ISSN (Print) : 2337-9030 ISSN (Online) : 2685-2608

PILLAR OF PHYSICS

Vol. 15 (1), 2022, page. 1-9
DOI : http://dx.doi.org/10.24036/12136171074

THE EFFECT OF VARIATIONS OF BAGASSE SUGARCANE FIBER COMPOSITION WITH PLASTIC/POLYPROPYLENE WASTE MATRIX AND PAPER SLUDGE FILLER ON ACOUSTIC TESTING ON COMPOSITE PANELS

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ABSTRACT

Noise can affect a person's health and comfort. Noise can cause mood disorders, anxiety, and stress. One of the efforts to control noise is the selection of acoustic materials. The utilization of these materials can use as panels that can muffle sound, thereby reducing noise. In this study, bagasse fiber, polypropylene plastic waste, and paper sludge were used as materials in the manufacturing of composite panels. The method used is the impedance tube method. The greater the sound absorption coefficient, the better the material is used as a sound dempening material. In this study, the composition of polypropylene plastic and paper sludge was 40:60, and variations in fiber composition is 0%,1%,2%,3% from the total weight of the composite panel. The bagasse fiber used is a fiber that has been alkalized to make a good mechanical interlocking between the fiber and the matrix. Based on the result, the highest sound absorption coefficient is 0,98 at a frequency of 8000 Hz for 3% fiber composition. The lowest sound absorption coefficient is 0,63 at a frequency of 2000 Hz, for 0% fiber composition. The more fiber composition used in the composite panel, the higher the resulting sound absorption coefficient. More bagasse fibers can increase the pores and thickness of the composite panel so it can absorb the sound that passes through it. The greater the sound absorption coefficient, the better the material is used as sound material. All sample variations qualify the standard requirements as noise matrials in buildings ISO 11654 is 0,15

Keywords : Composite Panel; Plastic/Polypropylene Waste; Paper Sludge; Sound Absorption Coefficient.

I. INTRODUCTION

Noise is defined as unwanted sound which is a natural and human activity [1]. Noise is one of the environmental aspects that need to be considered because it includes disturbing pollution and comes from sound or noise. Noise is a problem that is often faced, especially in urban communities. This can cause by activities such as construction or industry, traffic on highways or motor vehicles, noise from machines, and electronic equipment such as tv, karaoke, blenders, vacum cleaners, and others. Noise can cause emotional distubances anxiety, and stress. So that it has an impact on pyschological, social, intellectual, and spiritual conditions [2]. At certain levels and durations of exposure, noise can be more than just a nuisance. Based on research on noise levels and psychological disturbances of workers in the spinning industry, 29% of employee experience dizziness, 19,4% high blood pressure, 15,1% deafness, and 6,5 % of workers do not feel anything [3]. Offices, schools, and other personal work environments all need a quiet and comfortable room. So that if not treated properly it can cause physical disturbances to the eardrum and ear sensitive cells permanently or temporarily. Over time it can cause a decrease in a person's level of productivity.

One of the noise control is the selection of materials that can absorb sound or acoustic material [4]. The quality of the material that can use as a sound absorber is seen from the sound absorption coefficient (α). Sound has the characteristic of a general wave, when it passes a surface it can reflec, absorb, or transmit. The greater the sound absorption coefficient (α), the better the material is used as a sound absorber [5]. Sound absorbing material or acoustic material is a special material made with the function of absorbing sound at a certain frequency [6]. The use of existing sound-absorbing materials is porous materials, resonators, and panels.

Panels can be made with unused and enviromentally materials as sound-absorbing composites, thereby reducing noise and tackling enviromental problem. Composite material is a material composed of two or more constituents with different physical and structural properties, wich are combined to form a bond and become a new material with different properties from the constituents [7]. Composite manufacturing has many advantages including improving mechanical properties, ease in the fabrication process so that it can save manufacturing costs and can be adjusted based on need [8]. Composite material are composed of reinforcement as a reinforcement and a matrix as a binder.

