JPPIPA 10(4) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Determination of Sound Absorption and Water Absorption by Composite Boards Made from Egg Cardboard

Riska Aldania[1*], Suparno[1]

[1] Department of Physics Education, Faculty of Mathematics and Natural Sciences, Yogyakarta State University, Yogyakarta, Indonesia.

Received: January 3, 2024
Revised: February 17, 2024
Accepted: April 25, 2024
Published: April 30, 2024

Corresponding Author:
Riska Aldania
riskaaldania.2022@student.uny.ac.id

DOI: 10.29303/jppipa.v10i4.2830

Abstract: This research aims to determine the effect of the thickness of composite boards made from egg cardboard on sound absorption and water absorption. Composite boards are produced by crushing egg cartons with a blender, mixing them with water and tapioca glue to form slurry and then molding them to thicknesses varying from 1, 2, and 3 cm. The sound absorption results were measured using a Sound Level Meter GM1352, while the water absorption capacity was determined using the mass ratio before and after immersion. The results show that the sound absorption capacity of a composite board made from egg cardboard with a thickness of 1 cm is 6.58%, a thickness of 2 cm is 10.87%, and a thickness of 3 cm is 16.05%, while the water absorption capacity of a composite board made from egg cardboard with a thickness 1 cm is 29.41%, 2 cm thickness is 31.43%, and 3 cm thickness is 32.91%. This shows that the greater the thickness of the composite board made from egg cartons used, the greater the sound absorbed. Likewise, with the water absorption test, the results showed that the thicker the composite board made from egg cartons used, the greater the water absorption capacity produced.

Keywords: Composite board; Egg cardboard; Sound absorption; Sound level meter; Water absorption

Introduction

Currently, noise pollution in various places has reached an alarming level which can cause a lot of noise disturbance. This is due to the increased use of industrial machinery, transportation, shopping centers, airports and other sound sources (Rohim et al., 2020; Syahputra & Elvaswer, 2023). This noise causes disruption in many areas such as education, work and other daily activities. Continuous noise can have a negative impact on health (Aziza & Elvaswer, 2022). The disturbances felt include feelings of discomfort, lack of concentration, difficulty sleeping, increased stress, increased heart rate, hypertension and even hearing problems (Gupta et al., 2018; Oguntunde et al., 2019).

Due to this disturbance, it is necessary to make efforts to reduce the noise level, one of which is using materials that can reduce sound in the room (Bahri et al., 2016) or installing acoustic materials in the design of the room (Milawarni & Saifuddin, 2017; Putramulyo et al., 2018). Materials commonly used to reduce noise include mineral wool, glass fiber, acoustic tiles, foam, carpet, glass wool, and other synthetic materials (Ulrich & Arenas, 2020; Syahputra & Elvaswer, 2023). The use of this material is often found in buildings to control the sound quality in the room (Putra et al., 2018).

These synthetic materials are used because they are proven to be very strong, durable, resistant to water absorption and bacterial growth (Pickering et al., 2016). These materials often provide a high sound absorption coefficient, but are considered environmentally unfriendly (Astrauskas et al., 2022). The production of these synthetic materials not only has a negative impact on the environment, especially because it contributes to global warming, but also poses risks to human health and well-being (Galbrun & Scerri, 2017).

How to Cite:
Aldania, R., & Suparno. (2024). Determination of Sound Absorption and Water Absorption by Composite Boards Made from Egg Cardboard. *Jurnal Penelitian Pendidikan IPA*, *10*(4), 1801–1808. https://doi.org/10.29303/jppipa.v10i4.2830

