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Alternative Soundproof Material to Reduce Noise HVAC Round Duct System (Rockwool and Bamboo Fiber)

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Abstract: Rockwool is one of the materials that usually used as exterior sound insulation on air duct for HVAC in order to overcome break-out noise problem. However, this material is catogorized as non-biodegradable material and contribute to global warming. The purpose of this study was to investigate the acoustical properties of rockwool and Betung bamboo (*Dendrocalamus* Asper) fiber as new material for sound insulation. The acoustic parameters were measured are the sound absorption coefficient (SAC) and sound transmission loss (STL). The bamboo fiber of two different thickness (25 mm and 50 mm) with density of 60 kg/m^3 and 120 kg/m^3 respectively, while the rockwool also two different thickness (25 mm and 50 mm) with same density of 40 kg/m^3 were tested in this study. The SAC value was determined using impedance tube at low and high frequencies guided by EN ISO 10534-2:2001, while the STL was measured in a reverberation room by following EN ISO 140-3:1995. The results showed that bamboo fiber samples absorbed more sound energy compared to rockwool samples at both low and high frequency region. Maximum SAC value obtained by 50 mm thick and 120 kg/m^3 density of bamboo fiber sample at low frequency is 0.99 at 1250 Hz and 1350 Hz, while at high frequency, the maximum absorption was also obtained by 50 mm thick bamboo fiber sample with SAC value of 0.99 at 4000 Hz. The results also showed that bamboo fiber samples having higher STL value than rockwool samples. Maximum STC value of bamboo fiber is 72 dB at 4000 Hz. This results indicated that thicker and denser samples absorbed and eliminated more sound energy compared to thinner and less dense samples. In conclusion, bamboo fiber is highly potential to be used as raw material for sound absorption material replacing synthetic materials since these fiber are renewable, cheaper and give less negative effect to human health.

Keywords: Rockwool, Bamboo Fiber, Sound Absorption Coefficient, Sound Transmission Loss

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1. Introduction

Heating, ventilation, and air conditioning (HVAC) is one of the conventional methods used to comfort occupants in various types of buildings, such as residential, industrial, and institutional buildings. The mission of HVAC depends on outdoor conditions where the air conditions need to be heated or cooled before distributing into the occupied space [1]. Unfortunately, the involvement of HVAC system in a building is one of the significant problems of noise, and its effect on the interior acoustical environment is essential. Furthermore, this system also gives vibration onto the building when it is on the operation, which creates secondary noise that can make uncomfortable conditions such as vibrating walls, floor, and duct [2]. According to [3], air ducts are passages used in the HVAC system to deliver air into occupied space. The air duct is one of the noise problem sources known as breakout noise because of the air flowing through ducts induces vibration at the duct wall.

Most laboratories at University of Tun Hussein Onn Malaysia (UTHM) Pagoh are having noise problem which stems from breakout noise of air duct that propagates through the wall of the duct, thus impacting the adjacent space. This problem has become the most factor that causing students cannot hear clearly in studying session. The main target result of this study is overcoming the previous noise problem to achieve acceptable sound levels in the studying spaces of the building for the student and occupant comfortness by applying external sound insulation on the air duct. This study is focusing on finding the alternative soundproof material that should be able to replace previous sound proofing material usually rockwool or glass fiber that widely used in building industry. However, these synthetic fiber generate the highest non-renewable energy and global warming potential compared to natural material [4].

The types of material that tested during this research are rockwool and bio-based materials, which is bamboo fiber as a new material for sound insulation of air duct to make the it more noiseless. Bamboo fiber has lower environmental impact than the traditional synthetic materials. Bamboo fiber also excellent for sound absorbing and sound insulation performances [5]. Bamboo fibre has several advantages over other plant natural fibers such as high growth rate, strength, and fixing the carbon dioxide. Bamboo fiber also can be compared with glass fiber because of its characteristics which are lightweight, biodegradability, and low cost [6]. Other than that, bamboo fiber materials have acoustical properties equivalent to those glasswool which is a good sound absorber [7]. It could be used as a specimen for this research to dissipate and eliminate the noise.

This study aims to investigate performance of rockwool and bamboo fiber as soundproof material in two different thickness (25 mm and 50 mm) for optimize fiber performance as sound insulation material in HVAC system. At the end of the study, the most suitable soundproof material that has good acoustic properties in terms of sound absorption coefficient and sound transmission loss would be preferred.