The matrix has an important role in composites, as a binding material for fibers into a unified structure, so that the fibers and the matrix have a close relationship. The matrix generally has more elastic properties but has lower strength and stiffness so that the fibers can adhere to the matrix well. The matrix used in this study is plastic waste. Based on SIPSN the information on national waste management in indonesia, Plastic waste in Indonesia ranks fourth after food waste, twigs, and paper/cardboard with a percentage of 17.07%. It shows that the consumption of plastic in Indonesia is still very high. Plastic waste was choosen because plastic waste has become a world problem today. Plastic has many advantages including not being easily weathered, elastic, low cost, lightweight, and anti-rust. However, plastics are non-biodegradable because they are difficult to decompose and this contributes to the largest amount of waste in the destruction of nature. The plastic used in this study is a type of polypropylene plastic which is included in the type of thermoplastic polymer. Thermoplastic polymers will melt at certain high temperatures and become stiff at low temperatures. This allows other materials to be mixed, such as fibers or similar particles used in the manufacture of composite panels. Polypropylene plastic has high strength, resistance, hardness, and stiffness and is not easily damaged so that it can be applied in forming composite materials [9]

This study also used filler in composite panels. The filler material used in the manufacture of composites is usually in the form of fibers or powders [10]. The filler used in this research is paper sludge. Sludge waste continues to increase in line with growth of the pulp and paper industry, as in the January-April 2019 period, paper exports increase from the same period in 2018 by 6,75%, from 1,6 milion tons to 1,4 milion tons. So that this will have an impact on the environment if the paper sludge waste is not handle properly [11]. Paper sludge contains lime, clay, calcium carbonate, and can be an alternative to inorganic fillers and reinforcement in the manufacture of thermoplastic composites [12] with its cement-like properties, so it can be used as filler and support for strength in composites such as stiffness, strength, and strength other mechanical properties [13].

This study uses bagasse fiber as a reinforcement and increases the sound absorption value. Bagasse fiber was chosen because it comes from nature and has not been utilized properly. Sugarcane fiber contains fiber as much as 35-40% of the weight of sugarcane. Bagasse fiber contains cellulose and hemicellulose which is quite high, this fiber is also easy to obtain because of the availability of a lot of fiber, low cost, not harmful to health, and has a low density. So that the use of bagasse fiber is expected to increase the value of the porosity of the composite panel so that it can increase the value of the sound absorption coefficient the composite panel.

Research related to the use of bagasse fiber with MEKPO polyester resin matrix has been studied by Fajri Ridhola, by varying the mass of fiber used, the highest sound absorption coefficient value is 0.961 at a frequency of 1000 Hz obtained at 1 g mass o bagasse fiber [14]. According to Puspita Sari in a study related to the effect of bagasse fiber density with an epoxy resin matrix, it was found that the sound absorption coefficient value of each frequency was different. The absorption coefficient increases because the material has many cavities or pores so that sound waves can easily enter and be absorbed into the acoustic material [15].

In general, there are two advantages obtained from the use of waste in the raw material for making composites with acoustic properties in this study. First, the reduction of waste such as bagasse, recycling of plastic waste, and paper sludge from paper industry waste. If this is not avoided, it will cause various environmental pollution problems. Second, it can be a material that has good acoustic properties so that it can reduce noise problems at a low cost. So by using solid waste as the manufacture of this composite will be very useful both in terms of economy, manufacturing process, and the environment.

Therefore, this study focused on the effect of the composition of bagasse fibers used in testing the acoustic properties of composite panels using a plastic waste matrix of polypropylene and filler using paper sludge. In this study, the impedance tube method one microphone is used to determine the reflection and absorption coefficients of composite panels, because the impedance tube test uses a relatively small sample, is practical, and is suitable for theoretical research in research on new materials.

Based on the background that has been stated, in this study there are three following problems are formulated: First, how does the composition of bagasse fiber affect the sound absorption coefficient and sound reflection coefficient of the bagasse fiber composite panel with polypropylene plastic waste matrix and paper sludge filler. Second, how does the effect of frequency on the value of the sound absorption coefficient and the sound reflection coefficient on the bagasse fiber composite panel with polypropylene plastic waste matrix and paper sludge filler. Third, how are the acoustic properties of the bagasse fiber composite with polypropylene plastic waste matrix and paper sludge filler

II. METHOD

Based on the background and problems that have been stated, this research aims to three funtions are: First, knowing the effect of bagasse fiber composition on the value of the sound absorption coefficient and sound reflection coefficient of the bagasse fiber composite panel with polypropylene plastic waste matrix and paper sludge filler. Second, knowing the effect of frequency on the value of the sound absorption coefficient and the sound reflection coefficient on the bagasse fiber composite panel with polypropylene plastic waste matrix and paper sludge filler. Third, knowing the acoustic properties of bagasse fiber composites with polypropylene plastic waste matrix and paper sludge filler.

