# Investigation of sound absorption coefficient of materials using tube impedance method

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## ABSTRACT

The scope of this investigation was to investigate the sound absorption coefficient in impedance tube standing wave ratio method [1]. The study was twofold: one was to construct a setup to measure the sound absorption coefficient while the other was to test the possibility of finding the some natural sound absorbing materials. Using standard materials of glass wool and K-flex samples the accuracy of the constructed experimental setup was examined. The experimental values of sound absorption coefficient of two standard materials agreed well with the values provided in the datasheets under ASTM C-423 standards [2] demonstrating the capability of the experimental setup to use for the measurements. Two natural fiber samples used for this study were coir fiber and rice bran that are heavily wasted, and freely available as a natural materials in Sri Lanka. Absorption coefficients were measured using the experimental setup for those samples. The sound absorption coefficient variations on frequency and on the density were also examined for both natural samples. Both natural samples of coir fiber and rice bran show more than 80% of incident sound absorption at the lowest densities and the higher frequencies beyond 1500 Hz.

## 1. INTRODUCTION

Rapid growth of science and technology was observed in the recent past and many inventions were created intended for comfort of life. However, this rapid growth has several negative consequences. Environmental issues and human health are some of the examples of ever worsening conditions due to the rapid development of science and technology. Environmental issues are in terms of air pollution, water pollution and noise pollution.

Noise pollution currently has a serious influence on living conditions. Noise pollution occurs from a variety of sources. It may be due to manufacturing machines, vehicles, and, from daily activities.

Human comfort requires an environment with low decibel levels free of unwanted noises. In Sri Lanka, most of these problems occur in urban areas. If one is exposed continuously to high levels of noises during the day, he may experience latent effects as a result of this discomfort namely, hearing loss, nerve weakness, internal tissues pain, heart problems, and even high blood pressure [3]. Therefore sound absorption as a mitigation method for high noise levels becomes one of the major requirements. Hence, the understanding of noise elimination becomes an important field of study.

At present, scientists pay attention to develop more efficient ways of producing sound absorption materials, such as glass wool, foam, mineral fibers and various composites. Past studies show that glass wool is one of the most efficient absorber material for sound absorption. However use of glass wool has its health hazard. Researchers have now focused on finding eco-friendly composites with higher sound absorption coefficients, which also have applicability in a wide range of frequencies. Therefore researchers attempt to find absorbing materials having similar qualities as glass wool, being thin, low-weight, and low-cost material. Studies on the sound absorption properties of natural materials has become very important. The present study has addressed the natural samples that are freely available in Sri Lanka to be used as sound absorbing material.

## 2. EXPERIMENTAL

Two techniques commonly used to measure the sound absorption coefficient in impedance tube methods is impedance tube standing wave ratio method [1] and impedance tube transfer function method [4]. Impedance tube method was used for this investigations.

In the current study, the main purpose was to build an experimental setup to measure the sound absorption coefficient of materials. For these studies, two experimental setups had to be constructed separately having different lengths and diameters as the frequency range is depending on the dimension of the tube. Low frequency range was considered as 500 Hz – 1,000 Hz to observe the low frequency behavior whereas high frequency range was used as 1000 Hz – 4,000 Hz to detect the high frequency behavior.

Following Eq. 1 and Eq. 2 give semi-empirical formulae to determine the length (*l*) and diameter (*d*) of the tube for minimum frequency ($f_{min}$) and maximum frequency ($f_{max}$), where c is the propagation wave speed [2].

$$f_{min} = \frac{0.75c}{l-d} \qquad \text{................(1)}$$

$$f_{max} = \frac{0..586c}{d} \qquad \text{................(2)}$$

TRUE RTA software [5] was used to record each minimum value and maximum value in decibels (dB) of the pressure wave propagated inside the tube. Therefore standard ASTM C 384-04 method was used in the computerized software.