2. Materials and Methods

2.1 Preparation of Bamboo Fiber Material

The bamboo species that used throughout this experiment is Betung bamboo or known as *Dendrocalamus Asper*. The raw bamboo is delivered from the bamboo grove in Betong, Hulu Terengganu, Terengganu which supplied by the local. The extraction process of bamboo fiber for this study is started with collecting Betung bamboo, then washed using water to remove dirt and unwanted particles. The bamboo then soaked into water with the mixture of Sodium Hydroxide (NaOH) to dissolve the bamboo until turned into formation of fiber. After that, peel the fiber by using hand and rinse with clean water. The clean fiber being dried for 24 hours to remove its moisture. After being dried, the bamboo fiber being hot-presss with 180 °C under 1000 psi for 5 minutes into two different thicknesses (25 mm and 50 mm). Both samples were weighed for density measurement and cut into two different diameters (28 mm and 100 mm) for high and low frequency. Figure 1 summarized the preparation process of bamboo fiber that will be carried out for this study. The bamboo fiber with fine fiber diameter, thickness of 25 mm, and 50 mm with density of 60 kg/m^3 and 120 kg/m^3 respectively, tested as specimen for sound absorption. The fine diameter bamboo fiber that had been extracted is shown in Figure 2.

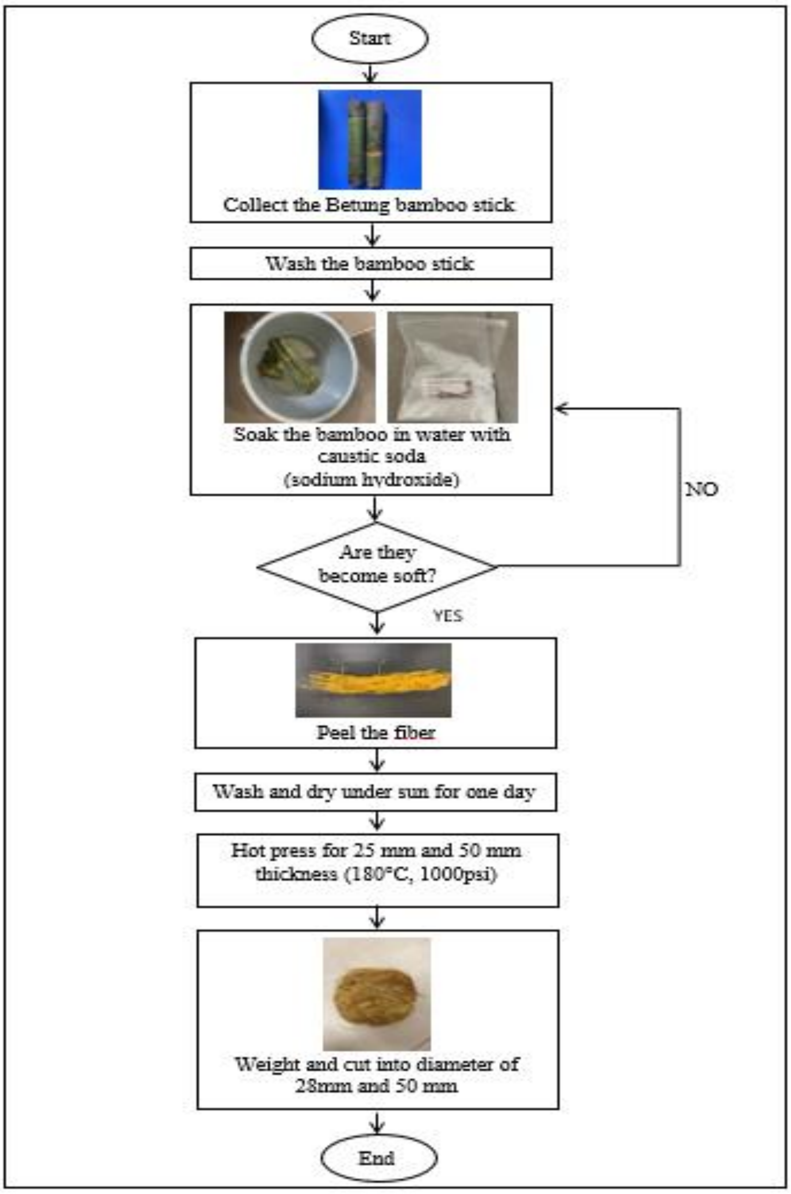

Figure 1: Extraction process of bamboo fiber

Figure 2: The fine bamboo fiber

The physical properties of bamboo fiber samples for this study is described in Table 1.

Table 1: The physical properties of bamboo fiber samples

Material of Fiber	Thickness (mm)	Density (kg/m^3)
Betung Bamboo	25	60
	50	120

1.1 Preparation of Rockwool Material

In this study, this fiber meterial will be used as the references to the bamboo fiber for the camparison between them as sound absorbing materials to be applied as sound insulation on exterior air duct. The rockwool with density of 40 kg/m^3 and thickness of 25 mm and 50 mm will be tested as soundproof material. Figure 3 shows the rockwool that tested for this study.