The method used in this research is the impedance tube method. This research is included in experimental research. The tests were carried out based on the ASTM C 384-04 standard. In this study, a matrix of polypropylene plastic waste and paper sludge filler was used by varying the composition of the bagasse fiber used. The composition of polypropylene plastic waste and paper sludge is 40:60 with a variation of bagasse fiber composition of 0%,1%,2% 3% from the total weight of the composite panel. The bagasse fiber used is the fiber that has been alkalized so that it can increase the interface adhesion between the fiber and the matrix to produce good mechanical interlocking [16].

The materials used in this study are unused and environmentally materials. The materials used are bagasse fiber, polypropylene plastic, and paper sludge. The following are the stages in the preparation of research materials.There are three steps on material preparation in this study, they are:

Preparation of sugarcane fiber: The sugarcane used comes from the Lawang area which is then distributed in the Tabing area, Padang. The bagasse is taken from a sugarcane mill in the Tabing area, Padang. The bagasse is then washed thoroughly using running water to remove the adhering dirt. Then it is dried in the sun for about 2 days, so that the bagasse becomes dry so that it is easy to clean. The bagasse then cleaned and brushed using a wire brush so that the bagasse becomes more biodegradable and the shape of the fibers can be seen. When the sugarcane fiber is visible, the fiber is cleaned using tweezers to remove the cork adhering to the fiber. After the fiber is formed, the fiber is cut to a size of ± 1 cm. Bagasse fiber has a size of ± 1cm then the fiber is alkalized using 5% NaOH for ± 2 hours [16]. The bagasse fibers are rinsed with running water then dried. The dried bagasse fiber is weighed according to the predetermined and ready to use. Bagasse fiber that is ready to used can be seen in Figure 1 below.

Fig. 1. Bagasse Fiber

Based on Figure 1, we can see that the bagasse used is alkaline treated so that it produces good and thin fibers without any sticking cork. Alkaline treatment is one of the chemical treatments, namely the immersion of fiber into alkaline alkali to increase the cellulose content through the removal of hemicellulose, lignin, wax, and oil that cover the outer surface of the fiber cell wall. Alkali/alkalization treatment is carried out to improve the compatibility of fibers as reinforcement in composites. Alkaline treatment has an effect on fiber, which can cleaning and modifying the fiber surface to reduce tension surface, increasing the interfacial adhesion between the natural fiber and the matrix polymer, resulting in better mechanical interlocking [16].

Preparation of polypropylene plastic waste: Polypropylene plastic was taken from garbage collectors in the Tabing area, Padang. The plastic used has been chopped with a size of ± 0.5 cm. The chopped plastic then cleaned to remove dirt. Polypropylene plastic is used with a 40% composition. PP that has been chopped can be seen in Figure 2.

Fig. 2. Polypropylene plastic waste

Based on Figure 2, it can be seen that the plastic used is recycled plastic so that it can reduce problems related to plastic waste. The plastic used is chopped before into small pieces so that it is faster and easier to melt.

Preparation of sludge paper waste*:* Paper sludge was taken in PT. Indah Kiat pulp & paper mill in Perawang, Riau. Sludge paper is hen dried in the sun for +- 4 days. then the paper sludge was dried using an oven at 110^{o} C for +-6 hours [13]. After the sludge is dried, it is pulverized and filtered using a 100 mesh sieve. Sludge paper that has been in powder form can be weighed according to calculations and can be used. The mass of paper sludge used is with a composition of 60%. Sludge paper that is ready to use can be seen in Figure 3.

Fig. 3. Paper Sludge

Based on Figure 3, we can see that the paper sludge used is paper sludge that has been treated. Sludge paper used is that which has become powder and in this study used a size of 100 mesh. This makes it easy to mix with other materials.

The composition used in the composite panel is 60% paper sludge, 40% polypropylene plastic waste and fiber variations, namely 0%, 1%2% and 3%. All materials are weighed according to a predetermined composition. Polypropylene plastic is melted using a stove at temperature 180 ^{o}C. When the polypropylene plastic has melted, the paper sludge is added and stir until well mixed. After the plastic and paper sludge have been mixed well, the fiber is added with variations in fiber of 1%, 2% and 3% of the total weight. After all the ingredients are well mixed, it will be poured into the mold for the pressing process. After being put into the mold then pressed with a pressure of 200 Mpa or $2 \times 10^5\, {}^{N}/_{m^3}$ [17]. Composite panels that are ready to be made then can be carried out testing the absorption and reflection coefficient of sound. Composite panels that have been made can be seen in the Figure 4 below:

