|  |
| --- |
| **THE EFFECT OF VARIATIONS OF BAGASSE SUGARCANE FIBER COMPOSITION WITH PLASTIC/POLYPROPYLENE WASTE MATRIX AND PAPER SLUDGE FILLER ON ACOUSTIC TESTING OF COMPOSITE PANELS** |
| Kasih Syirpia1\*, Hidayati1, Riri Jonuarti1, Yenni Darvina1 |
| |  |  | | --- | --- | | 1 *Department of Physics, Padang state University, Jalan.Prof. Hamka. Air Tawar Barat, Padang, 25171 Indonesia*  *Corresponding author. Email:* *kasihsyirpia12@gmail.com & yennidarvina@fmipa.unp.ac,id* | | | **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 greaterzthe sound absorption coefficient, the betterethe material is used as a sound dampening material. In this study, the composition of polypropylene plastic and paper sludge was 40:60, and variations in fiber composition of 0%,1%,2%,3% of the total weight of the composite panel. The bagasse fiber used is a fiber that has been alkalized to a good mechanical interlocking between the fiber and the matrix.*  *Based on the results, the highestasound absorptionrcoefficienteis 0.98 atea frequency of 8000 Hzsfor a 3% fiber composition. The lowest soundeabsorptionrcoefficient is 0.63 at arfrequency of 2000eHz, for a 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 soundaabsorption coefficient, the better the materialeis used as sound material. All sample variations meet the standard requirements as noise materials in buildings, namely 0.15* | | |  | | | **Keywords :** : Composite Panel, Bagasse Fiber, Plastic/Polypropylene Waste, Paper Sludge, Sound Absorption Coefficient. | | |  | **This is an open access article distributed under the Creative Commons 4.0 Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. ©2019 by author and Universitas Negeri Padang.** | |  | | |  | | |

# INTRODUCTION

Noise isadefined 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, vacuum cleaners, and others. Noise can cause emotional disturbances, anxiety, and stress. So that it has an impact on psychological, 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 yarn spinning industry, 29% of employees 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 materials [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 reflect, absorb, or transmit. The greater the soundaabsorption coefficient (α), the betterathe 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 environmentally materials as sound-absorbing composites, thereby reducing noise and tackling environmental problems. Compositeematerial is anmaterial composed of two or more constituents with differentaphysical and structural properties, which 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 needs [8]. Composite materials are composed of reinforcement as a reinforcement and a matrix as a binder.

Matrix has an important role in composites, as a material that binds fibers into a structural unit, so that the fiber and matrix are closely related. 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. Plastic waste in Indonesia is in fourth place after food waste, twigs, and paper/cardboard with a percentage of 17.07%. [9]. It shows that the consumption of plastic in Indonesia is still very high. The selection comes from plastic waste 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. 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 [10].

This study also used fillers in composite panels. The filler used in the manufacture of composites is usually a form of fiber or powder [11]. The filler used in this research is paper sludge. Sludge waste continues to increase in line with the growth of the pulp and paper industry, as in the January-April 2019 period, paper exports increased from the same period in 2018 by 6.75%, from 1.6 million tons to 1.74 million tons. so that this will have an impact on the environment if the paper sludge waste is not handled properly [12]. Paper sludge contains lime, clay, calcium carbonate, and can be an alternative to inorganic fillers and reinforcement in the manufacture of thermoplastic composites [13] 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 [14].

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 caneincrease the value of the sound absorption coefficientathe 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 highestesoundcabsorption coefficientwvalue is 0.961 at a frequencyrof 1000 Hzaobtainedeat 1 gtmass ofrbagasse fiber. [15] 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 [16].

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 that 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 propertiesaof composite panelsousing a plasticrwaste matrix of polypropylene and filler using paper6sludge. In this study, the impedance tube method is0used to determine the0reflection and absorption coefficients0of 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 the following problems are formulated:

1. How does the composition of bagasse fiber affectbthe sound absorption coefficient and soundtreflection coefficient of the bagasse fiber composite panel with polypropylene plastic waste matrix and paper sludge filler?
2. How does the effect of frequency onbthe value of theesound absorption coefficient and theesound reflection coefficient on the bagasse fiber composite panel with polypropylene plastic waste matrix and paper sludge filler?
3. What are the acoustic properties of the bagasse fiberccompositeiwith polypropyleneeplastic waste matrix andepaper sludgerfiller?