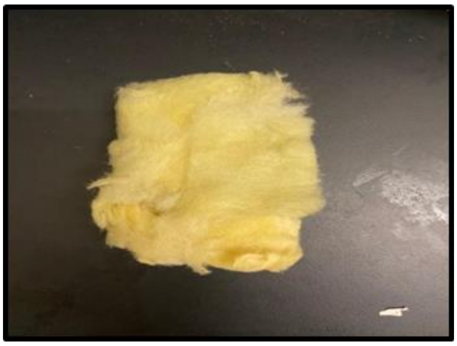

Figure 3: Rockwool

1.1. Sound Absorption Coefficient (SAC) Measurement Method

Impedance tube method according to EN ISO 10534-2:2001 as shown in Figure 4 was used as measurement method to determine sound absorption coefficient (α) of the specimens. All measurements for SAC were done at Building Service Technology Laboratory, Department of Civil Engineering Technology (JTKA), UTHM Pagoh.

The experimantal setup for this study consists of two round tube with diameter of 28 mm and 100 mm respectively, two microphone tubes type 4208 series and Atlas Sound Single Channel Power Amplifier type PA601 and an adjustable sample holder according to Bruel and Kjaer 227:1697. These microphones were placed at the front of the test specimen which are rock wool or bamboo fiber for the purposes of recording the reflective wave signal as well as the incident sound waves. The sound waves are converted into digital signal by using AED-1001 Acoustic Tube transfer function method software. The frequency range for the measurement of absorption coefficient is devided into two groups. The small tube with diameter of 28 mm will be tested for high frequency range from 2000 Hz up to 6000 Hz, while the large tube having diameter of 100 mm tested at low frequency range from 150 Hz to 1550 Hz. The determination of the results will be expressed in the graph formation which is frequency (Hz) versus sound absorption coefficient (α) at both (low and high) frequency region.

Figure 4: Impedence tube

1.2. Sound Transmission Loss (STL) Measurement Method

The sound transmission loss was measured using one-third octave –bands, according to EN ISO 140-3:1995. This measurement carried out in reverberation room at Noise and Vibration Laboratory, Faculty of Mechanical and Manufacturing Engineering (FKMP), UTHM Parit Raja.

Each panel was positioned as a wall in an opening between two rooms of the testing area. One room contained the noise generator as sound source room, while the other was the radiated room. Measurement of the sound pressure level within frequency range from 125 Hz to 4000 Hz in both the sound source partition and radiated room. The equipmet for this testing consisted noise generator, sound level meter, analyzer software, and loudspeaker. The determination of the results will be expressed in the graph formation which is frequency (Hz) versus sound transmission loss (dB).

3. Results and Discussion

3.1 Sound Absorption Coefficient (SAC)

Figure 5 below shows SAC value between rockwool and bamboo fiber with same thickness of 25 mm samples are almost same at low frequency region. Sound absorption performances of the both samples were found increases as the tested frequency increased. The bamboo fiber achieved its maximum SAC value at the higher frequency area which is 0.53 at 1550 Hz. Meanwhile, the maximum SAC value of rockwool shows 0.51 at 1550 Hz.

The results for 50 mm thickness of rockwool and bamboo fiber show different value of SAC at low frequency region as shown in Figure 6. Both specimens show excellent results in absorbing the sound compared to 25 mm thickness of samples. Bamboo fiber reached its highest value of SAC which is 0.99 at 1250 Hz and 1350 Hz. However, bamboo fiber sample were started to shows decrements of SAC value after reaching 1450 Hz which at 0.98 and 0.87 at frequency of 1550 Hz. The SAC value of rockwool is lower than bamboo fiber, but when reaching frequency of 1550 Hz, result shows the SAC value of rockwool little higher than bamboo fiber which is 0.98 while bamboo fiber is 0.97.

