Recent Trends in Civil Engineering and Built Environment Vol. 2 No. 1 (2021) 815-823
© Universiti Tun Hussein Onn Malaysia Publisher's Office

RTCEBE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rtcebe
e-ISSN :2773-5184

A Review on Sound Absorption Properties Using Natural Fibers

Muhammad Alimshah Mahadzir[1], **Hasniza Abu Bakar**[1,*]

[1]Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussien Onn Malaysia, Batu Pahat, 86400, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/rtcebe.2021.02.01.090
Received 30 January 2021; Accepted 28 April 2021; Available online 30 June 2021

Abstract: A study on the sound absorbing material is currently giving a pleasing environment. Thus, the choice of material for sound absorbing material is the priority. Based on the point of view of environmental protection, a new acoustic material was created. There are fewer reports on natural fibers usage that focus on the material as sound absorbing material using the different method in determination of coefficient. This research is carried out to identify type of natural fibers as a panel of sound absorption and to determine the performance of natural fibers through physical and mechanical properties. The determination of natural fibers as a panel of sound absorption are from reviewing from the previous research. Based on the list of natural fibers, the performance of natural fibers are compared through physical and mechanical properties using an analysis graph from Microsoft Excel. For the conclusion, the physical and mechanical properties also affect the properties of natural fibers and all the panels can be consider as good absorptive materials. Overall results for physical and mechanical properties showed that all the natural fibers are promises to be as one of the major requirements for human comfort today for sound absorption quality. Based on the result, majority of natural fibers fulfill the specification for physical properties in testing for thickness, density and porosity while also achieved higher value for mechanical properties in testing of MOR and MOE. The use of these materials as a sound insulation product provides effective solutions for waste management problems.

Keywords: Natural fibers, Sound Absorption Properties

1. Introduction

Sound absorbing materials are widely used for noise reduction or suppression of echoes in enclosed environments for the last 40 to 50 years [1]. Therefore, the requirement to apply sound absorbing materials as a noise shield grew because of public awareness and the consciousness of noise pollution in daily activities. Sound absorptive materials in every confined space can inhibit the sound environment by reducing the sound energy of a sonic wave and thus lowering wave amplitudes [2].

Lately, glass-fiber or mineral fiber become the most successful product sound absorption materials in the industry [3]. However, these materials were suspected to have negative effects on

Corresponding author: hasniza@uthm.edu.my

human health such as breathing difficulties and eyes or skin irritation when in contact with humans [4,5]. Thus, the selection of the appropriate natural fibers is essential in order to enhance the effectiveness of sound absorption for daily activities.

1.1 Problem Statements

Seddeq [2] stated that nowadays, with the rapid urbanization and transportation development, human lives around the world often faced with severe noise pollution problems that led to serious health risks such as irritation, tinnitus, sleep disturbances and even ischemic heart disease. There are some activities created by the noise that mainly found around the city area such as noise by railways, traffic, railways, social activities and also from construction [2]. Based on the previous reviews, the noise are particularly from the domestic environment such as the places near any housing areas, public spaces, schools and universities [6]. Therefore, the noise problem became more complicated that also effect raising the demand for a better surrounding environment and improvement for multicultural lifestyle. Thus, in the importance to apply the effectiveness of sound absorptive materials that can absorb sound at a higher frequency.

Previous researchers had contributed a lot in the research for the application of natural fibers as sound absorptive materials. The research by Karlinasari et al., [7] carried out the research on betung bamboo by using different thickness, density and stiffness of material. The result of this research was concluded which the particleboards created from betung bamboo were considered as high quality materials for construction that possesses acoustical purposes for further development [7].

Other examples of natural fibers are coconut coir fiber. According to Koizumi et al., [3], coconut coir fiber is the main raw material that treated with latex to cover the coir fiber and protect the coir fiber sheet structures. It was utilized to push the material into a pre-adjusted depth. Three different sample measurements were made for each material thickness and the average measured were recorded in the research [3].

From previous study, Dewi and Elvaswer [8] stated that the banana blade is a part of banana trunk which have a different structure of trunk among the other type of plant because it come from fake trunk in which arranged in order from the tighted group of blades. Fibers founded in the banana blade are categorized as strong fiber that has cellular-network vein with pores that were connected. When the blade was dried up, it will become compacted which the blade would be considered as materials that has good sound absorbing properties [8].