Materials that can absorb sound are soft, contain high levels of cellulose, absorbent panels, and are porous. Porous materials function as cavity resonators (Putra, 2020). Any material that is porous and has a high sound absorption coefficient can be used as a sound absorber (Sharma et al., 2020). So sound dampening materials are grouped into 3 groups including porous materials, absorbing panels, and cavity resonators (Ikhsan et al., 2016). Factors that can absorb sound include thickness, density and porosity (Amares et al., 2017). Sound-absorbing materials that can absorb as much sound as possible rather than reflect it are considered good sound-absorbing materials (Zulhiyah et al., 2022). Materials around us that have these properties are glasswool, rockwool, carpet and cardboard. Glasswool, rockwool and carpet are relatively expensive compared to cardboard, even though cardboard has only been treated as waste or trash. This causes researchers to prefer raw materials from waste as materials to be used in making sound absorbers (Hoque et al., 2022). Such an approach is becoming more attractive today as legislation in most countries is moving towards reducing or reusing waste in search of new, environmentally friendly alternatives for noise control (Astrauskas et al., 2022).

Waste materials have become the focus of researchers in making noise dampening materials. Safana et al. (2023) have conducted research on coconut shells as a sound-absorbing material with good ability to absorb noise. Aziza et al. (2022) also researched durian skin waste which can be used as a good noise control material. Apart from that, paper waste and husk ash combined with polyester resin can be used as a sound dampening material (Isran et al., 2018). It is proven that there is a lot of waste around us, such as agricultural waste, paper waste and others, which can be processed into noise dampening devices. One of them is an egg carton.

Cardboard is produced from recycled paper, and is a light and cheap material, mostly available throughout the world (Asdrubali et al., 2016). Egg cartons consist of a mixture of materials, including natural fibers and other ingredients. The use of natural alternative materials, either on their own or as components of composite materials will offer major advantages, especially in terms of environmental issues. Natural fibers are relatively cheap, available, abundant, environmentally friendly, and usually have low density (Taban et al., 2019a; Nikon & Elvaswer, 2023). Measurements carried out on natural fiber samples show that the material has a good sound absorption coefficient (Berardi & Iannace, 2017). Therefore, there will be double benefits if the cardboard can be used as a composite board material. Composite boards are produced from mixing two or more different elements to produce a material that has superior properties compared to the parent material (Hoque et al., 2022). This composite board is used as a sound-absorbing material.

Sound absorption changes the form of sound energy into another form when it passes through a certain material. Energy loss is caused by reflection and absorption by the medium (Putramulyo et al., 2018). The incoming sound energy will cause friction and turn into heat (Waryati et al., 2017). Temperature and humidity can affect sound absorption (Ringkeh et al., 2016). Material vibrations also contribute to the loss of sound energy (Yang et al., 2020). Vibrating objects will produce sound waves and density disturbances occur in a medium through the interaction of medium molecules along the direction of wave propagation (Putra, 2020). The intensity of the sound will be reduced if you use a material that is capable of absorbing sound so that the sound you hear can be more controlled (Putra, 2020). Sound waves that pass through a material will be reflected, transmitted and absorbed (González, 2019) by the material resulting in a reduction in the intensity of the sound waves (Haryadi et al., 2021). The more fibrous the material, the better the absorption capacity (Rus et al., 2017). Apart from the choice of material, the maximum efficiency of a sound absorbing material occurs in the thickness of the material where the thickness of the material plays an important role in sound absorption (Rus et al., 2017). So the thickness of a material can affect its sound absorption capacity.

Apart from measuring noise levels, composite boards made from cardboard can be measured for their water absorption capacity. Water absorption by composite boards is seen from their ability to absorb water when soaked for a specified time (Bactiar et al., 2015). The water that can be absorbed by the board is influenced by the shape of the board's particles. The attractive force of water molecules on the hydrogen bonds found in cellulose, lignin and hemicellulose can absorb water (Meldayanoor et al., 2020).

There are still a few who process egg cartons into sound dampening materials and few have researched the effect of egg carton thickness on sound absorption and water absorption. Therefore, researchers are interested in knowing whether the thickness of composite particle board made from egg cardboard has an effect on sound absorption and water absorption?

Method

This type of research is quantitative research with experimental methods. This composite board was tested for sound absorption and water absorption. The test was carried out at the Yogyakarta State University wave laboratory. The flow of this research can be seen in Figure 1.