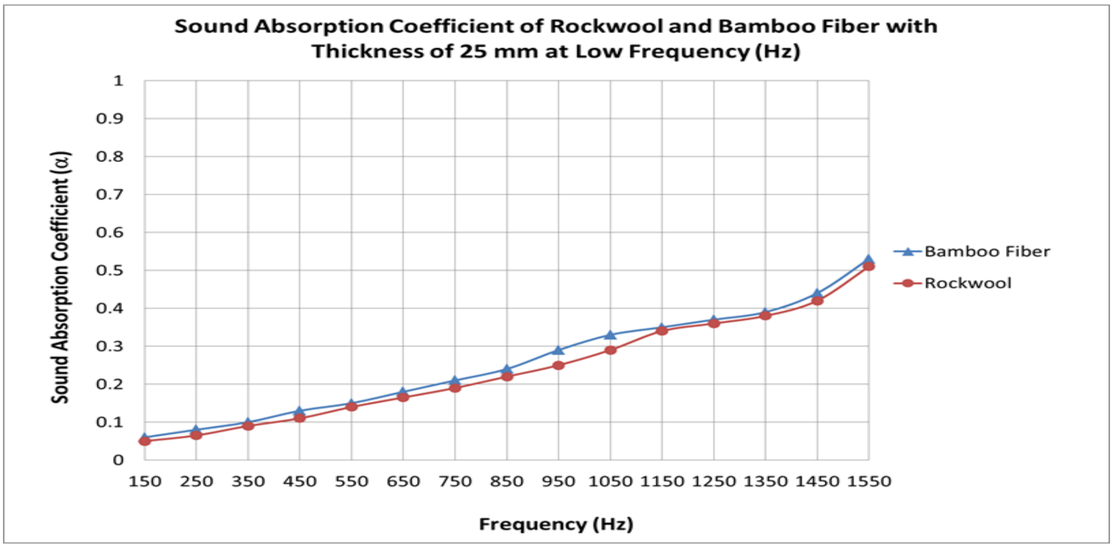

Figure 5: Sound absorption coefficient value of rockwool and bamboo with 25 mm thickness fiber at low frequency region

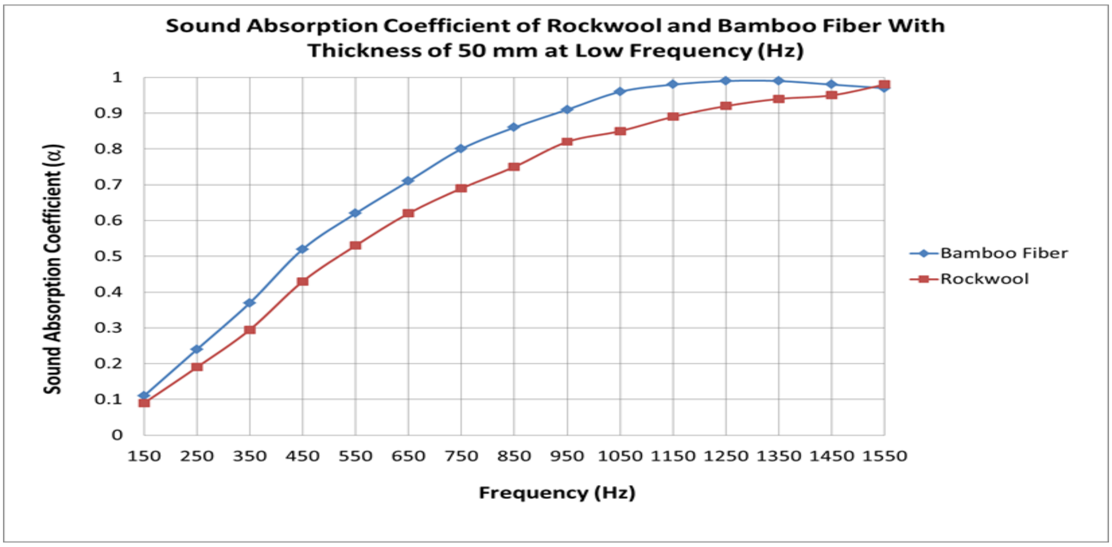

Figure 6: Sound absorption coefficient value of rockwool and bamboo with 50 mm thickness fiber at low frequency region

As been shown in Figure 7, SAC value showed by rockwool are much greater than bamboo fiber with same thickness at high frequency region. However, the results show the SAC value for both material are quiet close to each others. The highest absorption value of rockwool is 0.89 at frequency of 3000 Hz while bamboo fiber is 0.88 at same frequency. The value of SAC for both specimens were found started to increase after reaching 2000 Hz up to 3000 Hz, but then slowly decrease their SAC value at frequency range of 3000 Hz and 6000 Hz.