Putra et al., [9], studied the Eucalyptus and Pinus species to form a sugarcane particleboard commercialized in Brazil and the sugarcane panels sold in China. Moisture levels and bulk density was proven by the product. A hole was drilled in the bottom of the modules to be able pass and position equipment and the best sound energy absorption performance in the frequency range 630 Hz to 1000 Hz was proved by the sugarcane bagasse panels [9].

Common agricultural fibers like wheat and rice straw can easily be turned into chips or particle, considered as wood particle or fiber-like particles which can replace raw materials based on wood as stated by Yang et al., [10]. Rice straw has been utilized due to the its availability of rice straw-wood composite board, which is the method currently used in the wood-based panel sector, that manufacture isolation board. The checking for possible partial or complete substitute of rice straw for wood particles on a particle board were investigated by the mean of acoustic property, physical and mechanical properties [10].

Ersoy and Küçük [11] conducted a test on tea leaf fibre (TLF) for its sound absorption properties as a natural materials. Tea leaf-fibre is a processed tea leaf waste product that is processed after leaves are dried and chopped. Tea leaf fiber is a hygienic material as well as product of renewable bio-resources that makes it biodegradable. From the results in the studies, the samples with a thickness of 10 mm proves that TLF was a better sound absorptive materials compared to polypropylene non-woven (PNF) and polyester [11].

According to Samsudin et al., [12], oil palm processed becoming solid waste include empty fruit bunches (EFB) that can be utilized as sound absorption material for noise control in building. In order to determine the optimum frequencies and the maximum sound absorption coefficient, the effect of the EFB (coir and dust) in different form were investigated with three different thicknesses (6 mm, 12 mm and 18 mm). The maximum sound absorption coefficient (SAC) value obtained by EFB samples 18 mm thick is 0.6 at 1500Hz and the SAC value at the high frequency of 3750Hz was 0.990 at maximum absorption was obtained [12].

Arenga pinnata is a natural fiber that can be used for acoustic sound absorption material. The study by L. Lindawati et al., [13] shows the sound absorption of arenga pinnata with a thickness of 10, 20, 30 and 40 mm respectively. This work examined the potential of using pinnata fiber from arenga as the raw material for acoustic absorption. The optimal sound absorption factor of 40 mm thickness was acquired [13].

As conclusion, some natural fibers can be consider to be one of the materials which could be the best panel of sound absorption to improve comfortability for users. Based on the different natural fiber's properties, by increasing the composition of the natural fibers cause increasing in sound absorption.

1.2 Objectives

The objectives of this study are to identify the type of natural fibers as a panel of sound absorption and to determine the best performance of natural fibers through physical and mechanical properties.

2. Materials and Methods

This research is carried out to determine the type of natural fiber and its physical and mechanical properties in producing fibers panel that capable to absorb sound. Furthermore, this research is carried out to make the comparison by referring to the result data of physical and mechanical testing to identify natural fiber material that potential in fiber-based panel production industry.

2.1 Data collection

Data collection was the most important factor in making a study that want to do it. Before beginning the process of data analysis, choosing the right and appropriate method was important to ensure that the data collected is sufficient, quality and relevant to the researched. From the literature review, the data were compared with physical and mechanical properties using an analysis graph from Microsoft Excel.

2.2 Literature Review

The sound coefficient of each natural fibers as a panel of sound absorption was achieved by literature review by previous researcher. The different researcher gave different results for each sound absorption coefficient based on different sizes used, density, moisture content, specific gravity and others. Table 2.1 shows the list of past research related to the type of natural fibers. From the table are shown the frequency of past researcher versus the type of materials. The workability as sound absorption for each natural fiber depends on the physical properties including thickness, specific gravity and composition. Thus, data obtained for sound absorption coefficient are different by each type of natural fiber which is important to decide the best performance among the natural fiber.