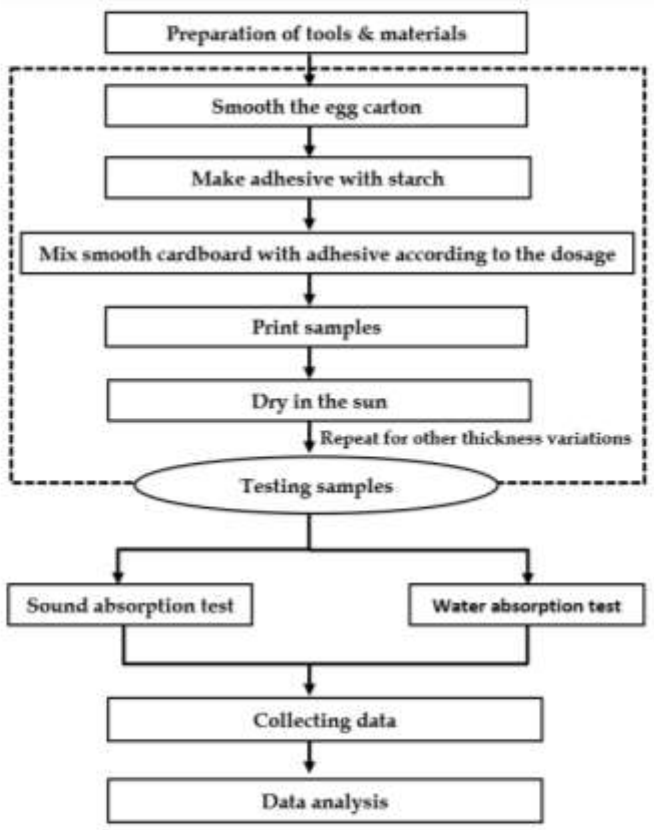

Figure 1. Research flow diagram

Sample Making

This research began by making 3 samples with a combination of thicknesses, namely 1 cm, 2 cm and 3 cm. The sample was made from a mixture of egg cartons with artificial adhesive produced from tapioca flour and water. The egg cartons are crushed with a blender as shown in figure 2, then mixed with the artificial adhesive provided. Artificial adhesive is made from a combination of 20 grams of tapioca flour and 200 milliliters of water, then heated until it thickens into a slurry. Egg cartons that have been mixed with artificial adhesive are molded into paralon and dried in the sun for several days so that the samples are dry and suitable for testing.

Figure 2. Process for making composite boards

Sound Absorption Testing

The research was carried out in a soundproof room to reduce the influence of noise from outside, so that the test could be carried out well. The testing process was carried out using a tube-shaped paralon. The end of the paralon is the sound source and the other end is the noise detection tool, while the sample is in the middle of the paralon, namely between the sound source and the noise detection tool. The sound detection flow can be seen in Figure 3.

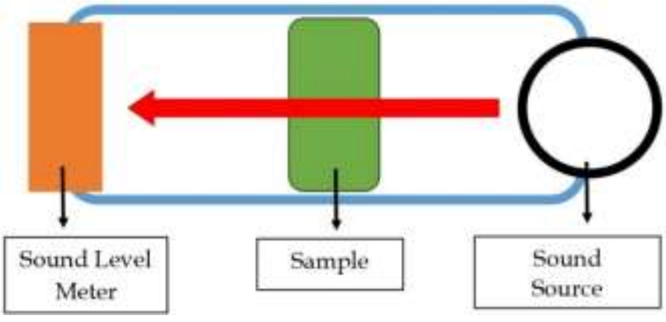

Figure 3. Flow of sound absorption testing

The sound results were measured using the GM1352 Sound Level Meter as in Figure 4.