# METHOD

Based on the background and problems that have been stated, this researchcaims to:

1. Knowing the effect0of bagasse fiber composition on thecvalue of the sound absorptionbcoefficient and sound reflection coefficient of the bagasse fiber composite panel with polypropylene plastic waste matrix and paper sludge filler
2. Knowing the effect of frequency on thecvalue 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
3. Knowing the acoustic properties of bagasse fiber compositesewith 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% of the total weight of the composite panel. The bagasse fiber used is the fiber that has been alkalized so that it can increaseethe interface adhesionabetween the fiber and the matrix to produce good mechanicalainterlocking [17].

A. Materials preparation

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.

1. 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 is 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 then 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 [17]. The bagasse fibers are rinsed with running water then dried and dried in the sun to dry. The dried bagasse fiber is weighed according to the predetermined and ready to use. Bagasse fiber that is ready to be used can be seen in Figure 1 below.



Fig. 1 Bagasse Fiber

1. 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 is then cleaned to remove dirt. Polypropylene plastic is then used with a 40% composition. PP that has been chopped can be seen in Figure 2.



Fig. 2. Polypropylene plastic waste

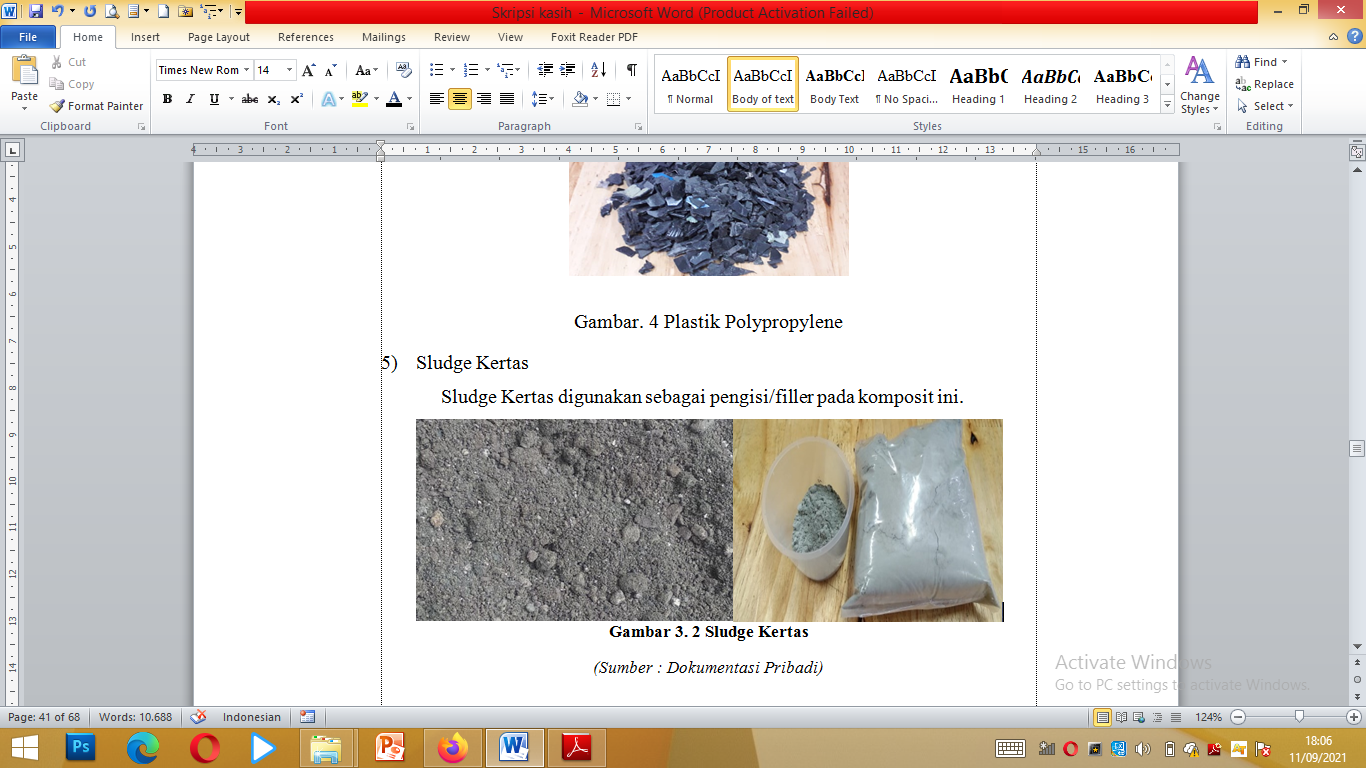
1. 3) Preparation of sludge paper waste: Paper sludge was taken in PT. Indah Kiat pulp & paperamill in Perawang,rRiau. Sludge paper iscthen dried in theesun for +- 4 days. then the paper sludge was dried using an oven at 110ᵒ for +-6 hours. [14] After the sludge is dried, it is pulverized and filtered 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.
2. 