Table 2.1*: List of natural fiber which had been investigated by previous researchers*

Fiber \ Reference	Koizumi et al [2]	N. Ismail et al [18]	L. Lindawati et al.,[13]	A. Dewi, Elvaswer [8]	N. Zainab, et al., 2013	Yang, et al., [10]	S. Ersoy and H. Küçük, [11]	E. Samsudin, et al., [12]	Zulkifli, et al., [4]	Carvalho, et al., 2015	A. Putra, et al., [9]	Kornellius Endi Marwanto, 2019	Bahari, A. Krause, 2015	Frequency
Bamboo	√											√	√	3
Coconut Coir								√	√					2
Banana Blade				√										1
Sago Waste					√									1
Sugarcane Waste										√	√			2
Rice Straw-Wood						√								1
Tea – Leaf – Fiber Waste							√							1
Empty Fruit Bunches (EFB)								√						1
Arenga Pinnata			√											1
Kenaf		√												1

3. Results and Discussion

The results and discussion section presents data and analysis of the data comparison according to its physical and mechanical properties. In this review, all data were analyzed using graph analysis from Microsoft Excel.

3.1 Graph Analysis

This research involved comparing data from past researchers and generate to graph analysis. This is to compare the data between the type of materials and plot according to its physical and mechanical properties that affect the ability as sound absorption material. The pattern from the graph was observed and the performances of natural were discussed based on data collected.

3.2 Comparison data for physical properties

The sound absorption materials were affected by the factor that influences the acoustic performance which include thickness, density, porosity, fiber size, tortuosity, airflow resistivity, compression, sound absorption placement, surface impedance, and sound absorption material performance [3]. However, this research only focuses on the physical properties of thickness, density and porosity.

3.2.1 Thickness

From Figure 1, bamboo fibers with 50mm thickness show a higher value of sound absorption coefficient at 0.9 with the frequency of 3200 Hz lower than frequency of other fibers. The sound absorption coefficient was explained by the principle of porous materials that attributed to thermoplastic damping and viscosity loss while the sound diffuses through the small cavities in the materials [5]. Tea-leaf-fiber (TLF) with 30 mm thickness shows an increase in the sound absorption coefficient for low frequencies ranging from 500 to 5500 Hz with a maximum value of sound absorption at 0.64. While empty fruit bunches (EFB) with 18mm also shows the increment from 150 Hz to 3500 Hz with a maximum value of sound absorption at 0.81 because.

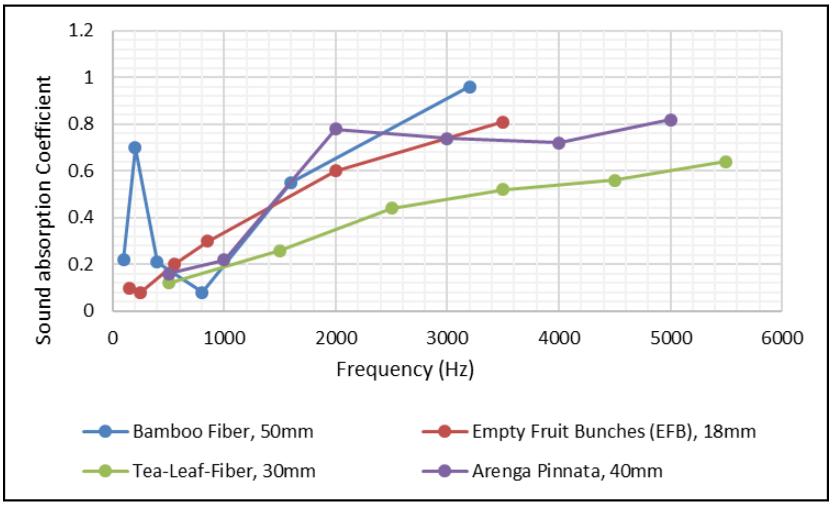

Figure 1: Comparison of sound absorption characteristics of the natural fibers based on different thickness

Meanwhile, sound absorption coefficient arenga pinnata fiber is better than the other materials at the frequency of 2000 Hz. This material with 40mm thickness resulted a higher value of sound absorption coefficient at 0.82. Thicker sample was observed capable to absorb more sound at lower frequency region and thinner samples absorb more sound at higher frequency region [14]. Similar with Al-Rahman et al., [1] stated that more energy loss due to a long journey by the impacted wave which resulted in the thicker samples to absorb more sound. From the above results, the thicker sample gives the best result of performance on sound absorption.

