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Preparation Of Sound Absorption Acoustic Panels Using Coir

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Abstract
Coir, also known as Coconut fibre is extracted from the outer husk of coconut. Found between the hard internal shell and the outer coat of a coconut. Eco-friendly ligno-cellulosic fibre. Thickest and most resistant of all commercial fibres. Coir is extracted in two forms, white and brown coir. Brown coir is extracted from fully ripe coconuts. It is golden yellow in colour. Completely natural and biodegradable. The majority of acoustic panels used today contain fibre glass or synthetic fibres, which, if damaged, can harm the eyes and lungs. The US department of Health and Human Services found that the fibres most frequently in traditional sound absorption panels can be reasonably anticipated to be carcinogenic.[1].

Key words coconut fibre, lignocellulosic fibre, bio degradable.

1. Introduction

More than 80% of the total world production of coir comes from India. Other important coir producing countries are Sri Lanka, the Philippines, Thailand, Vietnam and Mexico. Coir industry is mainly an export-oriented industry which earned more than Rs.2192 Crores of foreign exchange for the country during 2018-19. Coir and coir products are now exported to 110 countries all over the world. The top coir importing countries are USA, China, South Korea, Netherlands, and UK. Recent research into the properties of coir has shown that it can be used to replace synthetic fibres in a number of products.[1] These studies found that coir panels, on their own or layered with perforated plates, can absorb sound and improve the acoustics of a space nearly as well as standard acoustic panels. Furthermore, because coir fibres are highly customizable, it is possible to build panels to absorb either higher or lower frequencies, depending on the particular needs of the consumer.[1]

1.1 Literature Review

Natural fibres such as coir, has a common characteristic that is crucial for acoustical appliances which is, they all have porous surface. This characteristic, enable them to be used in acoustical appliances such as acoustic panels where they could absorb and insulate sound that propagates at

them. The author in this study finds that coir fibres have a good potential as sound absorbing panel as it have a good sound absorbing properties for a wide frequency range.

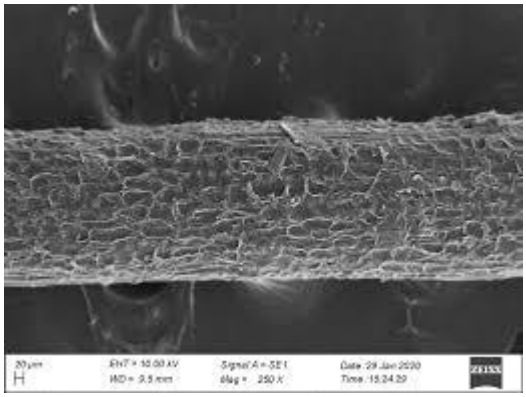
The author gives the idea of using coir panels in cinema theatres, auditoriums, as sound absorbing panels, so that usage of synthetic materials can be avoided. [2].

1.2 Chemical composition of coir and its structure

Lignin	-	45.84%
Cellulose	-	43.44%
Water soluble components	-	5.35%
Pectin	-	3.3%
Ash	-	2.22%
Hemi cellulose	-	0.25%

1.3 Microscopic view of coir

The coir fibre is multicellular (the fibre contains 30 to 300 or more cells in its total crossection) and its crosssection is polygonal or round. Figures 1 and 2 show the transverse and longitudinal section of coir fibre, indicating the number of cells and distribution of cells around the central pore called “lacuna”. The individual cell size is 1-14μm in diameter and the length – to – diameter ratio of the cell is of the order of 35. The walls are thin to fairly thick with lense- shaped silicified stegmata (15μm in diameter) on their surface. These are delicate thickenings with a few of them being circular or spiral in shape. There is a central cavity in each cell called lumen, which is medium to large in size (polygonal, round or rounded to elliptic in shape) and is estimated to be 5 – 7.5μm in diameter. The surface of the individual cell is smooth or rough with certain defects like cross markings, while the surface of the fibre is coated with a waxy material called cuticle.[3].