Figure 4. GM1352 sound level meter

The test steps carried out began by measuring the sound without sound dampening media (composite board). The next step is that noise is measured using a composite board as a medium for sound absorption. This test was carried out as many samples as were used with the same frequency, namely 1,000 Hz. The equation used to determine the effectiveness of sound absorption is written as equation 1.

$$DSS = \frac{KTP - KP}{KP} \times 100\% \quad (1)$$

Description:
KTP = untreated noise level (dB)
KP = noise level with treatment (dB)
DSS = Sound absorption capacity

Water Absorption Testing

The measurement of water absorption capacity was carried out using the mass ratio before and after immersion. The test begins by measuring the mass of the sample before immersing it in water (m_1). Next, the sample was dipped into water for 10 seconds. The mass that has been dipped is measured again in the wet state (m_2). The equation used to determine water absorption capacity is written as equation 2.

$$\mathrm{DSA} = \frac{\mathrm{B_2} - \mathrm{B_1}}{\mathrm{B_2}} \times 100\% \quad (2)$$

Description:
B_2 = sample weight before immersion (g)
B_1 = sample weight after immersion (g)
DSA = Water absorption capacity

Results and Discussion

Composite boards made from processed egg cartons will be tested for sound absorption. These samples can be seen in Figure 5. The process of collecting data on sound absorption capacity and water absorption capacity was carried out 3 times for 3 samples. The results of the Sound Level Meter GM1352 measurements are included in the noise reduction effectiveness equation, while the mass results before and after immersing the sample are included in the water absorption capacity equation.

Figure 5. Composite board sample

Sound Absorption

The sound absorption value of the composite board made from egg cartons varies with each sample thickness. The results show that the sound absorption capacity of a 1 cm thickness composite board is 6.58%, a 2 cm thickness is 10.87%, and a 3 cm thickness is 16.05%. These results can be seen in Table 1.

Table 1. Sound Test Data

Thickness (cm)	Sound Without Media (Db)	Sound With Media (Db)
1	100.3	93.7
2	100.3	89.4
3	100.3	84.2

The data obtained from testing each sample calculated the sound absorption capacity from equation 1. The results of the sound absorption capacity can be seen in Figure 6.

The treatment of variations in the thickness of the composite board made from egg cartons greatly influences the sound absorption capacity. The thicker the composite board, the lower the noise level produced, and vice versa, the thinner the composite board, the higher the noise level. The highest average value of sound absorption at a thickness of 3 cm is 17.35%, while the lowest average value of sound absorption is at a thickness of 1 cm, namely 6.58%. Variations in the sound absorption value of the composite board are influenced by the thickness of the composite board. This is in line with research conducted by Waryati et al. (2017) which states that the sound absorption coefficient value increases with the addition of materials. Azkorra et al. (2015) stated that as the sample thickness increases, the sound absorption coefficient also increases. It can be interpreted that increasing thickness can increase sound absorption capacity.

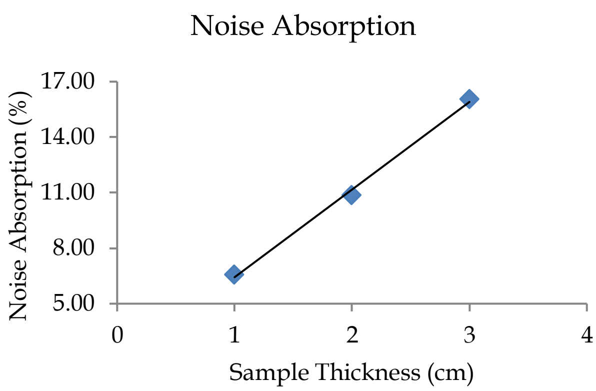

Figure 6. Sound absorption test results

Judging from the results of sound absorption by composite boards, it can be interpreted that egg cartons can absorb sound well. Egg cartons can be used as a soundproofing medium because the material is capable of reducing noise. This was also proven by Ritonga et al. (2022) that egg try can be used as a sound dampener in a room and is considered a better sound dampening medium than ordinary newspapers or cardboard. Other research also found that the results of the sound absorption coefficient on cardboard samples showed that this material had a good absorption coefficient only at medium and high frequencies (Berardi & Iannace, 2017). If the composite board is added with cardboard fiber, it will increase noise absorption.