3.2.2 Density

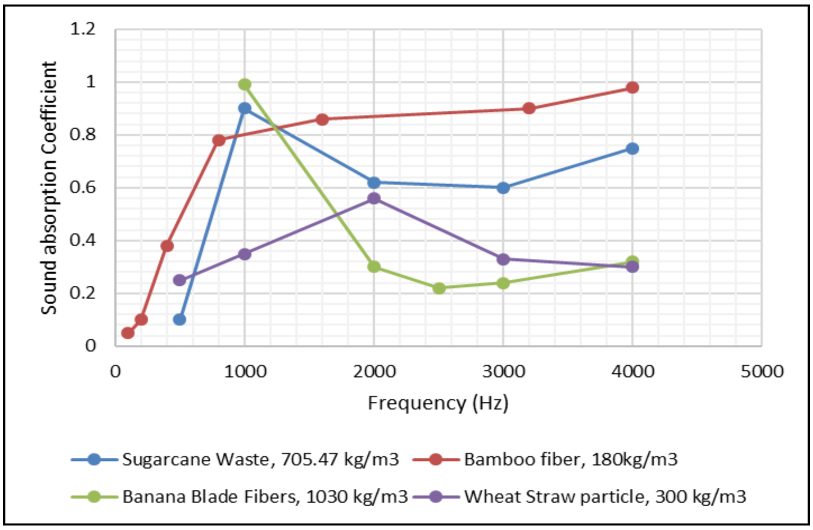

Figure 2: Comparison of sound absorption characteristics of the natural fibers based on different density

The sound absorption characteristics of the natural fibers based on different composition were compared as shown in Figure 2. The bamboo fiber with density of 180 kg/m^3 shows the sound absorption coefficient increases at the medium frequency to high frequency range while wheat straw particle, 300 kg/m^3 shows a higher absorption of 0.57 at 2000 Hz. Thus, it clearly shows that the sound absorption coefficient decreases as the density of the boards increases [14]. The fact that when this happens are the density increases, the number of natural fibers per unit area of the sample increases too [14].

The porosity will increases too due to the increment of surface friction, the loss of sound energy happens to be increases as well. Therefore contributes to the increment of sound absorption coefficient of the materials [15]. Banana blade fiber with density of 1030 kg/m^3 shows the higher sound absorption value of 1.0 at 1000 Hz while sugarcane bagasse with 705.47 kg also shows the higher asound absorption value of 0.75 at 1000 Hz. Thus, low fiber composition indicates low sound absorption coefficient [14].

3.2.3 Porosity

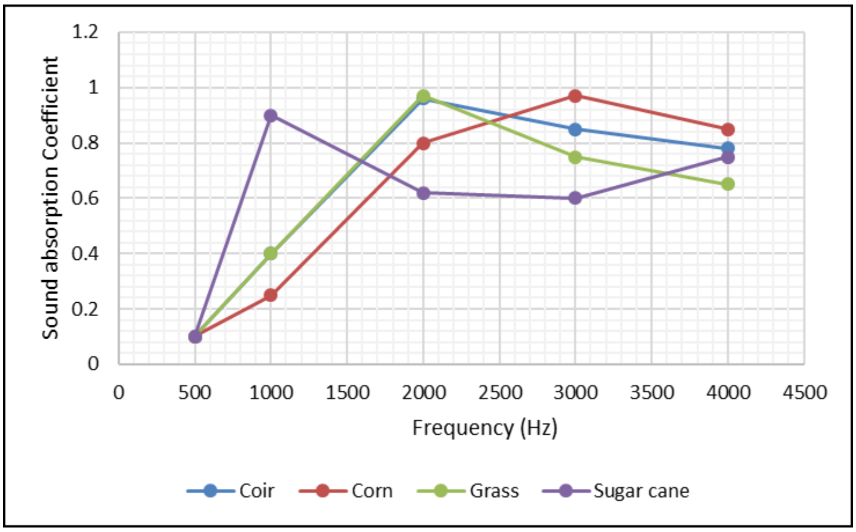

Figure 3: Comparison of sound absorption characteristics of the natural fibers based on different porosity

The comparison values of sound absorption coefficient of natural fibers based on different porosity were shown in Figure 3. At frequencies greater than 2000 Hz, coir and grass shows the decreasing sound absorption coefficient, while corn showed similar behaviour which are over 2000 Hz but increase in sound absorption coefficient. For sugar cane absorption, the sound absorption coefficient achieved with the peak of around 0.9 at 1000 Hz which the frequency lower than the other fibers. This is because the sugar cane fibers have a diameter of about 400 µm, which is greater than the rest. According to Fouladi et al., [16], there is no significant elastic behaviour for sample with greater diameter of fibers, but also less resistivity to fluids since more hollow areas for fibres can be assembled. Hence, the lower the flow resistivity causes the decreases in absorption coefficient of sample.