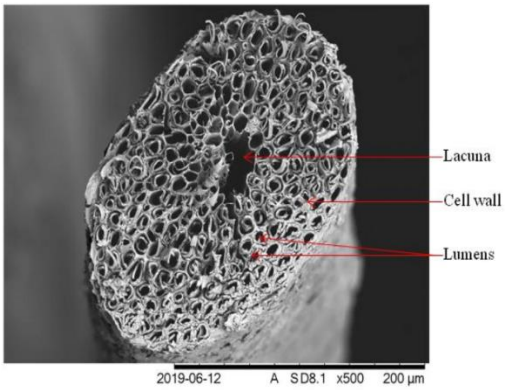


Fig. 1.1 Microscopic view of coir

1.4 Properties of coir

Physical Properties

Due to its high lignin content, coir is more durable when compared to other natural fibres.

Colour : Golden yellow to brown
Ultimate length :0.6 mm
Single fibre length: 6-8 inches
Diameter : 16 microns
Density : 1.4 g/cc
Tenacity : 10 g/tex
Breaking extension : 30%
Moisture Regain : 10.5%
Swelling in water : 5% in diameter
Elastic Modulus : 3-6

1.5 Sound Absorption & Acoustics

Sound Absorption must not be confused with Sound Proofing. Sound proofing keeps the outside noise out of a given space, whereas sound absorption absorbs sound and improves the acoustics of the given area. Acoustics is a term referring to the qualities that determine a room's ability to reflect sound waves in such a way as to produce distinct hearing. It also refers to the science of sound with respect to its production, effects, control, transmission, and reception. Acoustics should be the central focus while designing auditoriums, theatres, concert venues, etc. The sound coming from the stage must reach the audience clearly, without any echoing regardless of where they are located with equal distribution of sound.

1.6 Effective auditorium design should address the following goals

-Speech, vocal performances and music should all sound clear rather than distorted or echoey.
-Sounds should be loud enough for the audience to hear, including those sitting at the very back of the auditorium.

-The right sounds should be isolated, meaning performances and speeches ring clearly over other sounds from the room.
-When a sound is produced, the sound waves continue to travel until they run out of energy and eventually stop. This resonating persistence of sound is known as reverberation.
-Unwanted levels of sound wave reverberation will echo throughout the area and blur original sound signals coming from the stage. This compromises sound clarity and ability of the audience to understand speech or music
-The acoustics of a room is improved by absorption, which refers to use of materials having sound absorptive properties.

1.7 Conventional Sound Absorption Materials

Rock Wool

Fig. 1.2 Rock Wool

Acoustic Foam

Fig. 1.3 Acoustic Foam

1.8 Commercially used sound absorption materials are

Acoustic foam, made of polyurethane
Mineral fibre
Fibre glass
Rock wool or stone wool.

1.9 Rock wool and why it is used as a sound absorption material

Rock wool is one of the synthetic forms of mineral wool. Its main component is inorganic rock or slag, typically around 98% and the remaining 2% is organic content. Acoustic absorption coefficient of 0.4 to 0.6, Noise reduction coefficient of 0.5 to 0.9, High density and weight, Good thermal insulation properties, Fire resistant qualities,Good thermal insulation properties and able to block lower frequencies and vibrations.

2. Methods and Materials

2.1 Making of coir panel

Fig. 2.1 Making of coir panel

Fibre is extracted from the husks of coconut. They are then soaked in water for one to ten months. While submerged, the husks undergo anaerobic fermentation, which causes them to soften and separate. Husks are crushed and their fibres are broken up. The coarse fibres are separated from the short, woody parts. They are then washed, dried, cleaned and brushed. Fibres are dyed if colour is needed. They are led into a conveyor belt and through a roller, where all fibres are aligned in such a way that it makes a single sheet of the required thickness. The fibres are then sprayed over by rubber latex at boil. Then the fibre – rubber latex mixture is punched and compressed with a hydraulic press at high temperature. The sheet is then allowed to cool. The coir sheets are given a fire retardant finish. After proper cooling, the sheet is cut into shaped as required.