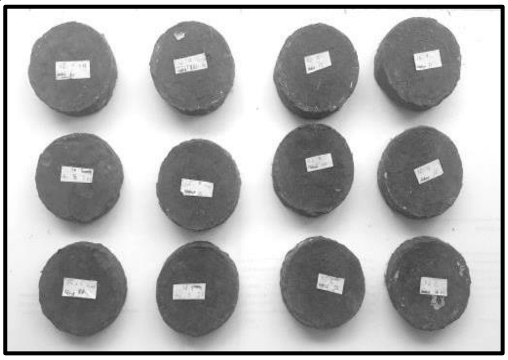

Fig. 4. Acoustic test sample composites panels

Based on Figure 4. Composite samples were made with a diameter of 8 cm. The composite sample consists of four variations of the sample with each variation consisting of three samples.

The test was carried out based on the ASTM C 384-04 standard. The impedance tube used was made of iron which is arranged in such a way. The impedance tube operation is connected to several tools including sound generators, microphones, loudspeakers, amplifiers, and oscilloscopes. The impedance tube testing can be seen in the following Figure 5 [18]

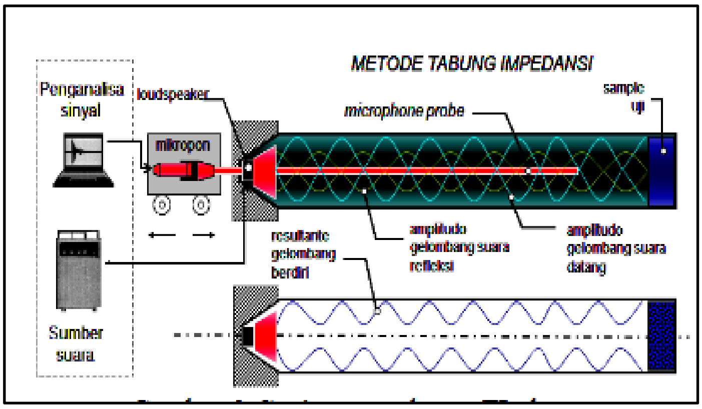

Fig. 5. Impedance tube method [18]

Based on Figure 5, The loudspeaker connected to the sound generator is used to generate acoustic waves that propagate in the tube and are then reflected by the test sample. Phase interference between incident and reflected waves in the tube from the test sample will produce a standing pattern. The pressure amplitudes at the node and antinode were measured using a sliding microphone. The ratio of the maximum pressure (antinode) to the minimum pressure (node) is the standing wave ratio and can be seen using an oscilloscope.

Based on the characterization data using the impedance tube method, the coefficient of sound absorption produced from the sample can be analyzed. Data was carried out based on the ASTM C 384-04 standard [19]. Determination of the sound absorption coefficient in the impedance tube method by calculating the ratio of the maximum pressure amplitude to the minimum pressure amplitude. This pressure amplitude ratio is called the standing wave ratio (SWR) [20]

$$SWR = \frac{A+B}{A-B} \quad \ldots\ldots 1$$

For the reflection coefficient can be determined by the following equation:

$$R_{\Pi} = \left|\frac{B}{A}\right|^2 = \left(\frac{SWR-1}{SWR+1}\right)^2 \quad \ldots\ldots 2$$

For the absorption coefficient can be determined by the following equation:

$$\alpha = 1 - \left(\frac{\mathrm{SWR}-1}{\mathrm{SWR}+1}\right)^2 = \frac{4}{SWR+\frac{1}{SWR}+2} \quad \ldots\ldots 3$$

III. RESULTS AND DISCUSSION

The results of this study are the values of the sound absorption coefficient and the sound reflection coefficient resulting from the variation of the sample that has been made, there are 0%, 1%, 2%, and 3%. by varying the frequency, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, and 8000 Hz.

The sound absorption and reflection coefficient tests were carried out according to the impedance tube method by determined 2 and 3. The test was carried out at the Physics Materials Laboratory, Andalas University. The devices used in the test include impedance tubes, microphones, loudspeakers, amplifiers, sound generators, and oscilloscopes. The sample is placed at the end of the tube in a transverse position. Then sound waves are emitted from the sound generator using a loudspeaker with low to high frequencies. The measurement of the value of the absorption and reflection coefficient of sound in this study uses the standing wave ratio, which is the ratio between the maximum amplitude and the minimum amplitude obtained seen on an oscilloscope.