The addition of fiber causes more pores to form in the composite structure, so the density increases. It makes sound waves more difficult to escape and increases the sound absorption coefficient (Pöhler et al., 2017; Xu et al., 2018). In addition, the addition of materials can cause the composite to become hollow. The cavities formed in the composite specimen will absorb more sound because more sound energy hitting the specimen surface as a whole will be absorbed (Nurbaiti et al., 2022). This is in line with research conducted by Sari et al. (2022) that the addition of fiber to the composite causes the absorption coefficient to increase due to the cellulose content and fiber structure. In porous absorbers made of fibrous materials, sound waves propagate through a network of cavities (Taban et al., 2019b). Because this cavity network has a very small size and the interaction of waves with the walls, viscous and thermal dissipation occurs which converts sound wave energy into heat (Rwawiire et al., 2017). Therefore, the pores on the composite board are useful for capturing sound waves that pass through.

Water Absorption Capacity

The water absorption test was carried out after the sound absorption test using the same egg cardboard composite board with thickness variations of 1, 2, and 3 cm. The water absorption capacity is seen from mass measurements before immersion and after immersion with a controlled time so that the value of the water absorption capacity of composite boards made from egg cardboard varies with each thickness of the composite board. This test is to determine the level of water absorption by the composite board. Data obtained from the water absorption test can be seen in Table 2.

Table 2. Water Absorption Test Data

Thickness (cm)	B0 (g)	B1 (g)	Water Weight (g)
1	51	66	15
2	70	92	22
3	158	210	52

The data that has been obtained from testing each sample is calculated for the water absorption level from equation 2. The results of the water absorption level can be seen in Figure 7.

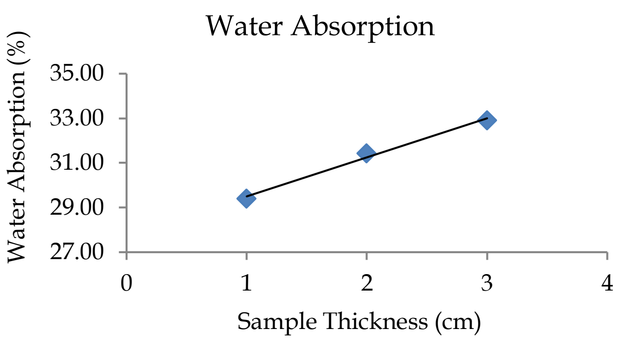

Figure 7. Water absorption test results

The results show that the water absorption capacity of a 1 cm thickness composite board is 29.41%, a 2 cm thickness is 31.43%, and a 3 cm thickness is 32.91%. The difference in thickness of the composite board made from egg cardboard also greatly influences water absorption capacity. The highest water absorption value at a thickness of 3 cm is 32.91%, while the lowest average value for water absorption at a thickness of 1 cm is 29.41%. Water absorption by composite boards is seen from the ability to absorb water when soaked for a specified time (Bactiar et al., 2015). The results of the water absorption capacity are higher if a thicker composite board is used, and vice versa, the thinner the composite board used, the lower the water absorption capacity. This is in line with research conducted by Ismail et al. (2021) who stated that the high water absorption results were influenced by increasing the volume of powder filling material. He also mentioned that another factor in water absorption is the random distribution, position and orientation of the composition of the material on the surface which is the source of water absorption. The adhesive used also affects the high water absorption capacity, apart from that the size of the powder material used is not uniform which results in when mixing the adhesive with the material there are still voids so that water can easily enter the composite board (Meldayanoor et al., 2020). The presence of empty space in the board that is not covered by adhesive can accommodate water between the particles (Hasan et al., 2020). Safana et al. (2023) also found that the thicker the partition board material, the greater the water that can be absorbed. Therefore, the thickness of the composite board made from egg cardboard can affect the water absorption capacity.