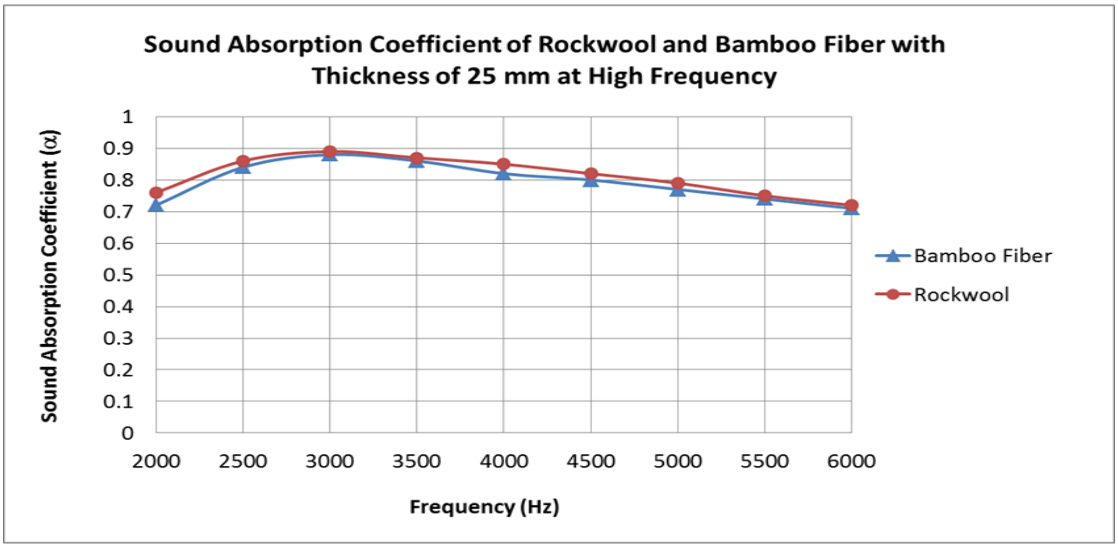

Figure 7: Sound absorption coefficient value of rockwool and bamboo with 25 mm thickness fiber at high frequency region

Figure 8 shows the comparison of SAC value with 50 mm thickness of rockwool and bamboo fiber. The absorption performance of bamboo fiber was found increases with the SAC value of 0.89 up to 0.99 at frequency range in between 2000 Hz and 4000 Hz but then dropped after reaching its maximum SAC value. While rockwool shows fluctuated value of SAC at frequency range between 2000 Hz and 4000 Hz but also shows decreament after surpassed 4000 Hz. However, the bamboo fiber has high sound absorption compared to rockwool after reaching 3650 Hz.

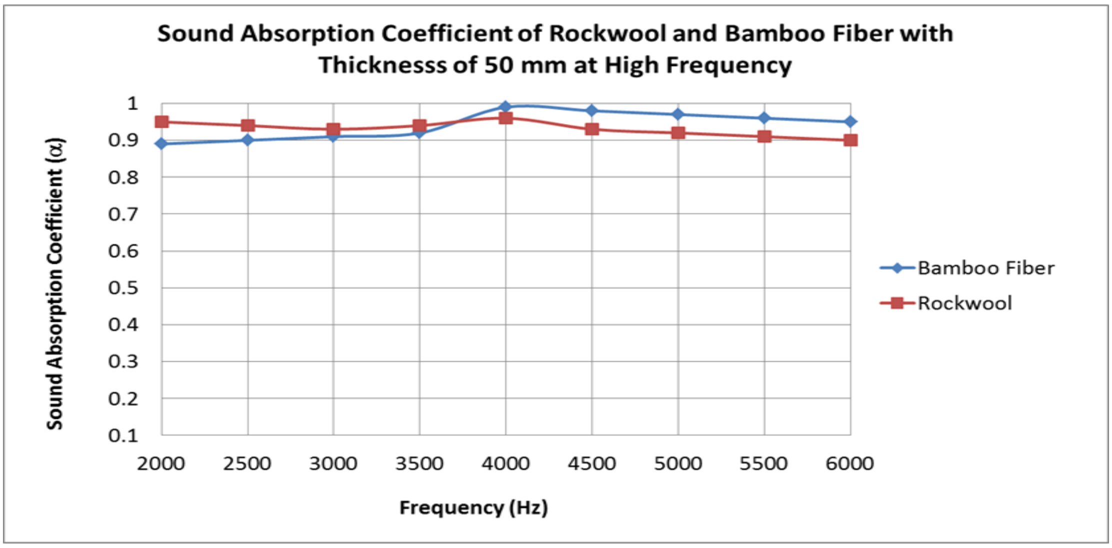

Figure 8: Sound absorption coefficient value of rockwool and bamboo fiber with 50 mm thickness at high frequency region

3.2 Comparison of Sound Absorption Coefficient Between Rockwool and Bamboo Fiber With Different Thickness

Both rockwool and bamboo fiber having 50 mm thickness had better performance in SAC value compared to 25 mm thickness throughout the tested frequencies. The maximum of SAC obtained by 50 mm bamboo fiber is 0.99 at frequencies of 1250 Hz, 1350 Hz, and 4000 Hz. The highest SAC value for rockwool with thickness of 50 mm is 0.98 at frequency of 1550 Hz. The collected data shows the bamboo fiber uniformity and increasingly high in sound absorption performance at all thickness compared to rockwool at low frequency region. The SAC performance of rockwool having 50 mm thickness is more higher than bamboo fiber with same thickness at frequency range 2000 Hz and 3650 Hz in high frequency region. However, after reaching 3650 Hz, bamboo fiber with same thickness has greater performance than rockwool. As conclusion, bamboo fiber has more prominent is absorping the sound compared to rockwool as the density of bamboo fiber samples that had been tested had more higher than density of rockwool sample. Comparison of sound absorption coefficient between rockwool and bamboo fiber having 25 mm and 50 mm thickness are shown in Figure 9 and 10 below.