The recorded values of the pressure wave in dB were used to calculate the maximum and minimum root mean square values of the pressure $P_{rms}$ using Eq. 3.

$$\text{Level dB} = 20 \log P_{rms} \qquad \text{................(3)}$$

The standing wave ratio (SWR) and the values of absorption coefficient α were calculated using Eq. 4 and Eq. 5.

$$\text{SWR} = \frac{P_{rms,min}}{P_{rms,max}} \qquad \text{................(4)}$$

$$\alpha = 1 - \left(\frac{\text{SWR}-1}{\text{SWR}+1}\right)^2 \qquad \text{................(5)}$$

## 2.1 High Frequency Setup and Low Frequency Setup

Fig. 1 shows the cross sectional view of the experimental setup for both high frequency setup and low frequency setup. Tube dimensions were calculated according to the Eq. 1 and Eq. 2 and the tubes were chosen accordingly.

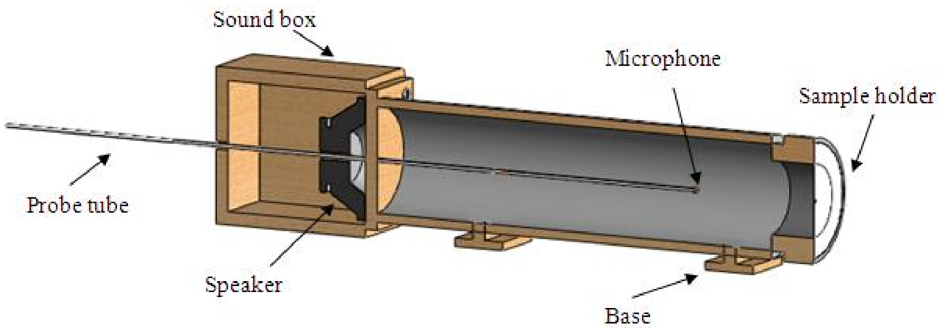


Fig. 1: Cross sectional view of the experimental setup

The short tube for high frequency setup was having a length of 100 cm, an inner and an outer diameter of 6.3 cm and 6.8 cm respectively. From this tube frequency range of 1,000 Hz – 4,000 Hz could be examined. Sound box was made which have 15×15×15 $cm^3$ dimensions with a speaker of 8 Ω resistance and power of 5W. Speaker sensitivity was 90 dB and frequency response of 200 Hz -12,000 Hz.

The long tube for low frequency arrangement was selected in such a way that the inner diameter was 20.3 cm and outer diameter was 21.1 cm having a length of 120 cm. From this tube 500 Hz – 1,000 Hz frequency range could be studied. Dimensions of sound box for this setup is 25×25×25 $cm^3$ having the same speaker used for the high frequency setup. Same piezo electric microphone was used for both setups.

To measure the absorption coefficient, a sample of absorbing material was placed in the sample holder and it was connected tightly to the tube of standing wave apparatus as shown in the Fig. 1. The microphone jack was connected to the frequency analyzer and then powered up. The signal generator was connected to the loudspeaker through an amplifier. The function generator was turned on after it was set to produce a 500 Hz sine wave. Then the [Go] key on the frequency analyzer was clicked to start the measurements. Microphone was moved to the vicinity of the loudspeaker as much as possible and then was moved away from the sample until the frequency analyzer indicated first maximum level and first minimum level. Then corresponding minimum and maximum levels (in dB) were recorded for a corresponding frequency. These measurements were repeated for low frequencies of 500 Hz – 1,000 Hz using low frequency setup with the long tube and for high frequencies of 1,000 Hz – 4,000 Hz using the high frequency setup with the short tube by increasing the frequency by 100 Hz steps.

## 2.2 Analysis of Sound Absorbers

Initial measurements were taken for the standard materials of glass wool and K-flex in order to examine the accuracy of the high frequency setup and low frequency setup. Then the measurements were taken for natural materials of coir fiber and rice bran using high frequency setup to study the sound absorption behaviors of natural materials. Both natural samples were sifted before they were placed in the sample holders. As physical parameters also play a major role for sound absorption, the density variation on sound absorption was studied. Measurements for this purposes were repeated by reducing the known thickness of each natural sample while keeping the mass of the sample constant.