The test was carried out repeatedly with three tests for each sample variation, with each variation consisting of samples A, B, and C and five repetitions in each sound absorption coefficient test. The following data from the test results of each sample with variations in the mass of the fiber used. The result of data analysis of the sound reflection coefficient value of each sample variation is shown by Table 1.

Table 1. Sound reflection coefficient

Frequency (Hz)	Sound Reflection Coefficient			
	0%fiber	1%fiber	2%fiber	3%fiber
500	0,18	0,11	0,06	0,06
1000	0,23	0,19	0,11	0,12
2000	0,37	0,29	0,21	0,17
4000	0,32	0,22	0,14	0,11
8000	0,14	0,06	0,06	0,02

Based on Table 1. that data that has been obtained, the highest sound reflection coefficient value is 0.37 at afrequency of 2000 Hz with a sample without fiber or 0%. The lowest sound reflection coefficient value is 0.02 at a frequency of 8000 Hz with a sample variation of 3% fiber. The graph of the correlation between fiber composition and sound reflection coefiicient can be seen in Figure 6.

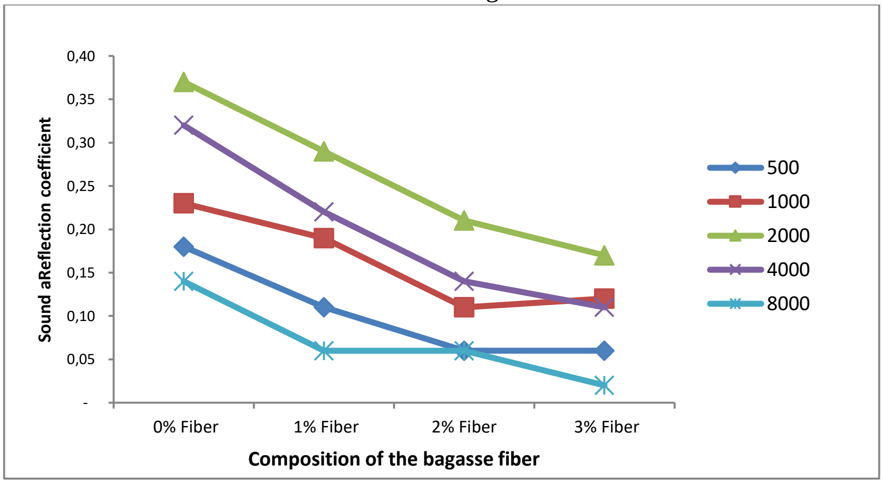

Fig. 6. Graph of the correlation between fiber composition and the value of the reflection coefficient of sound

Based on Figure 6, it can be seen that the sound reflection coefficient decreases with the addition of the fiber composition used. So the correlation between the reflection coefficient with the addition of variations in fiber composition is inversely proportional. Based on the graph that has been obtained, the more fiber used, the less reflected sound is produced.

Based on the data that has been obtained, the sound absorption coefficient can be seen in Table 2 below.

Tabel 2. Sound Absorbtion Coefficient

Frequency (Hz)	Sound Absorbstion Coefficient			
	0%fiber	1%fiber	2%fiber	3%fiber
500	0,82	0,89	0,91	0,94
1000	0,77	0,81	0,87	0,88
2000	0,63	0,71	0,78	0,83
4000	0,68	0,78	0,85	0,89
8000	0,86	0,94	0,94	0,98

Based on Table. 2 it can be seen that the sound absorption coefficient is lowest in the sample with 0% fiber and the highest sound absorption coefficient is in the sample with the most fiber, which is 3%. The sound absorption coefficient of all variations of the resulting sample passes the requirements as a sound-absorbing material, namely 0.15 according to the ISO 11654 standard [21]. The following is a graphic image of the relationship between variations in fiber composition and the value of the sound absorption coefficient can be seen in Figure 7.