3.3 Comparison data for mechanical properties.

The mechanical properties of the materials involved in the testing are Modulus of Rupture (MOR), Modulus of Elasticity (MOE), Internal Bonding (IB) and tensile strength (T). However, this research only focuses on the mechanical test of MOR and MOE.

3.3.1 Modulus of Rupture (MOR) and Modulus of Elasticity (MOE)

From the previous research, the panel were tested on MOR and MOE to determine the mechanical properties.

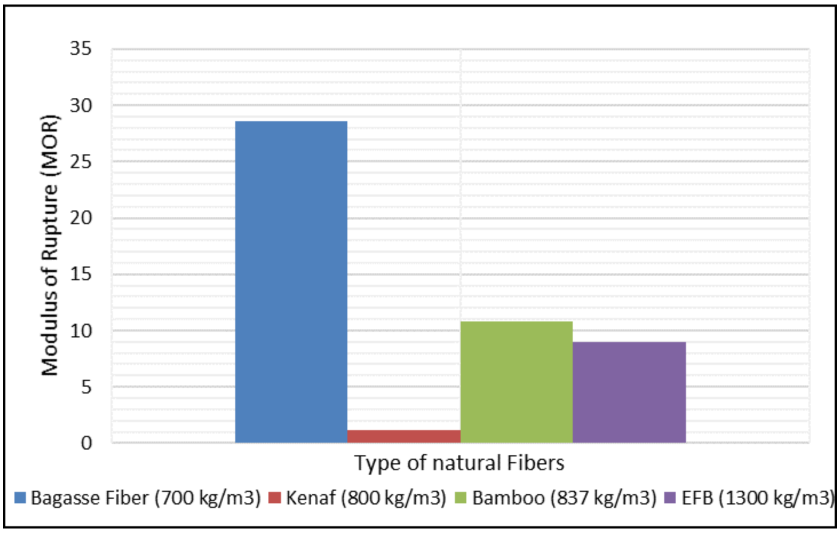

Figure 4: Comparison of mechanical properties, MOR of the natural fibers based on different density

From Figure 4, Bagasse fiber with 700 kg/m^3 possesses the higher value of MOR with 28.6 MPa and the second highest value of MOR which was 11.10 for bamboo fiber with density of 837 kg/m^3. Compare to EFB shows the high density of medium density fiberboard (MDF) which shows the density of 1300 kg/m3 but the value of MOR was 9 Mpa which slightly lower than bamboo. The MDF for kenaf shows the density of 800 kg/m^3 with the highest value of MOR was 1.15 MPa. Based on Samsudin et. al., [14], MDF based on EFB modified to form a cement bonded fiberboards to ensure workability of EFB in the mechanical test. Similar to Marinho et. al., [17], higher mean rates of density in their profile affect mechanical properties positively.