Fig. 3. Paper Sludge

*B.* *Composite panels formulation and manufacturing*

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 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 180ᵒC. 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 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 panel composites

C. *Materials acoustic characterization*

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 [19].

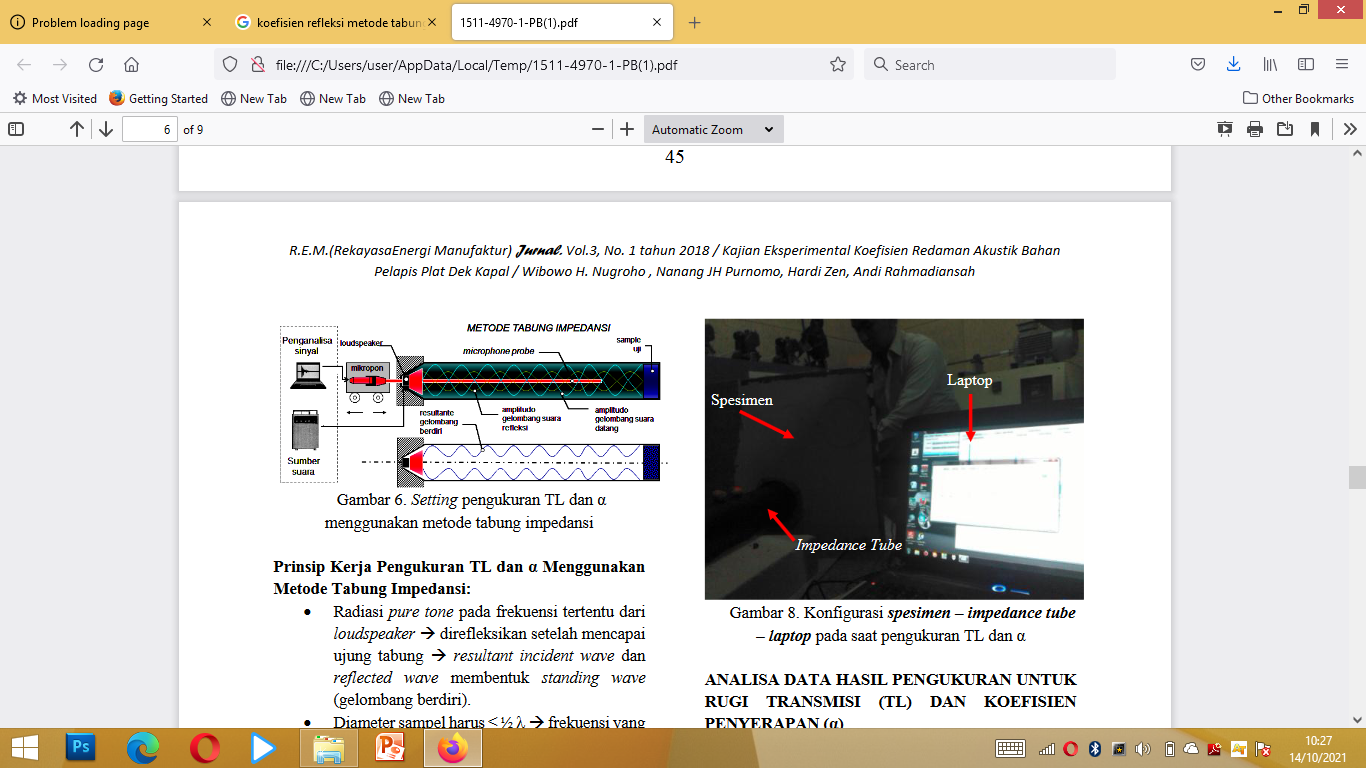


Fig. 5 Impedance tube testing[12]

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 thecmaximum pressure (antinode) to the minimumcpressure (node) is the standing waverratio 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 [20]. Determination of the sound absorption coefficient in the impedancertube method by calculating the ratio0of the maximumcpressure amplitudeeto the minimum pressureaamplitude. This pressure amplitude ratio is calledethe standing wave ratior(SWR) [21].