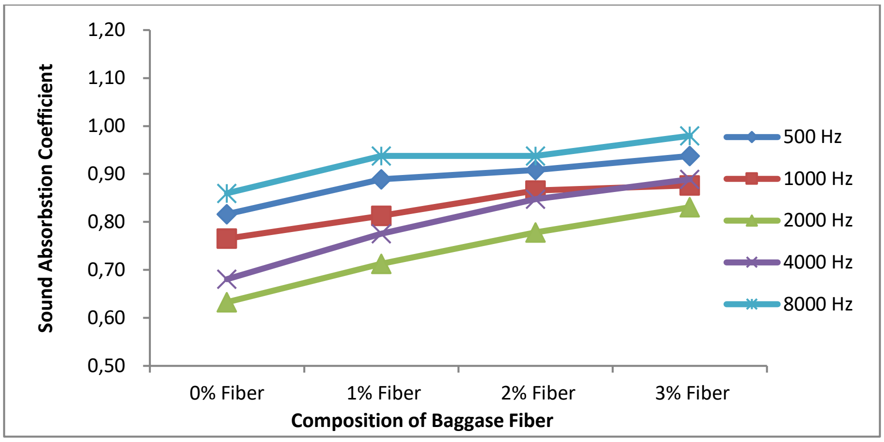

Fig. 7. Graph of the correlation between fiber composition and the sound absorption coefficient

Based on Figure 7, it can be seen that the sound absorption coefficient increases with the addition of the fiber composition used. So the correlation between the sound absorption coefficient with the addition of variations in fiber composition is directly proportional. Based on the graph that has been obtained, the more fiber used, the more sound is absorbed by the material. The sound absorption coefficient increases because the material has many cavities so that sound waves can easily enter and be absorbed in the acoustic materials [15]. Therefore, bagasse fiber has the potential to be used as as a sound-absorbing material. The more fiber used, the greater the value of the sound absorption coefficient [22]. Case this affects the number of pores formed in the sample and there is resistance to airflow on the webbed surface of the samples.

Based on the data analysis, the composite sample has a decrease in the sound absorption coefficient at a frequency of 2000 Hz. this can be seen in Figure 8 below.

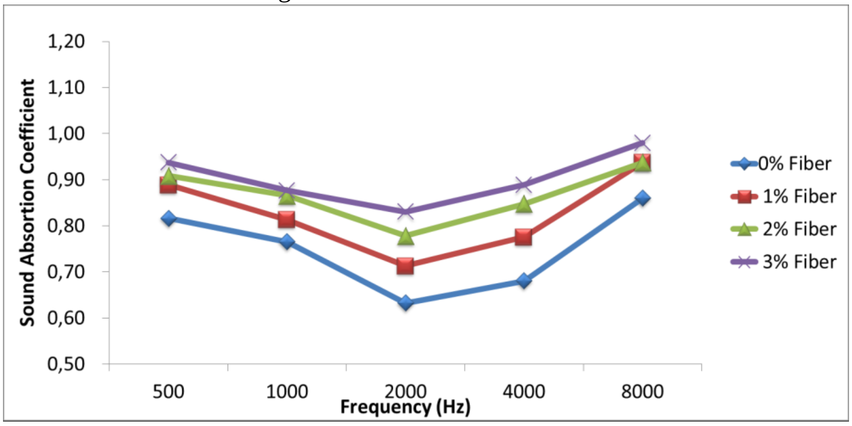

Fig. 8. Graph of correlation between Frequency and the sound absorption coefficient on the sample variation

Based on the graph at Figure 8, it can be seen that the composite sample has a decrease in the medium frequency, namely the frequency range of 1000 Hz - 4000 Hz. Composite samples have the best coefficient values in the low and high-frequency ranges, namely the frequencies of 500 Hz and 8000 Hz.

Based on this reaserch, samples with 3% fiber composition have the highest sound absorbtion coefficient at a frequency of 8000 Hz is 0.98 and the lowest sound coefficient absorption is 0.63 with 0% fiber composition. so that the value of the sound absorption coefficient increases as the fiber composition increases used. Sound absorption coefficient increases because the material has many cavities so that sound waves can easily enter and be absorbed in the acoustic materials [15]. Therefore, bagasse fiber has the potential to be used as as a sound-absorbing material. The more fiber used, the greater the value of the sound absorption coefficient [22]. This affects the number of pores formed in the sample and the presence of airflow resistance on the sample surface.Thus, more sound waves are absorbed than reflected. So that with the addition of bagasse fiber in the composite sample can increase the value of the absorption coefficient of the resulting sound.