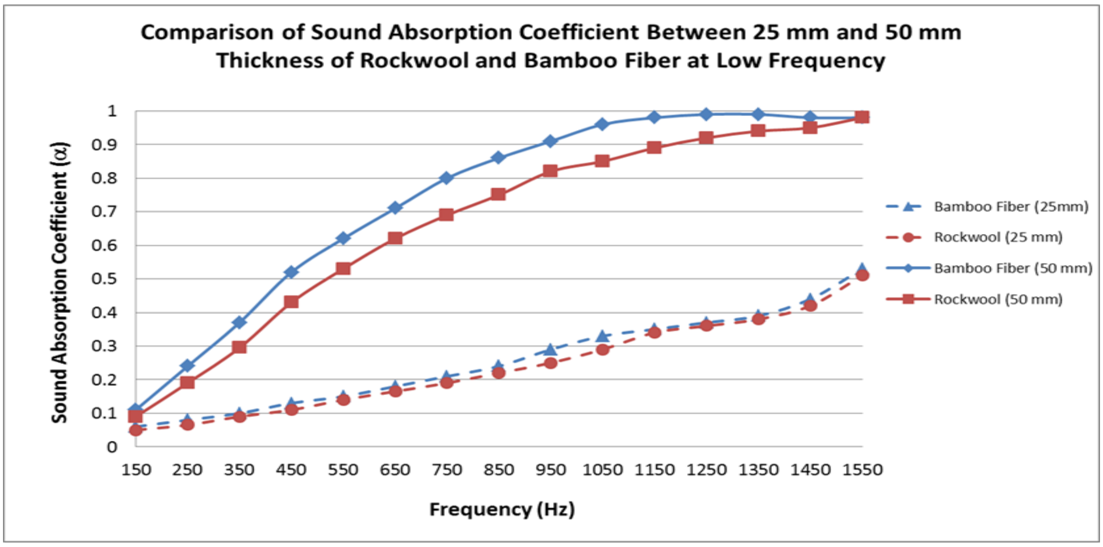

Figure 9: Sound absorption coefficient of 25 mm and 50 mm thick rockwool and bamboo fiber at low frequency region

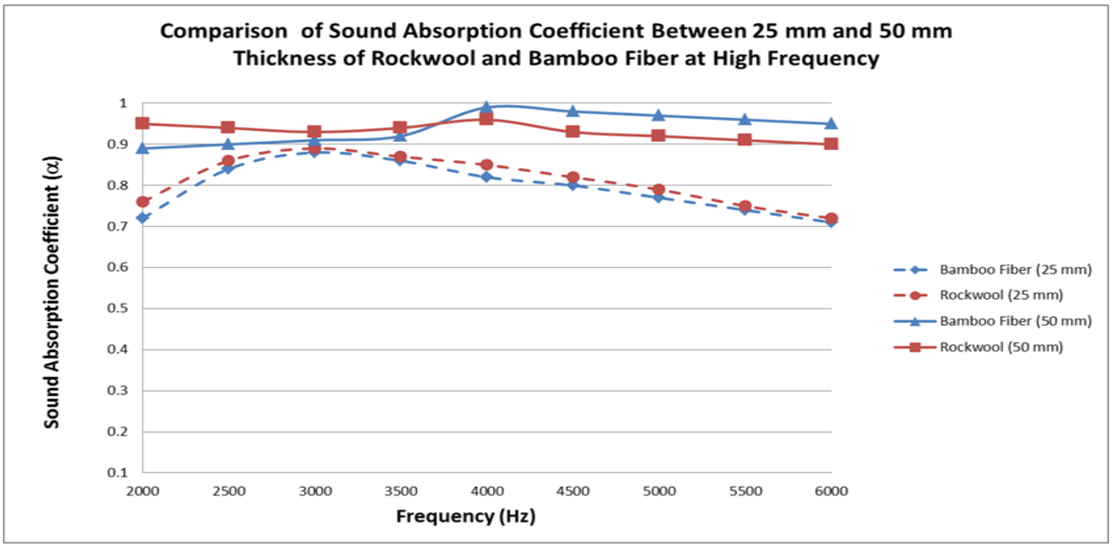

Figure 10: Sound absorption coefficient for 25 mm and 50 mm thick of rockwool and bamboo fiber at high frequency region

3.3 Sound Transmission Loss (STL)

Figure 11 shows the results of STL measurement for rockwool and bamboo fiber that having 25 mm thickness. The results showed both materials that having same thickness had almost same value of STL. Both materials showed somehow quiet constant value of STL within frequency range of 125 Hz and 1000 Hz. However, all the specimens were having increment in value of STL after reaching 1000 Hz and achieved their maximum value of STL at frequency of 4000 Hz. The bamboo fiber has greater STL value which is 36 dB than rockwool which is 35 dB at highest frequency. Meanwhile, both samples having same value of STL within frequency range of 1750 Hz and 3050 Hz.