Each measurement of this study was taken as the average value of three repeated measurements at 26.5 $^{o}$C room temperature.

# 3. RESULTS AND DISCUSSION

To verify the accuracy of the setup, data obtained from measurements were processed and graphs for sound absorption coefficient variation were plotted as a function of frequency. Fig. 2 and Fig. 3 show the results for the standards materials of glass wool and K-flex in the frequency range from 500 Hz – 4,000 Hz using both high frequency setup and low frequency setup.

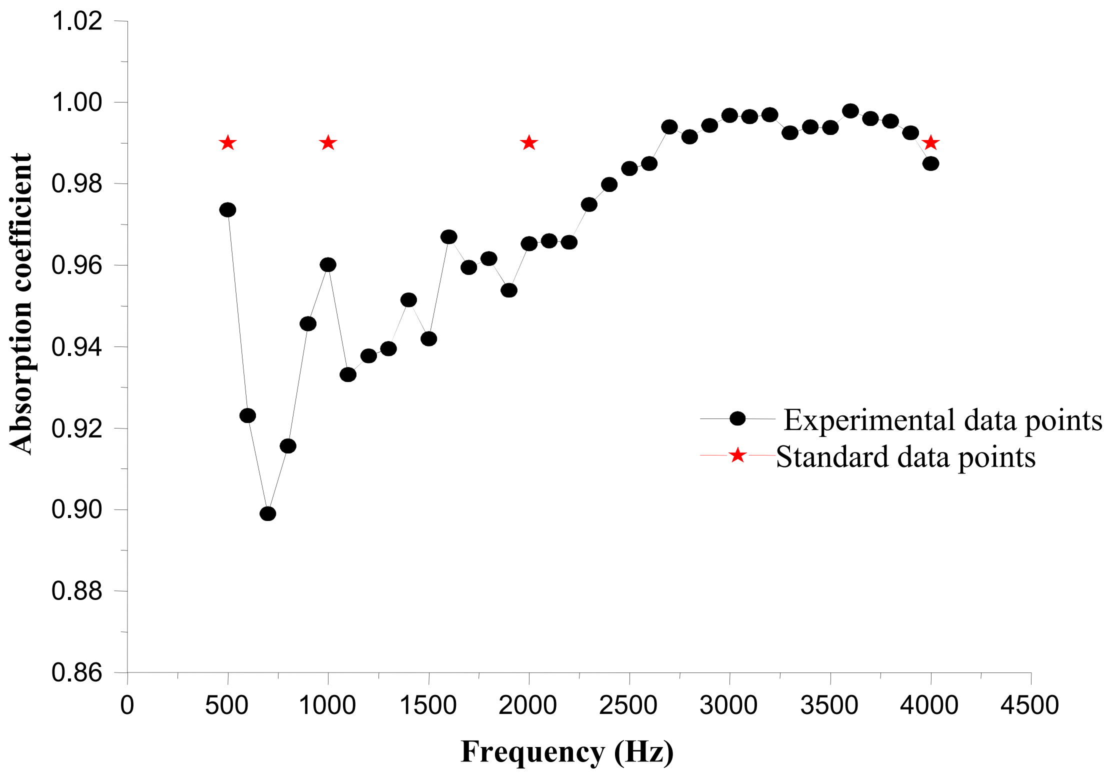


Fig. 2: Absorption coefficient variation at different frequencies for the glass wool sample

Data points labeled • mark indicate the experimentally observed values whereas * mark labeled data points are the standards points obtained from the data sheets under ASTM C-423 standards for the experimental frequency range.

Only four standards data points could be found for the study frequency range for both glass wool and K-flex. When comparing standards values obtained from the standard data sheets for the frequency range studied, both glass wool and K-flex sample, the sound absorption coefficient variations are different. The sound absorption coefficient of the glass wool sample is frequency independent while it is highly dependent on frequency for K-flex sample. The experimental values (indicated as • marks) also show the similar variations for both samples even the frequency is increased by 100 Hz steps.