Conclusion

This research can be concluded that the thicker the composite board made from egg cartons used, the greater the sound absorbed so that it can reduce the noise level. Likewise with the water absorption test, the thicker the egg cardboard composite board used, the greater the water absorption capacity produced. The thickness of the composite board made from egg cardboard affects sound absorption and water absorption.

Acknowledgments
Thank you to all parties who helped in this research.

Author Contributions
The first author performed the conceptual analysis, materials creation, and data collection. Meanwhile, the second author carried out conceptual analysis, writing procedures and research flow.

Funding
This research received no external funding.

Conflicts of Interest
This research is to help complete electrodynamics course assignments and final assignments. The authors declare no conflict of interest.

References

Amares, S., Sujatmika, E., Hong, T. W., Durairaj, R., & Hamid, H. S. (2017). A Review: Characteristics of Noise Absorption Material. *Journal of Physics: Conference Series*, *908*, 012005. https://dx.doi.org/10.1088/1742-6596/908/1/012005

Asdrubali, F., Pisello, A. L., D'Alessandro, F., Bianchi, F., Fabiani, C., Cornicchia, M., & Rotili, A. (2016). Experimental and Numerical Characterization of Innovative Cardboard Based Panels: Thermal and Acoustic Performance Analysis and Life Cycle Assessment. *Building and Environment*, *95*, 145-159. https://doi.org/10.1016/j.buildenv.2015.09.003

Astrauskas, T., Januševiˇcius, T., & Grubliauskas, R. (2022). Acoustic Panels Made of Paper Sludge and Clay Composites. *Sustainability*, *13*, 637. https://doi.org/10.3390/su13020637

Aziza, Y., & Elvaswer, E. (2023). Pengaruh Ketebalan Panel Akustik dari Limbah Kulit Durian terhadap Koefisien Absorbsi dan Impedansi Akustik. *Jurnal Fisika Unand (JFU)*, *11*(2), 208-213. https://doi.org/10.25077/jfu.11.2.208-213.2022

Azkorra, Z., Pérez, P., Coma, J., Cabeza, L. F., Bures, S., Álvaro, J. E., Erkoreka, A., & Urrestarazu, M. (2015). *Applied Acoustics*. 89. 46-56. http://dx.doi.org/10.1016/j.apacoust.2014.09.010

Bactiar, S., Sulistyowati, E. D., & Catur, A. D. (2015). Analisis Sifat Penyerapan Air dan Indeks Nyala Api pada Papan Komposit yang Diperkuat Serat Daun Pandna Duri dan Limbah Serbuk Gergaji Kayu Sengon dengan Resin Polyester. *Dinamika Teknik Mesin*, *5*(2), 73-81. Retrieved from https://dinamika.unram.ac.id/index.php/DTM/article/view/32

Bahri, S., Manik, T. N., & Suryajaya, S. (2016). Pengukuran Sifat Akustik Material dengan Metode Tabung Impedansi Berbasis Platform Arduino. *Jurnal Fisika FLUX*, *13*(2), 148-154. Retrieved from https://ppjp.ulm.ac.id/journal/index.php/f/article/view/3460

Berardi, U., & Iannace, G. (2017). Predicting the Sound Absorption of Natural Materials: Best-Fit Inverse Laws For The Acoustic Impedance and The Propagation Constant. *Applied Acoustics*, *115*, 131-138. https://doi.org/10.1016/j.apacoust.2016.08.012

Galbrun, L., & Scerri, L. (2017). Sound Insulation of Lightweight Extensive Green Roofs. *Building and Environment*, *116*, 130-139. https://doi.org/10.1016/j.buildenv.2017.02.008

González, A. E. (2019). How Do Acoustic Materials Work? In Z. E. A. Fellah & E. Ogam (Eds.), Acoustics of Materials (pp. 1–17). *IntechOpen*. Retrieved from https://www.researchgate.net/publication/331351282_How_Do_Acoustic_Materials_Work

