.025m	t=0.035m	Glass wool	t=0.045m	t=0.080m
Porosity	0.85	0.85	Porosity	0.0999	0.999
Flow resistivity (Ns/m4)	52178	64458	Flow resistivity (Ns/m4)	27948	38863
Tortuosity	6.976	6.979	Tortuosity	1	1

5. Results Discussion

Neem Wood powder is an organic material derived from wood fibers, often used in the production of sound-absorbing panels. The sound absorption performance of Neem wood powder specimens can vary depending on factors such as particle size, density, and surface treatment. The results of wood powder specimens can be evaluated based on their Sound Absorption Coefficient (SAC).

Sound Absorption: Neem Wood powder specimens tend to exhibit good sound absorption properties, particularly in the mid to high-frequency range. 1000, 1500, 2000, 2500, 3000 3500, 4000, 4500 at the D=35mm and t=25mm the SAC Value are 0.679, 0.516,0.457, 0.476, 0.484, 0.483,0.486,0.499,0.529 and t=35mm the SAC value are0.474,0.660, 0.429,0.382,0.409,0.435, 0.459, 0.478 0.495 respectively the porous nature of the Neem wood powder structure allows sound waves to penetrate and get trapped within the material, reducing sound reflections. The specific Sound Absorption Coefficient (SAC) values will depend on the characteristics of the wood powder used.

Comparative Analysis: When comparing Neem wood powder specimens to Glass wool Specimens of acoustic materials, factors such as cost, aesthetic appeal, and environmental sustainability should also be considered. In applications where aesthetics are important, such as architectural spaces, wood powder panels may offer a natural and visually pleasing appearance.

Glass wool is a synthetic fibrous material made from melted glass fibers. It is widely used in building insulation and soundproofing applications due to its excellent sound absorption properties. The performance of glass wool specimens can be evaluated using Sound Absorption Coefficient (SAC), Porosity, Flow resistivity and Tortuosity results.

Sound Absorption: Glass wool exhibits high sound absorption across a broad frequency range. 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500, at the D=35mm and t=45 the SAC Value is 0.700, 0.921, 0.934, 0.908, 0.919, 0.956, 0.956, 0.984, 0.991, 0.989 and t=80mm the SAC value is 0.683, 0.781, 0.854, 0.8922, 0915, 0.934, 0.949, 0.960, 0.967 respectively the randomly distributed glass fibers create a porous structure that effectively traps and dissipates sound energy. This results in a high Sound Absorption Coefficient (SAC), indicating significant sound absorption capability.

Comparative Analysis: Compared to wood powder, glass wool generally offers superior sound absorption. It is often preferred in applications where maximum acoustic control is desired, such as recording studios, theatres, and industrial settings.

Different parameters which affect the sound absorption coefficient of natural material are listed below in the Ishikawa diagram.