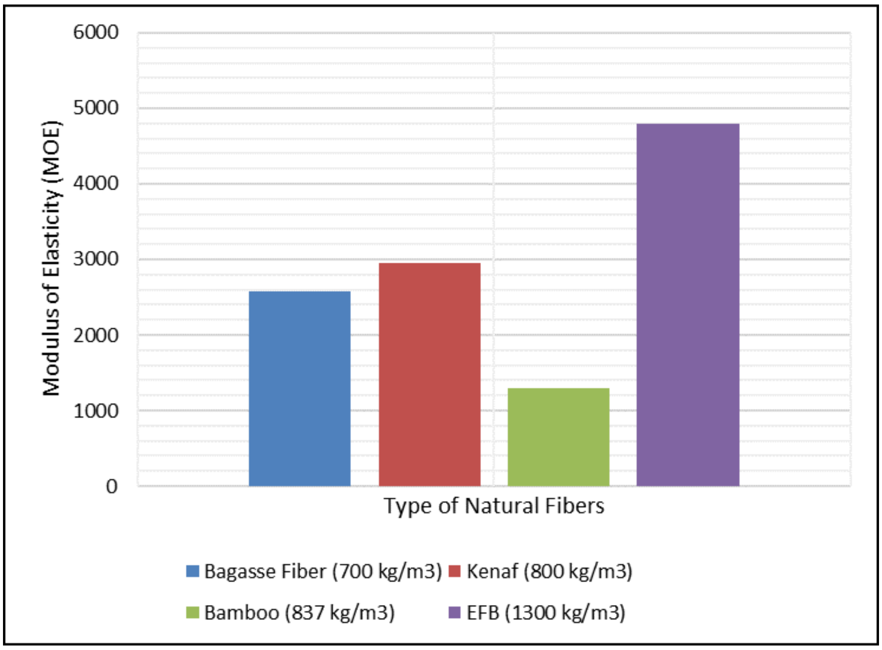

Figure 5: Comparison of mechanical properties, MOE of the natural fibers based on different density

Figure 5 shows the density of EFB was 1300 kg/m^3 with the highest value of MOR was 2800 MPa. Compare to Kenaf shows the high density of MDF which shows the increment of MOR for 800 kg/m^3 with the highest value of MOR was 4800 Mpa. MDF based on EFB were used the same properties in MOR testing [18]. The increment shows that the target density of MDF indicated the increment of MOR and MOE [18]. Although bamboo possesses higher density than kenaf and bagasse fibers, the value of MOE was the lowest with 1067.73 MPa because interfacial connections between thickness and diameter, which produce wider areas of contact as observed [17].

4. Conclusion

It has been found that many different types of raw natural fibres, loose natural fiber combine as filling materials, and natural fibres composed of other materials that can be used as sound absorbers. The majority of this type of natural fibers can be good sound absorbers mainly in improving comfort whether in the construction industry or manufacturing industry.

The optimal thickness of natural fibers affect the sound absorption by the loss of friction of air space molecules that increase the value of sound absorption coefficient at the low frequency region. The effectiveness of bamboo fiber was confirmed, but not forget to other natural fibers such as empty fruit bunches, tea-leaf-fiber arenga pinnata and others. Moreover, it can be concluded that with the same compression ratio, samples with larger thickness possessed lower porosity value.

In conclusion, the physical and mechanical properties also affect the properties of natural fibers and all the panels can be considered as good absorptive materials. Overall results showed that all the natural fibers are promises to be as one of the major requirements for human comfort today for sound absorption quality. The use of these materials as a sound insulation product provides effective solutions for waste management problems.

Therefore, some recommendation that can be made to ensure the workability of natural fiber as sound absorber materials which is use the higher thickness or composition of natural fibers, considering appropriate density in applying the natural fibers or as MDF, use the lower porosity of natural fibers, managing the pretreatment and the operating conditions of MDF.

Acknowledgement

The authors would also like to thank the Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia for its support in expertise, understanding, generous guidance and support made it possible to work on this study.

References

[1] L. A. Al-Rahman, R. Raja, R. Abdul Rahman and Z. Ibrahim. “Comparison of Acoustic Characteristics of Date Palm Fibre and Oil Palm Fibre.” 7(8), pp. 1656-1661. 2014

[2] H. S. Seddeq, 2009. Factors influencing acoustic performance of sound absorptive materials. Australian Journal of Basic and Applied Sciences. 3(4), pp. 4610-4617.

[3] T. Koizumi, Tsujiuchi, N. and Adachi, A.. (2002). The development of sound absorbing materials using natural bamboo fibers. High Performance Structures and Materials. 4. 157-166.

[4] Zulkifli, R., Zulkarnain and Nor, M.J.M. (2010). Noise Control Using Coconut Coir Fiber Sound Absorber with Porous Layer Backing and Perforated Panel. American Journal of Applied Sciences, 7(2), 260-264.doi:10.3844/ajassp.2010.260.264proeng.2013.02

[5] Ballagh, K.O. 1996. Acoustical properties of wool. Applied Acoustics, 48(2), pp. 101-120.