2.2 Sound absorption test

Measuring the sound absorption coefficient of an acoustic material can be divided into two main method, namely, the normal incidence method and the diffuse field method. In the first method, the material is excited by sound energy at angle normal to the surface of the material. For this purpose, the wave length of the sound incident must be much greater to the diameter of the test material. Thus, only relatively small size of mater : ial is required (usually circular shape with less than 100mm in diameter) and sound energy is contained inside a circular tube, known as impedance tube. Mean while in the diffuse field method, the sound excites the material from any possible angles of incidence and thus closely resembles the situation in practice. However, a special, large room is required to enable the sound energy to be diffuse in the room to the lowest frequency possible, known as reverberation chamber.[4].

The sound absorption test for coir was done using Impedance tube: ITA 219 HOLMARK, following ISO 10534-2, ASTM 1050 & ASTM E2611 standards.

2.2.1 Impedance tube apparatus

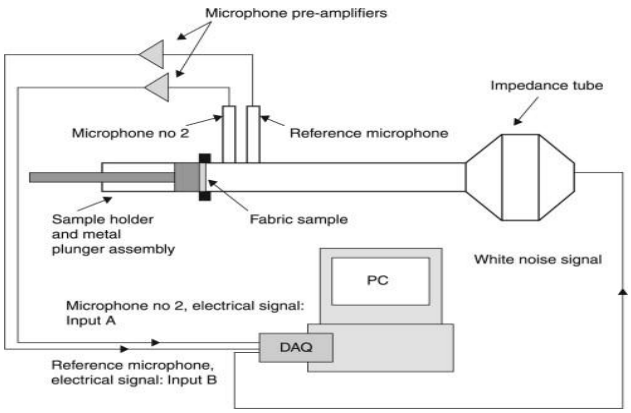


Fig. 2.2 Impedance tube apparatus

The impedance tube measurement obtains the normal incidence absorption coefficient of a layer of material. The result can be used to compare the basic absorption performance of a material and for acoustics simulations.

The complete set of Holmark Impedance tube system includes: hollow tubes, micro phones, sample holders, DAQ unit and measurement software as per International standards. The tube is designed using anodized aluminium to measure sound absorption coefficient and transmission loss as per test standards described in following ISO 10534-2, ASTM 1050 & ASTM E2611 at normal incident, that is 0^0. The measurement is based on transfer function method which separates the incident and reflected energy from the measured transfer function, and then estimates the acoustic properties of the test sample. The properties measured with this test method are useful in basic research and product development of sound absorptive materials.

Tube	Large	Small
Frequency range	100Hz – 1600Hz	500Hz – 6300Hz
Inner diameter	100mm	29mm
Scanning frequencies	1/3 octaves	

Standard	ISO10534-2,ASTME1050,ASTME2611	
Value to be measured	Sound Absorption Coefficient (α) and transmission loss (TL)	
Sample holder inner diameter	100mm	29mm
Sample holder max length	200mm	200mm
Loud speaker	3.5 inch diameter, 30 watts, 4 ohm	
Micro phone	0.25 inch in diameter, -3Db at 1.5V sensitivity, 20-16,000Hz frequency response	
Measurement soft ware	Holmarc Wave Analyzer 4C	

Measurement is based on transfer – function method according to ISO10534-2 and ASTME1050 International standards for absorption coefficient. The apparatus consists of two kinds of tubes to measure full range of frequencies. Sound absorption is measured in 1/3 octave frequencies. The software Holmark wave Analyzer 4C analyzes the data and produces the test report ready to print.

2.2.2 Testing

Preparation of test samples

Coir panel is carefully and accurately cut into a cylinder of thickness 40mm. two samples were cut; one with a diameter of 100mm and the other with a diameter of 29mm. It should be ensured that the coir is cut very precisely so that it fits perfectly in the tubes of the Impedance tube. If the diameter is a few millimeters more, it will not be able to enter and if the diameter is lesser than the diameter of the tube, sound can pass through the vacant spaces and interfere with the test result. Therefore, proper care must be taken to ensure that the specimen is a perfect fit with the tube.

Fig. 2.3 Preparation of test samples

Coir test specimens of dia 100mm and 29mm.