At a frequency of 2000 Hz, all samples experienced a decrease in the value of the sound absorption coefficient. At low and high frequencies, each sample variation has almost the same absorption coefficient value. However, at medium frequency the value of the sound absorption coefficient decreases at a frequency of 2000 Hz and then increases at a frequency of 4000 Hz. At medium frequency, the sample with 3% fiber composition has the highest coefficient value. While the sample variation without bagasse fiber or 0% fiber composition has the lowest absorption coefficient value of 0.63. So that the composite sample has the best sound absorption coefficient at low and high frequencies, and decreases at medium frequencies. Therefore, composite samples are used both at low and high frequencies. The decrease in the value of the sound absorption coefficient at a certain frequency, this is due to the acoustic material tends to be recessive where the sound absorption coefficient decreases at a certain frequency [14]. regarding the natural frequency of the samples, [22] so that the amplitude of the reflected wave becomes small so that the absorption coefficient value decreases at a frequency of 2000 Hz. Therefore, the composite sample with bagasse fiber with polypropylene plastic waste matrix and paper sludge has the best absorption coefficient value in the low and high frequency ranges.

IV. CONCLUSION

Based on the research that has been regarding the effect of bagasse sugarcane fiber composition with polypropylene matrix and paper sludge filler on the acoustic properties of composite panels, there are three conclusionsin this research, they are first, the more composition of bagasse sugarcane fiber used in the composite sample, the higher the value of the sound absorption coefficient. So that the composition of bagasse fiber can increase the sound absorption coefficient of the composite samples. Second, all variations of the composite sample have a decrease in the value of the sound absorption coefficient at a frequency of 2000 Hz, namely in the medium frequency range, and have the best sound absorption coefficient value at low and high frequencies, namely the frequency of 500 and 8000 Hz. So that the composite sample is good for use in low dan high frequency range. Third, the composite sample of bagasse fiber with polypropylene plastic waste matrix and paper sludge filler has good acoustic properties, this can be seen in the sound absorbtion coefficient produced. The lowest sound absorption coefficienr is 0,63, and the .highest is 0.98. So that all sample variations qualify the standard requirements as sound-dampening materials in building ISO 11654 is 0.15[20]

REFERENCES

[1] R. A. Dewanty and S. Sudarmaji, "Impact Analysis of Noise Intensity with Hearing Loss on Laundry Worker," *J. Kesehat. Lingkung.*, vol. 8, no. 2, p. 229, 2016, doi: 10.20473/jkl.v8i2.2016.229-237.

[2] Sumardiyono, R. Wijayanti, Hartono, and A. H. Sutomo, "KEBISINGAN LINGKUNGAN KERJA : KERENTANAN KESEHATAN PADA PEKERJA," *J. Kesehat. Lingkung.*, vol. 11, no. 4, 2019, doi: 10.20473/jkl.v11i4.2019.267-275.

[3] Darlani and Sugiharto, "Kebisingan Dan Gangguan Psikologis Pekerja Weaving Loom Dan Inspection Pt. Primatexco Indonesia," *JHE (Journal Heal. Educ.*, vol. 2, no. 2, pp. 130–137, 2017, doi: 10.15294/jhe.v2i2.22618.

[4] W. Hayat, Syakbaniah, and Y. Darvina, "Pengaruh Kerapatan terhadap Koefisien Absorbsi Bunyi Papan Partikel Serat Daun Nenas," *J. Pillar Physycs*, vol. 1, no. April, pp. 44–51, 2013.

[5] A. D. Laksono, L. Ernawati, and D. Martanti, "Pengaruh Fraksi Volume Komposit Polyester Berpenguat Limbah Serbuk Kayu Bangkirai Terhadap Sifat Material Akustik," *Rekayasa Mesin*, vol. 10 no 3, no. e ISSN 2477 5041, pp. 277–285, 2019.

[6] K. Khotimah, S. -, and H. Soeprianto, "Sifat Penyerapan Bunyi Pada Komposit Serat Batang Pisang (Sbp) – Polyester," *J. Penelit. Pendidik. IPA*, vol. 1, no. 1, pp. 91–101, 2015, doi: 10.29303/jppipa.v1i1.9.

[7] A. Nasution, A. Wahab, and D. Nuari, "Analisis Pengaruh Benang Wol Dan Limbah Batang Pisang Dalam Rancangan Produk Komposit Peredam Bunyi Ruang Akustik," *J. Sist. Tek. Ind.*, vol. 20, no. 2, pp. 53–62, 2018, doi: 10.32734/jsti.v20i2.490.

[8] F. Ulfah, Syakbaniah, and Y. Darvina, "Pengaruh Variasi Komposisi Serat Tandan Kosong Sawit (TKS) dan Serbuk Kayu Terhadap Sifat Fisis dan Sifat Mekanis Papan Partikel," *Pillar Phys.*, vol. 5, no. April, pp. 113–120, 2015.