The observed experimental variation of sound absorption coefficient for the glass wool sample shown in Fig. 2 is about 0.9 for the whole frequency range. It reveals that the difference is always less than 0.05 between standard values and experiment values when frequency is less than 2,500 Hz and it becomes negligible for higher frequencies. This can happen due to changing the surface distribution of the sample surface when mounting the glass wool sample in the sample holder. In addition the same reason causes vibrations of the sample especially in low frequencies.

Fig. 3 shows the variation of sound absorption coefficient for K-flex sample. The experimental data points almost coincide with the standard data points and hence the difference is insignificant.

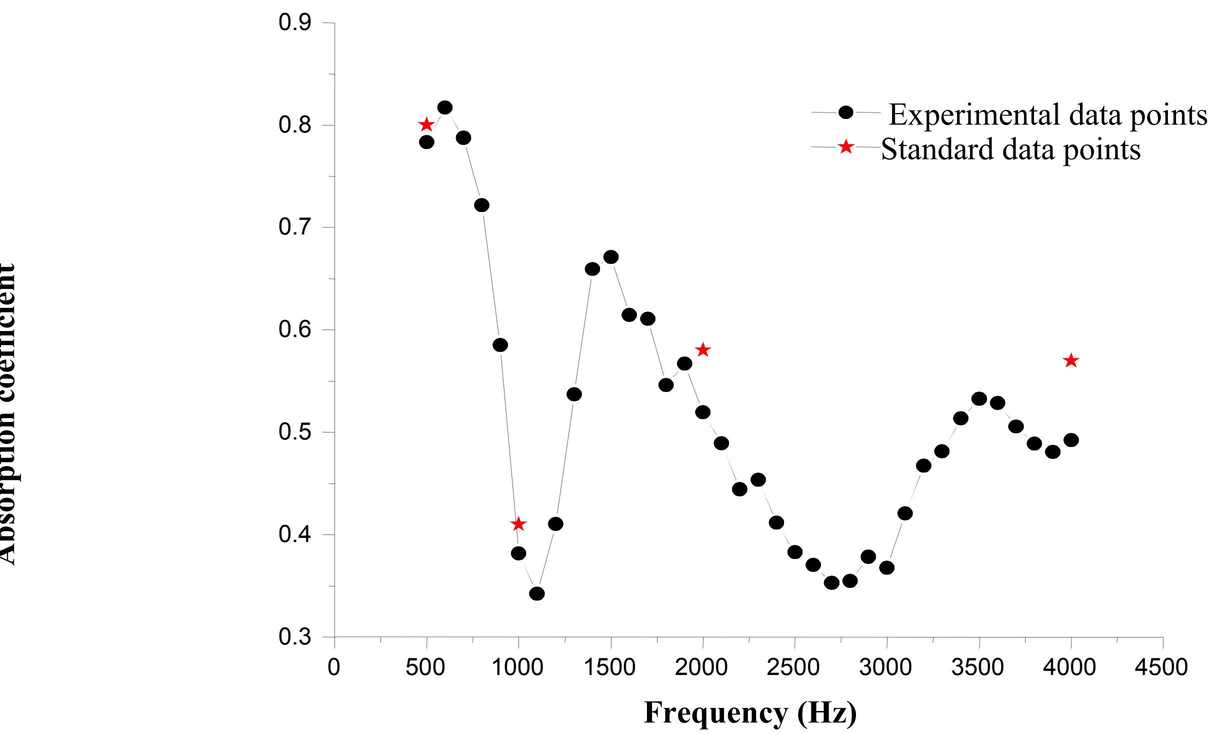


Fig. 3: Absorption coefficient variation at different frequencies for the K-flex sample

When comparing standard data points with experimental data points the accuracy of the experimental setup could be identified. The experimental variation is also almost constant for the glass wool sample whereas a significant variation is seen depending on the frequency for the K-flex sample. Physical nature of the both samples is quite different. When the sample was loaded to the sample holder the surface nature of the samples could play a major role for this difference depending on the physical nature.