The STL value for 50 mm thickness of rockwool and bamboo fiber is shown in Figure 12. Based on the data, both specimens having constant value of STL within frequency range started from 1250 Hz up to 1850 Hz. The experiment results indicated STL value of bamboo fiber is higher than rockwool. However, the STL value for materials are closed together at frequencies within 2000 Hz to 4000 Hz. The maximum STL value of bamboo fiber is 72 dB when reached at frequency of 4000 Hz while rockwool showed maximum STL is 70 dB at same frequency.

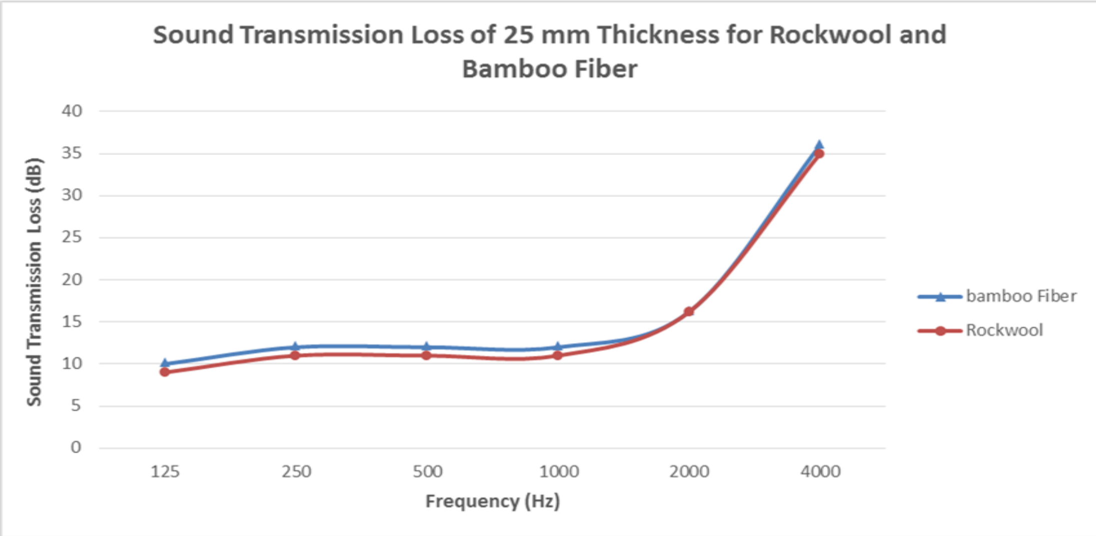

Figure 11: Sound transmission loss for 25 mm thick of rockwool and bamboo fiber

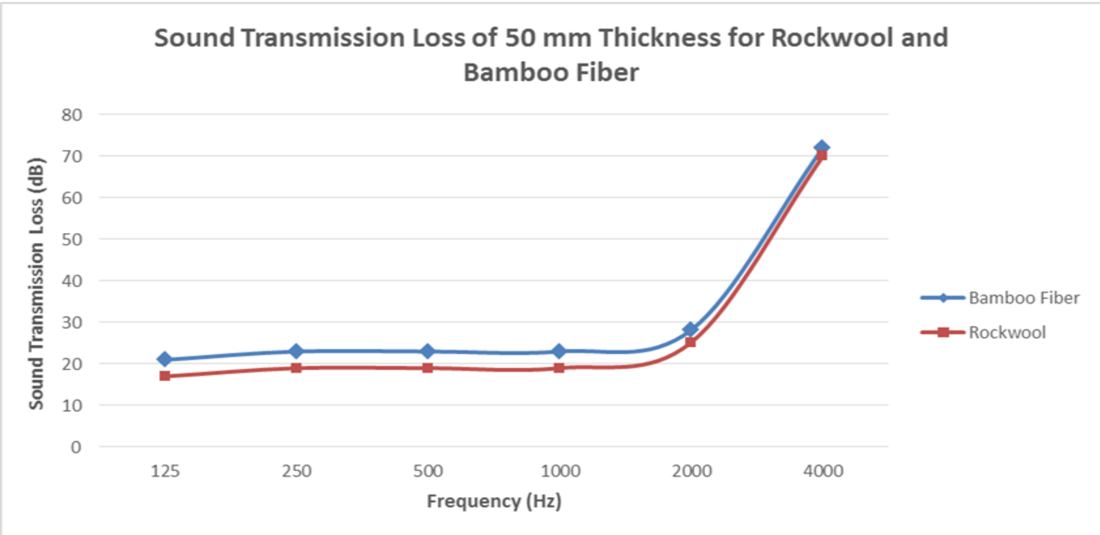

Figure 12: Sound transmission loss for 50 mm thick of rockwool and bamboo fiber

3.4 Comparison of Sound Transmission Loss Between Rockwool and Bamboo Fiber With Different Thickness

In this section, the STL comparison of rockwool and bamboo fiber with 25 mm and 20 mm thickness are shown in Figure 13. The 50 mm for both specimens is showed greater compared to 25 mm specimens in overall. Based on the experiment, the STL value of bamboo fiber more superior than rockwool. All the specimens achieved their highest STL at the frequency of 4000 Hz, where 50 mm thick of bamboo fiber scores the highest STL of 72 dB. However, in the thickness 50 mm and 25 mm, both materials only slightly different value of STL at frequency 4000 Hz. This experiment results showed that bamboo fiber possessed good potential as sound insulation as density of bamboo fiber sample is more higher than rockwool sample. This phenomenon can be explained by the mass law, where the sound transmission loss is directly proportional to the surface density of the materials [3].