2.2.3 Testing procedure

1. Start the application "Wave Analyzer 4C" the main window will open.
2. Connect the device via USB port.
3. Confirm that the signal to noise calibration has been completed prior to proceeding with sample measurements.
4. Click on create.
5. Choose absorption measurement from the measurement method drop down menu.
6. Tube selection: In the tube choose drop down menu, select the type of tube to be used for testing. The distance between two microphones, the distance from the sample to the nearest microphones, the diameter and effective frequency range are automatically set for each tube.
7. Thickness of the sample should be filled with the actual value.
8. Environment: The default value of atmospheric pressure, temperature and humidity is 101325PA, 27^0C AND 50% respectively.
9. For 100mm tube, take the tubes for testing, connect speaker wires, place the two microphones in the respective holes.
10. Place the specimen under test inside the sample holder. Ensure that there is no space between the specimen and the backing plate. The back plate of the holder should be adjusted so it is in contact with the rear surface of the specimen. The specimen shall fit snugly in the holder though it should not be compressed excessively nor fitted so tightly that it bulges. It is recommended to fill in the interspaces by using petroleum jelly. The test samples can be held firmly, if necessary, by means of adhesive tape or grease. Since the layers of coir fibres were beginning to separate due to the specimen size, the 100mm specimen was held together by means of a fine yarn. The 29mm specimen was held together by means of adhesive tape.
11. Join both the tubes tightly using holding clips.
12. Press start measurement to begin the measurement. After the measurement is complete, the window shows the sound absorption curve, which shows the sound absorption percentage at different levels of frequencies.
13. For each tube, the absorption results will only be calculated for the effective frequency range. To get results across a wider frequency spectrum, other tubes with different inner diameter is used. The test is repeated for the 29mm tube using the 29mm diameter specimen.

14. For 29mm tube, join 29mm tube and large tube with sound source lightly.
15. Place the two microphones to respective holes.
16. Place specimen under test inside the sample holder.
17. Join sample holder tube lightly using the holding clips and supporting stands.
18. Press start measurement, and upon completion the window shows the sound absorption curve and noise reduction coefficient.

Fig. 2.4 Testing procedure

2.2.4 Analyzing the data

Two different measurements using both the tubes are required to get full spectrum results. This requires making and saving the original curve of the sound absorption coefficient measurements using 100mm large tube and 29mm tube.

a) Click view – Data combination.
b) Select data type absorption coefficients.
c) Click load to chose the results needed to combine different measurements. Load the saved sound absorption coefficient results of each tube.
d) Click combine to combine the selected curves. The window shows the sound absorption curve of both the tests combined.
e) Clicking on export, the final report to print is generated. [5]

2.2.5 Test report analysis

Coir sheet of 40mm thickness and 100kg/m^3 density was used for this test. The sound absorption of coir was tested in a cycle of frequency ranging from 100Hz to 6300Hz. The sound absorption curve in the test report shows the graph between absorption coefficient percentages and frequencies. While observing the curve, it is evident that coir absorbs considerably a smaller percentage of sound. Sound absorption varies from 1 to 23% frequencies, ranging from 100 to 500. As the frequency is increased, we see a rise in sound absorption percentage. Sound

absorption goes up to the range of 55, 63, 75, 78 and 100% as frequency is increased up to 6300Hz.

The noise reduction coefficient(NRC) of coir is calculated as the arithmetic average of absorption coefficients at the octave band centre frequencies of 250, 500, 1000 and 2000Hz and was found to be 0.27.

The NRC of conventional sound absorption materials range from 0.5 to 0.8, which means panels using coir absorbs more than half of conventional materials, which have higher densities and which are backed by supplementary backing materials like porous absorbers. Therefore, coir possesses good sound absorption properties, considering that there is no backing material incorporated.

3. Conclusion

Coir is easily available, biodegradable, non hazardous to nature and human, and contains non toxic elements as opposed to synthetic sound absorption materials. Since coir is highly customizable, it is possible to build panels to absorb either higher or lower frequencies. Treatments can be applied to make the panels resistant to fire and mildew attack. To improve sound absorption of coir, and match with the levels of synthetic absorbers, additional elements such as cotton fibre, jute saw dust etc. can be incorporated as backing materials. Using coir for sound absorption can bring new opportunities to boost the economy of the state and the country as a whole. Coir has excellent properties which deserves to be utilized not only for mere door mats and ropes, but also by innovation and application in technical textiles.

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