Both the operation of experimental setup and the method was successfully validated according to the observed data for both standard samples.

Most of the materials uses in sound absorbers are toxic and they are health hazards. Hence attention was paid for the natural samples to observe the absorption performance in order to check the possibility of naturally and freely available materials in Sri Lanka. Coir fiber and rice bran were chosen for this study as they are wasted by-products and can be found easily and inexpensively found in large quantities. As physical parameters also play a major role on sound absorption, density variation was included for this study. The measurements of these samples were obtained using only high frequency setup of 1,000 Hz – 3,500 Hz. By varying the density of the sample, the absorption coefficients were obtained in different frequencies as mentioned in section 3.1. Fig. 4 and Fig. 5 show the variations of sound absorption coefficients for coir fiber and the rice bran samples obtained from high frequency tube of 1,000 Hz – 4,000 Hz and also indicate how the density affects sound absorption.

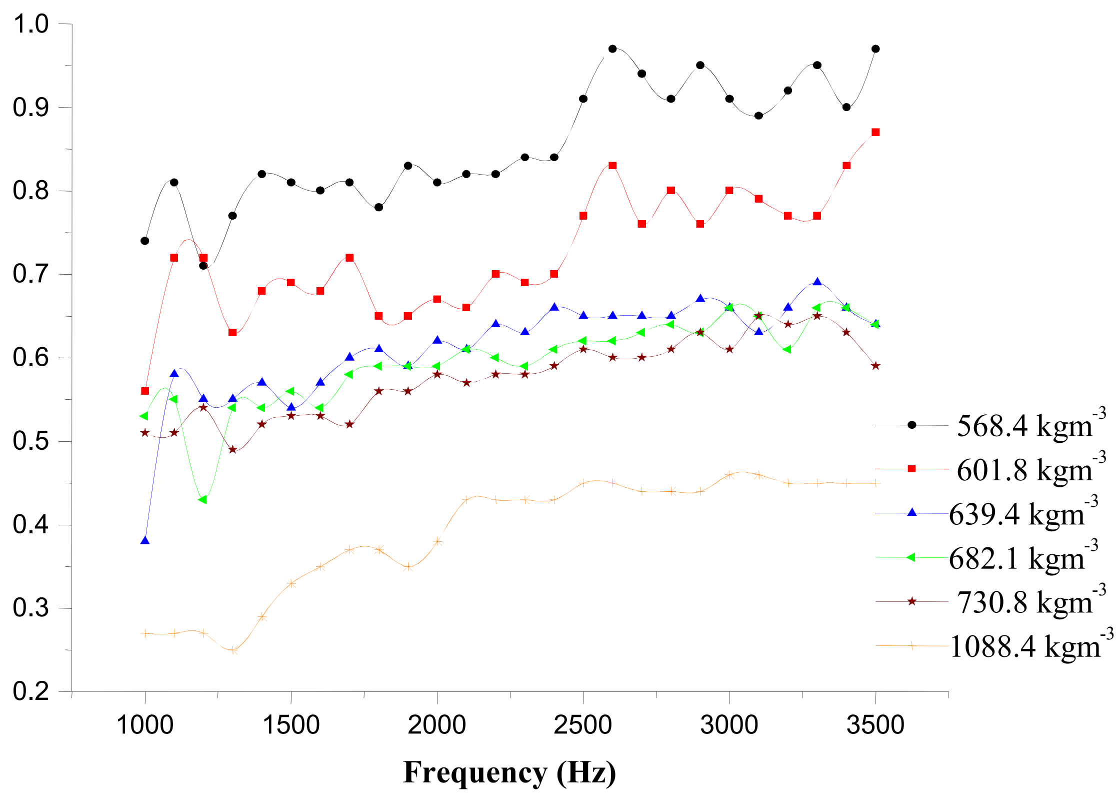

Fig. 4: Both frequency and density variation of absorption coefficient for coir fiber sample