[6] Zhang, M. and Kang, Jian. (2007). Towards the evaluation, description, and creation of soundscapes in urban open spaces. Environment and Planning B: Planning and Design. 34. 68-86. 10.1068/b31162.

[7] L. Karlinasari, D. Hermawan and A. Maddu, M. Bagus and I. K. Lucky, N. Nugroho and Y. S. Hadi (2012). Acoustical properties of particleboards made from Betung bamboo (Dendrocalamus asper) as building construction material. BioResources. 7. 10.15376/biores.7.4.5700-5709.

[8] A. K. Dewi, and Elvaswer. (2015). Material akustik serat pelepah pisang (musa acuminax balbasiana calla) sebagai pengendali polusi bunyi. Jurnal Fisika Unand, 4(1), 78-82. Available online: http://jfu.fmipa.unand.ac.id/index.php/jfu/article/download/129/110

[9] A. Putra, Y. Abdullah, H. Efendy, W. M. Farid, M. R. Ayob and M. S. Py. (2013). Utilizing Sugarcane Wasted Fibers as a Sustainable Acoustic Absorber. Procedia Engineering, 53, 632-638. doi:10.1016/j.proeng.2013.02.081

[10] Yang, H., Kim, D., and amp; Kim, H. (2003). Rice straw–wood particle composite for sound absorbing wooden construction materials. Bioresource Technology, 86(2),

[11] S. Ersoy and H. Küçük (2009). Investigation of industrial tea-leaf-fibre waste material for its sound absorption properties. Applied Acoustics, Volume 70, Issue 1, pages 215-220, ISSN 0003-682X. doi.org/10.1016/j.apacoust.2007.12.005.117-121. doi:10.1016/s0960-8524(02)00163-3

[12] E. Samsudin, L. H. Ismail and Mokdar (2016). Comparison on Acoustic Performance Between Dust And Coir Form Empty Fruit Bunches (EFB) As Sound Absorption Material. Jurnal Teknologi, 78(5). doi:10.11113/jt.v78.8280

[13] L. Lindawati, M. I. Ghazali, S. Mahzan and A.M.A. Zaidi (2010). Sound absorption of Arenga Pinnata natural fiber. World Academy of Science, Engineering and Technology. 43. 804-806. 2009

[14] E. Samsudin, L. H. Ismail and A. Abd Kadir. “A review on physical factors influencing absorption performance of fibrous sound absorption material from natural fibers.” Journal of Engineering and Applied Sciences. 11. 3703-3710. 2016.

[15] M. Delany and E. Bazley, Acoustical properties of fibrous absorbent materials. Applied acoustics, 1970. 3(2): p. 105-116.

[16] Fouladi, Mohammad & H., Mohamed & Ghassem, Masomeh & Shamel, Marwan & Yeng, Sim & Yi, Sin & Zong, Pang & Mohd Nor, Jailani. (2013). Utilizing Malaysian Natural Fibers as Sound Absorber. 10.5772/53197.

[17] Marinho, Nelson and Nascimento, Eduardo and Nisgoski, Silvana and Valarelli, Ivaldo. (2013). Some Physical and Mechanical Properties of Medium-Density Fiberboard Made from Giant Bamboo. Materials Research. 16. 1398-1404.10.1590/S1516-14392013005000127.

[18] N. Ismail, M. A. Mohmed Jomali, H. Abu Bakar, T. Y. Ghing, N. M. Z. Nik Soh, and R. M. A. Mohd Azam (2020). Influence of varying density on the mechanical and physical properties of Medium Density Fibreboard (MDF) containing kenaf. IOP Conference Series: Materials Science and Engineering, 713, 012020. doi:10.1088/1757-899x/713/1/012020

[19] Ngaini, Zainab Azlin, A.R. and Shaari, Nazlina & Hussain, Hasnain & Norhaizat, S. & Teng, J.X. & Lawai, V.. (2013). Production of fire-retardant sound-absorbing panels from sago waste. Journal of Tropical Forest Science. 25. 510-515.

[20] Yang, T., Hu, L., Xiong, X., Petrů, M., Noman, M. T., Mishra, R., and amp; Militký, J. (2020). Sound Absorption Properties of Natural Fibers: A Review. Sustainability, 12(20), 8477. doi:10.3390/su12208477