[9] A. Dea, S. Hidayat, M. Farid, and T. Wibisono, "Karakterisasi Morfologi Sifat Akustik dan Sifat Fisik

Komposit Polypropylene Berpenguat Serat Dendrocalamus Asper untuk Otomotif," no. September 2017, pp. 2–7, 2019, doi: 10.12962/j23373539.v6i2.25275.
[10] H. Said, L. K. Mangalla, and B. Sudia, "Analisa Mampu Redam Suara Komposit Serat Sabut Kelapa Dengan Matriks Polyvinyl Acetate (Lem Fox)," *ENTHALPY-Jurnal Ilm. Mhs. Tek. Mesin Anal.*, vol. 4, no. 1, pp. 66–71, 2019, doi: 10.1016/b978-0-408-15960-9.50013-9.
[11] M. Kinda, N. Turnip, C. Sitorus, and P. Sibuea, "Kajian Literatur Pengaruh Tekanan dan Temperatur Kempa Serta Jenis Adhesive Terhadap Sifat Fisik dan Mekanik Particleboard dari Limbah Sludge Industri Pulp dan Kertas," *J. Ilm. Simantek ISSN 2550-0414*, vol. 4, no. 4, pp. 195–205, 2020.
[12] X. Yang, W. Wang, and H. Huang, "Resistance of paper mill sludge/wood fiber/high-density polyethylene composites to water immersion and thermotreatment," *J. Appl. Polym. Sci.*, vol. 132, no. 11, pp. 1–7, 2015, doi: 10.1002/app.41655.
[13] T. R. Hidayani and E. Pelita, "Analisis Sifat Fisika dari Komposit Panel Dinding dengan Matriks Limbah Plastik Polipropilena dan Pengisi Sabut Kelapa - Sludge Kertas Analysis of the Physical Properties of Composite Wall Panels Containing Polypropylene Plastic Waste Matrix and Cocofiber," *Pros. Semin. Nas. kulit, karet dan Plast. ke -7 ISSN 2477-3298*, pp. 119–126, 2018.
[14] F. Ridhola and Elvaswer, "Pengukuran koefisien absorbsi material akustik dari serat alam ampas tebu sebagai pengendali kebisingan," *J. Ilmu Fis. ISSN 1979-4657*, vol. 7, no. 1, pp. 1–6, 2015.
[15] T. P. Sari and Elvaswer, "Pengaruh Densitas Panel Serat Ampas Tebu terhadap Koefisien Absorbsi Bunyi dan Impedansi Akustik," *J. Fis. Unand*, vol. 9, no. 3, pp. 304–310, 2020.
[16] S. kumar Acharya, P. Mishra, and S. K. Mehar, "Effect Of Surfaces Treatment on the Mechanical Properties of Bagasse Fiber Reinforced Polymer Composite," *BioResources*, vol. 6, no. 3, pp. 3155–3165, 2011.
[17] Fajriyanto and F. Firdaus, "Komposit Limbah Pabrik Kertas (Sludge), Sabut Kelapa Dan Sampah Plastik : Pengaruh Komposisi Bahan Dan Beban Pengempaan Terhadap Kuat Lentur (Bending)," *Semin. Nas. Telknoin 2008*, pp. 55–62, 2008.
[18] W. H. Nugroho, N. J. H. Purnomo, H. Zen, and A. Rahmadiansah, "Kajian Eksperimental Koefisien Redaman Akustik Bahan Pelapis Plat Dek Kapal," *R.E.M. (Rekayasa Energi Manufaktur) J.*, vol. 3, no. 1, p. 41, 2018, doi: 10.21070/r.e.m.v3i1.1511.
[19] ASTM C284-04, "Standard Test Method for Impedance and Absorption of Acoustical Materials by Impedance Tube Method," *United States*, vol. 04, no. Reapproved, pp. 1–9, doi: 10.1520/C0384-04R16.2.
[20] D. A. Russell, "Absorption Coefficients and Impedance," in *Science and Mathematics Department, Kettering University, Flint MI 48504*, pp. 1–6.
[21] I. 11654:1997, "ISO 11654." .
[22] R. Arwanda and R. A. Sani, "Koefisien Absorbsi Bunyi Pada Bahan Beton Komposit Serat Daun Nanas dengan Menggunakan Metode Tabung Impedansi," *EINSTEIN J. Has. Penelit. Bid. Fis.*, pp. 21–24, 2020.