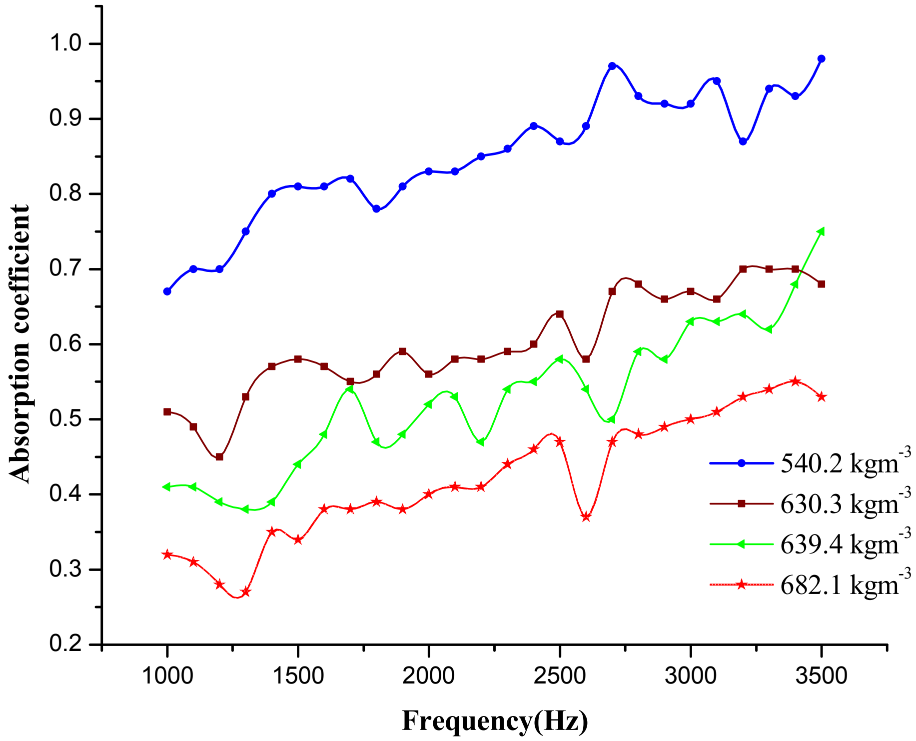


Fig. 5: Both frequency and density variation of absorption coefficient for rice bran sample

Both Fig. 4 and Fig. 5 show the variations of the sound absorption coefficient increase while increasing the frequency for all densities. However, it also illustrate that the sound absorption coefficient decreases while increasing the density.

If a sample is made of low density, it has a lower flow resistivity because there contain more hollow spaces when putting fibers together. Increasing density causes to shrink inter-connected cavities in the medium causing the reduced flow resistivity. Reduction in flow resistivity decreases the absorption coefficient of the sample. As expected overall results show that there is decrement of absorption coefficient in the frequency range 1,000 Hz – 3,500 Hz.

More than 80% of incident sound is absorbed by both natural samples of coir fiber and rice bran at the lowest densities over the higher frequencies beyond 1500 Hz. When compared with glass wool sample it is roughly 95% of sound absorption achieved. Comparing those results it reveals that the natural sample examined in this study can be used as substituted materials as good sound absorbers in low density range and at high frequency range.

## 4. CONCLUSION

The experimental setup for both high frequency setup and low frequency setup were constructed to measure the absorption coefficient using impedance tube method. ASTM standard C 384-04 method has been incorporated in the computerized software. Using two standard materials of K-flex and glass wool the whole procedure of this setup was validated.

The same study was used to understand the acoustic behavior of natural materials of coir fiber and rice bran samples as a sound absorber at low density range. Even though artificial materials such as glass wool have best absorption coefficient they are hazardous and a risk to use. As good performance can be achieved from natural samples they can be used to replace the hazardous synthetic materials in the future.

## REFERENCES

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