*SWR* =..............................................................................................................1

For the reflection coefficientican be determinedcby the following equation:

=..............................................................................................2

For the absorbtion coefficientccan be determinedcby the followingcequation:

*α=* 1..............................................................................3

# RESULTS AND DISCUSSION

The resultscof this studyqare the valuescof the sound absorptionccoefficienteand the sound reflection coefficient resulting from the variation of the sample that has been made, namely 0%, 1%, 2%, and 3%. by varying the frequency, namelyr500 Hz, i1000 Hz, i2000 Hz, i4000 Hz, andi8000 Hz.

The sound absorption and reflection coefficient tests were carried out according to the impedance tube method by determined 2 and 3.. The test wasxcarried out at the Physics MaterialswLaboratory, Andalas University. The devices used in the test include impedance tubes, microphones, loudspeakers, amplifiers, sound generators, and oscilloscopes. The samplesis placed at the end of the tubeain 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 standingswave ratio, which is thewratio between the maximumwamplitude and the minimumwamplitude 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 is data from the test results of each sample with variations in the mass of the fiber used. The following table1 is the result of data analysis of the sound reflection coefficient value of each sample variation.

Tabel 1. Sound Reflection Coefficient

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

Based on the data that has been obtained, the highestesound reflection coefficientrvalue is 0.37 ateafrequency of 2000 Hz with a sample without fiber or 0%. The lowest sound reflection coefficient valueeis 0.02 at a frequency of 8000 Hzwwith 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 beeseen that the sound reflection coefficientedecreases with theaaddition 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 data that has been obtained, the sound absorption coefficient can beeseen in Tabler2 below.

Tabel 2. Sound AbsorbtionrCoefficient

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

Based on Table. 2 it canebe seen thatethe soundrabsorptionccoefficient is lowest inathe samplecwith 0% fiber andethe highest sound absorptionecoefficient is in the sample with the most fiber, which is 3%. Theesound absorption coefficientoof all variations of theeresulting sampleapasses the requirements as a sound-absorbing material, namely 0.15 according to the ISO 11654 standard [22]. The following is a graphic image of the relationship between variations in fiber composition and the value of the sound absorption coefficient.

Fig. 7. Graph of the correlation between fiber compositionsand the sound absorption coefficiente

Based onrFigure 7, it canebe seen that the sound absorptionecoefficient increases with the addition of the fiber composition used. So the correlation between theesound absorption coefficient withwthe addition of variations in fiber composition is directly proportional.

Based on the data analysis, the composite sample has a decrease in the soundeabsorptionbcoefficient at a frequencyeof 2000 Hz. This canebe seen in Figure 8 below.

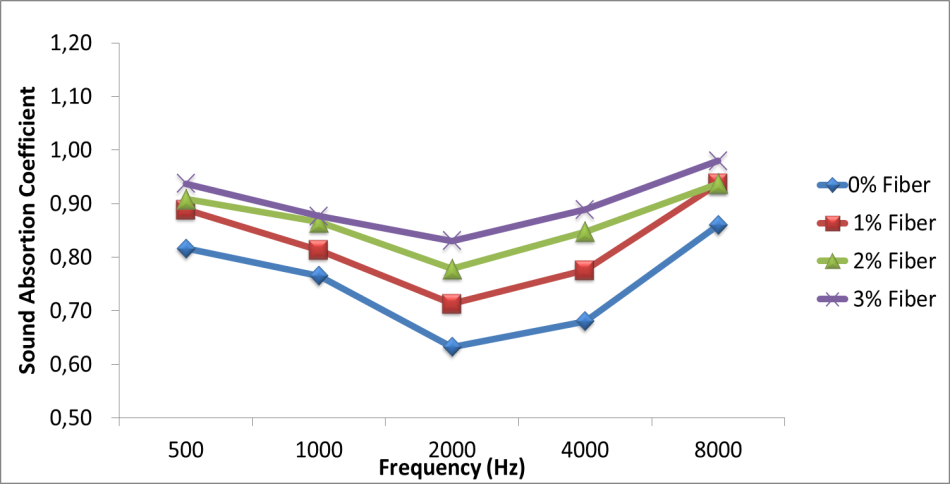


Fig. 8.iGraph ofocorrelation betweern Frequency and the sound absorption coefficient on the sample variation

Based on the graph, it canebe seen that thercomposite 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.