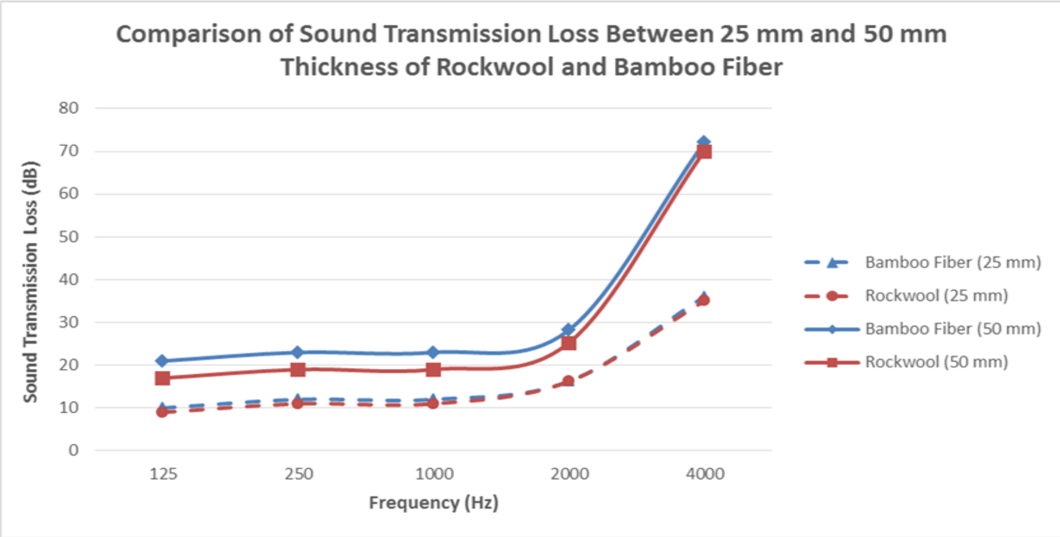

Figure 13: Sound transmission loss for 25 mm and 50 mm thick of rockwool and bamboo fiber

4. Conclusion and Recommendation

In this study, rockwool and fine bamboo fiber as sound absorbing material were developed. The performances of rockwool and bamboo fiber were investigated by measuring the sound absorption coefficient and sound transmission loss for both types of material. This study has proven that bamboo fiber is a good material in sound absorption coefficient and sound transmission loss at low and high frequency region compared to rockwool. The bamboo fiber having 50 mm thickness and density of 120 kg/m^3 showed highest sound absorption about 0.99 at frequencies of 1250 Hz, 1350 Hz, and 4000 Hz, while transmission loss is 72 dB at 4000 Hz. This shows that physical factors such as thickness and density of fiber affect the absorption and the transmission loss of sound. In conclusion, bamboo fiber have good acoustical properties equivalent to those of rockwool, which is good as sound absorber material. Based on positive performance shown by bamboo fiber in this study, it is worth to introduce this fiber as sound absorption material and potential to replace readily available synthetic fiber in the market for noise control application in HVAC system. However, further research is required to investigate the mechanical properties that comply with requirements as sound insulation material for HVAC system, such as thermal conductivity, tensile strength, and water absorption of bamboo fiber.

Acknowledgement

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