Gupta, A., Jain, K., & Gupta, S. (2018). Noise Pollution and Impact on Children Health. *The Indian Journal of Pediatrics*, *84*(4), 300–306. https://doi.org/10.1007/s12098-017-2579-7

Haryadi, A. N. M., Isnen, Y. Z., Khusaenah, N., Adira, K. F., Sa'adah, H., Muawanah, A., & Sari, K. (2021). Sifat Fisis dan Akustik Komposit Serat Daun Lidah Mertua dengan Serbuk Gergaji sebagai Peredam Bunyi. *Jurnal Rekayasa Mesin*, *16*(3). Retrieved from https://jurnal.polines.ac.id/index.php/rekayasa/article/view/3057/107706

Hasan, A., Yerizam, M., & Kusuma, M. N. (2020). Papan Partikel Ampas Tebu (Saccharum Officinarum) dengan Perekat High Density Polyethylene. *Politeknik Negeri Sriwijaya*, *11*(3), 8-13. Retrieved from https://jurnal.polsri.ac.id/index.php/kimia/article/view/3094

Hoque, M. B., Hannan, M. A., Mollah, M. Z. I., Faruque, M. R. I., & Khan, R. A. (2022). Physico-Mechanical Properties Enhancement of Pineapple Leaf Fiber (PALF) Reinforced Epoxy Resin-Based Composites Using Guar Gum (Polysaccharide) Filler: Effects of Gamma Radiation. *Radiation Effects and Defects in Solids*. https://doi.org/10.1080/10420150.2022.2043317

Ikhsan, K., Elvaswer, E., & Harmadi, H. (2016). Karakteristik Koefisien Absorbsi Bunyi dan Impedansi Akustik dari Material Berongga Plafon PVC Menggunakan Metode Tabung Impedansi. *Jurnal Ilmu Fisika (JIF)*, *8*(2), 64-69. Retrieved from http://jif.fmipa.unand.ac.id/index.php/jif/article/view/152

Ismail, A. I., Rasidah, R., & Haliq, R. (2021). Pengaruh Massa Filler Matriks terhadap Sifat Mekanik dan Daya Serap Air pada Komposit Cangkang Biji Karet. *Rekayasa Mesin*, *12*(2), 297-304. Retrieved from https://rekayasamesin.ub.ac.id/index.php/rm/article/view/808

Isran, I., Kadir, A., & Hasanudin, L. (2018). Pembuatan Material Komposit Resin Poliester yang Dipadukan Limbah Kertas dan Abu Sekam Padi sebagai Peredam Akustik. *Enthalpy: Jurnal Ilmiah Mahasiswa Teknik Mesin*, *3*(2). Retrieved from http://ojs.uho.ac.id/index.php/ENTHALPY/article/view/4212

Meldayanoor, M., Darmawan, M. I., & Norhalimah, N. (2020). Pembuatan Papan Komposit dengan Memanfaatkan Limbah Pelepah Kelapa Sawit dan Plastik Polyethylene Terephthalate (PET) Daur Ulang. *Jurnal Teknologi Agro-Industri*, *7*(1), 56-69. https://doi.org/10.34128/jtai.v7i1.116

Milawarni, M., & Saifuddin, S. (2017). Pembuatan Plazore dari Plastik Bekas dengan Media Minyak Jelantah dan Aplikasi sebagai Peredam Bunyi. *Jurnal Teknologi Kimia Unimal*, *6*(2), 52-62. Https://doi.org/10.29103/jtku.v6i2.475

Nikon, M., & Elvaswer, E. (2023). Karakterisasi Koefisien Absorpsi Bunyi dan Impedansi Akustik dari Panel Serat Tandan Kosong Kelapa Sawit dengan Menggunakan Metode Tabung. *Jurnal Fisika Unand (JFU)*, *12*(3), 493–499. https://doi.org/10.25077/jfu.12.3.492-498.2023