# CONCLUSION

Based on the research that has regarding the effect of bagasse sugarcane fiber composition with polypropylene matrix and paper sludge filler on the acoustic properties of composite panels, the conclusions are:

1. The more composition of bagasse sugarcane fiber used in the composite sample, the higher theevalue of theasound absorption coefficientaproduced. So that the composition of bagasse fiber can increase the sound absorption coefficient of the compositeasamples.
2. All variations of the composite sample have a decrease in the value of theesound absorptionecoefficient at a frequency of 2000Hz, namely in theemedium frequency range, and have the best sound absorption coefficientevalue at loweand high frequencies,enamely the frequency of 500 and 8000 Hz. So that the composite sample is good for use in low and high-frequency ranges.
3. The composite sample of bagasse fiber with polypropylene plastic waste matrix and paper sludge filler has good acoustic properties, this can be seenain the soundaabsorption coefficient produced.aTheelowest sound absorptionecoefficient is 0.63 and, the highestais 0.98. So that all sample variations exceed the standard requirements as sound-dampening materials in buildings, namely 0.15.

REFERENCES

1. Dewanty. R.A.Sudarmaji.(2015). Analisis Dampak Intensitas Kebisingan Terhadap Gangguan Pendengaran Petugas Laundy. Impact Analysis Of Noise Intensity With Hearing Loss On Laundry Worker. *Jurnal Kesehatan Lingkungan*. 8(02).229-237
2. Sumardiyono, R. Wijayanti, Hartono, A. H. Sutomo (2019). Kebisingan Lingkungan Kerja : Kerentanan Kesehatan Pada Pekerja. *Jurnal Kesehatan Lingkungan.* 11(4) ISSN: 1829 - 7285 E-ISSN: 2040 - 881X https://doi.org/10.20473/jkl.v11i4.2019.267-275J..
3. Darlani, Sugiharto.(2017). Kebisingan Dan Gangguan Psikologis Pekerja Weaving Loom Dan Inspection PT. Primatexco Indonesia. *Jurnal of Health Education* 2(2) ISSN 2527-4252
4. Hayat Wahyudil, Syakbaniah, Yenni Darvina. (2013). Pengaruh Kerapatan Terhadap Koefisien Absorbsi Bunyi Papan Partikel Serat Daun Nenas (Ananas Comosus L Merr). PILLAR OF PHYSICS, Vol. 1. 44-51 http://dx.doi.org/10.24036/501171074
5. Laksono. A.D. Ernawati. L & Maryanti. D.(2019). Pengaruh Fraksi Volume Komposit Polyester Berpen-Guat Limbah Serbuk Kayu Bangkirai Terhadap Sifat Material Akustik. *Rekayasa Mesin*.10(3). eISSN 2477-6041 artikel 8, pp. 277-285, 2019
6. Khotimah, K., S., & Soeprianto, H. (2015). Sifat Penyerapan Bunyi Pada Komposit Serat Batang Pisang (Sbp) – Polyester. *Jurnal Penelitian Pendidikan IPA,* 1(1), 91–101. <https://doi.org/10.29303/jppipa.v1i1.9>.
7. Nasution, A., Wahab, A., & Nuari, D. (2018). Analisis Pengaruh Benang Wol Dan Limbah Batang Pisang Dalam Rancangan Produk Komposit Peredam Bunyi Ruang Akustik. Jurnal Sistem Teknik Industri, 20(2), 53–62. <https://doi.org/10.32734/jsti.v20i2.490>.
8. Fadillah Ulfah,Syakbaniah, Yenni Darvina.(2015).Pengaruh Variasi Komposisi serat tandah kosong sawit (TKS) dan serbuk kayu terhadap sifat fisis dan sifat mekanis papa partikel. PILLAR OF PHYSICS, Vol 5. 113-120.http://dx.doi.org/10.24036/1836171074