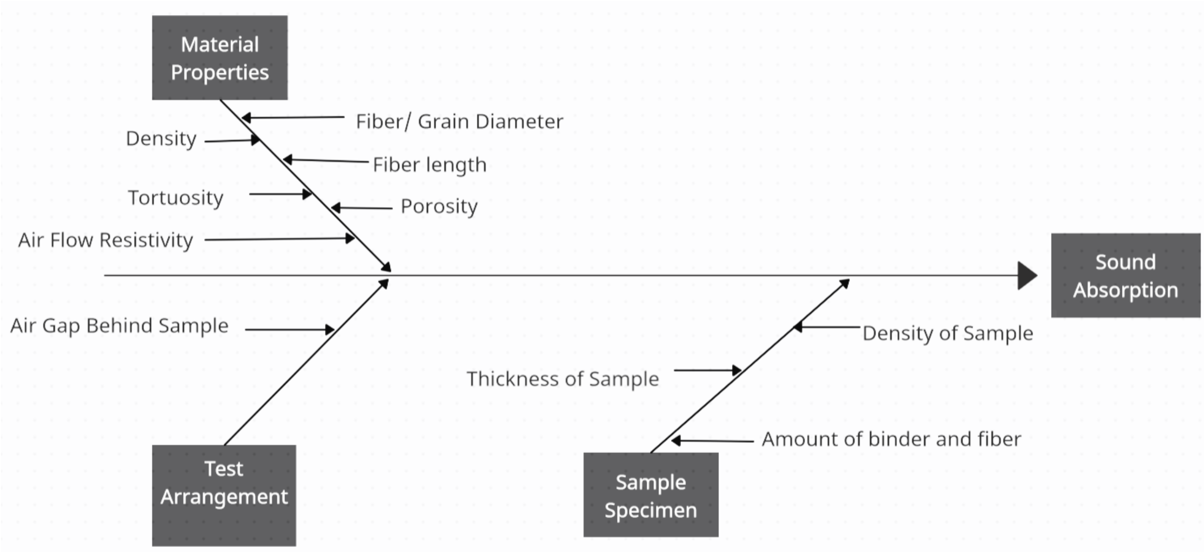

Figure 12. Ishikawa diagram.

Natural materials such as coconut coir, waste wood powder, bamboo, broom fibers, and kapok fibers possess high sound absorption coefficients, comparable to those of synthetic materials. Additionally, composites made from synthetic resin (polystyrene, polyurethane, glass wool) combined with waste or natural materials can be utilized in building applications, acoustic panels, and enclosures. Figure 12 illustrates the various parameters that influence the sound absorption coefficient of materials, which are primarily categorized into three sections:

- Material properties (fiber diameter, fiber length, density, porosity, air flow resistivity, tortuosity).
- Test arrangement (air gap provided behind the sample).
- Sample specifications (thickness of sample, composition of binder and fiber) Acoustic performance of natural materials like coconut coir, jute, and sugarcane waste fiber improved for higher frequency as thickness and density of material increased though it shows unsuitable performance at low frequency. Important parameters are discussed below.

Effect of fiber diameter

The diameter of fibers has a significant impact on the sound absorption coefficient of porous materials. A reduction in fiber diameter leads to an increase in the sound absorption coefficient, owing to an increase in the number of internal pores and a larger contact area.

Effect of the air gap

Incorporating an air gap during the installation of a sample in an impedance tube is crucial for low-frequency performance (below 2 kHz). The efficacy of natural materials like coconut coir and sugarcane is significantly enhanced by this air gap. By providing an air gap behind the sample, the sound absorption coefficient is improved, and material usage is optimized, yielding results comparable to those of a full-thickness sample in the same space. Therefore, an air gap behind the sample is an effective method to boost the performance of natural materials in low-frequency areas.

Effect of Thickness

The sound absorption coefficient increases with the thickness of the sample across all material types, offering more area for sound waves to dissipate through viscous and frictional effects. A material with consistent density exhibits a rising trend in sound absorption coefficient as its thickness increases.

Effect of density

With consistent sample thickness, sound absorption escalates with material density until reaching a threshold. Excessively high density may diminish porosity, thereby augmenting flow resistivity and obstructing sound wave penetration. Conversely, as material density lessens, tortuosity heightens, capturing more sound waves within the material.

Tortuosity

Tortuosity is nothing but a measure of the actual path travelled by sound waves relative to the straight distance between start and end points. As the porosity of the material enhances tortuosity increases and the distance travelled by sound waves increases which corresponds to more loss of sound energy in the material resulting in a high sound absorption coefficient.

Conclusion

Specimens of Neem wood powder exhibit efficient sound absorption, particularly when they have a diameter of 35 mm. The specimen's Sound Absorption Coefficient (SAC) is affected by its thickness; the SAC rises with an increase in thickness and decreases when the thickness diminishes. The porous nature of the wood powder aids in trapping sound waves, reducing sound reflections. The exact SAC values depend on variables like the specimen's thickness, diameter, and porosity.

Glass wool samples demonstrate superior sound absorption over a wide frequency range. The fibrous composition of glass wool efficiently captures and diminishes sound energy. These samples attain a high Sound Absorption Coefficient (SAC), which is influenced by the material's density and porosity. It has been observed that a lower density in glass wool specimens correlates with an increase in the Sound Absorption Coefficient (SAC).

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