9. SIPSN. https://sipsn.menlhk.go.id/sipsn/public/data/komposisi
10. Dea, A., Hidayat, S., Farid, M., & Wibisono, T. (2019). Karakterisasi Morfologi Sifat Akustik dan Sifat Fisik Komposit Polypropylene Berpenguat Serat Dendrocalamus Asper untuk Otomotif. Jurnal Teknik ITS ISSN: 2337-3539 (2301-9271 Print) 6(02) 2–7. https://doi.org/10.12962/j23373539.v6i2.25275
11. Said H., L Kano Mangalla & B.Sudia. (2019). Analisa Mampu Redam Suara Komposit Serat Sabut Kelapa Dengan Matriks Polyvinyl Acetate (Lem Fox). ENTHALPY-Jurnal Ilmiah Mahasiswa Teknik Mesin. 4(03) e-ISSN: 2502-8944
12. Kinda, M., Turnip, N., Sitorus, C., & Sibuea, P. (2020) Kajian Literatur Pengaruh Tekanan dan Temperatur Kempa Serta Jenis Adhesive Terhadap Sifat Fisik dan Mekanik Particleboard Dari Limbah Sludge Industri Pulp Dan Kertas. JURNAL ILMIAH SIMANTEK 4(04) ISSN. 2550-0414
13. Yang, X., Wang, W., & Huang, H. (2015). Resistance of Paper Mill Sludge/Wood fiber/High-Density Polyethylene Composites to Water Immersion and Thermotreatment. Journal Of Applied Polymer Science. 132(11) 41655, 1–7. http://doi.org/10.1002/app.41655
14. Hidayani, T. R., & Pelita, E. (2018). 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. Prosiding Seminar Nasional Kulit, Karet dan Plastik ke-7 hal 119–126. ISSN : 2477-3298
15. Ridhola.F & Elvaswer.(2015) Pengukuran Koefisien Absorbsi Material Akustik Dari Serat Alam Ampas Tebu Sebagai Pengendali Kebisingan. *JURNAL ILMU FISIKA (JIF).* 7(1). ISSN 1979-4657
16. Sari,T.P & Elvaswer. (2020). Pengaruh Densitas Panel Serat Ampas Tebu terhadap Koefisien Absorbsi Bunyi dan Impedansi Akustik. *Jurnal Fisika Unand (JFU)* 9(3) hal 304-310 ISSN: 2302-8491 (Print); 2686-2433 (Online). https://doi.org/10.25077/jfu.9.3.304-310.2020
17. Khumar.A. P Mishra,& S.K Mehar.2011. Effect Of Surface Treatment On The Mechanical Properties Of Bagasse Fiber Reinforced Polymer Composite. BioResources 6(3), 3155-3165.
18. Fajriyanto dan Feris Firdaus.(2008) Panel Dinding Bangunan Ramah Lingkungan Dari Komposit Limbah Pabrik Kertas (Sludge), Sabut Kelapa Dan Sampah Plastik: Pengaruh Komposisi Bahan Dan Beban Pengempaan Terhadap Kuat Lentur (Bending) *Prosiding Seminar Nasional Teknoin Bidang Teknik Mesin* ISBN: 978-979-3980-15-7
19. Nugroho.W.H Nanang J.H. Purnomo. Hardi Zen. & Andi Rahmadiansah. (2018). Kajian Eksperimental Koefisien Redaman Akustik Bahan Pelapis Plat Dek Kapal. R.E.M (RekayasaEnergiManufactur).3(1) ISSN.2527-5674 (print), ISSN 2528-3723 (online) Journal Homepage: http://ojs.umsida.ac.id/index.php/rem DOI: <https://doi.org/10.21070/r.e.m.v3i1.1511>
20. ASTM International (2016). Standard Test Method For Impedance And Absorbtion Materials By Impedance Tube Method. ASTM. C384-04.ASTM: United State.
21. Bruel & Kjaer. (1955). Technical Review. Teletechical.Acoustical and Vibrational Research.Standing wave apparatus.*PEARL. Perkins Electro Acoustic Research Lab.*
22. Khuriati.A.Eko Komaruddin. Muhammad Nur. 2006. Disain Peredam Suara Berbahan Dasar Sabut Kelapa dan Pengukuran Koefisien Penyerapan Bunyinya. *Berkala Fisika.* 9(1). 43-53 ISSN : 1410 – 9662