Nurbaiti, Y., Yulianto, A., & Nurbaiti, U. (2022). The Natural Composite of Sawdust Teak as a Sound Absorption Material Using The Resonator Space Method. *Physics Education Research Journal*, *4*(1), 29-34. https://doi.org/10.21580/perj.2022.4.1.8601

Oguntunde, P. E., Okagbue, H. I., Oguntunde, O. A., & Odetunmibi, O. O. (2019). A Study of Noise Pollution Measurements and Possible Effects on Public Health in Ota Metropolis, Nigeria. *Open Access Macedonian Journal of Medical Sciences*, 7(8), 1391–1395. Retrieved from https://www.researchgate.net/publication/332869062

Pickering, K. L., Efendy, M. G. A., & Le, T. M. (2016). A Review of Recent Developments in Natural Fibre Composites and Their Mechanical Performance. *Composites: Part A*, *83*, 98-112. https://doi.org/10.1016/j.compositesa.2015.08.038

Pöhler, T., Jetsu, P., Fougerón, A., & Barraud, V. (2017). Use of Papermaking Pulps in Foam-Formed Thermal Insulation Materials. *Nordic Pulp & Paper Research Journal*, *32*(3), 367–374. https://doi.org/10.3183/npprj-2017-32-03-p367-374

Putra, A. S. (2020). Penentuan Koefisien Serap Bunyi Papan Partikel dari Limbah Pelepah Kelapa Sawit. *Jurnal Surya Teknika*, *7*(2), 182–185. https://doi.org/10.37859/jst.v7i2.2386

Putra, A., Or, K. H., Selamat, M. Z., Nor, M. J. M., Hassan, M. H., & Prasetiyo, I. (2018). Sound Absorption of Extracted Pineapple-Leaf Fibres. *Applied Acoustics*, *136*, 9-15. https://doi.org/10.1016/j.apacoust.2018.01.029

Putramulyo, S., Wirawan, R., Alaa, S., & Qomariyah, N. (2018). The Analysis of Attenuation Coefficient and Acoustic Impedance of Ceiling Panel Using Impedance Chamber Method. *Indonesian Physical Review*, *1*(1). https://doi.org/10.29303/ipr.v1i1.7

Ringkeh, A. S., Pauzi, G. A., & Warsito, W. (2016) Pengukuran Suhu dan Kelembaban Udara Melalui Analisis Perubahan Tingkat Penyerapan Bunyi dan Kecepatan Gelombang Bunyi di Udara. *Jurnal Teori dan Aplikasi Fisika*, 4(2), 131-136. http://dx.doi.org/10.23960%2Fjtaf.v4i2.1328

Ritonga, K. N., Yulianti, M., Nurianti, T., Mustika, D., & Putri, M. D. (2022). Pemanfaatan Egg Try, Kertas, Koran dan Kardus sebagai Peredam Suara. *Gravitasi Jurnal Pendidikan Fisika dan Sains*, *5*(1), 7-10. Retrieved from https://ejurnalunsam.id/index.php/jpfs

Rohim, A. M., Fianti, F., & Nurbaiti, U. (2020). Potensi Sekam Padi dan Jerami sebagai Alternatif Material Akustik. *Physics Education Research Journal*, *2*(1), 35-42. https://doi.org/10.21580/perj.2020.2.1.4883

Rus, A. Z. M., Azahari, M. S. M., Kormin, S., Soon, L. B., Zaliran, M. T., & Sadrina, A. M. F. L. (2017). Hybrid Waste Filler Filled Bio-Polymer Foam Composites for Sound Absorbent Materials. *AIP Conference Proceedings*, *1877*. https://doi.org/10.1063/1.4999883

Rwawiire, S., Tomkova, B., Militky, J., Hes, L., & Kale, B. M. (2017). Acoustic and Thermal Properties of A Cellulose Nonwoven Natural Fabric (Barkcloth). *Applied Acoustics*, *116*, 177-183. https://doi.org/10.1016/j.apacoust.2016.09.027

Safana, M., Suparno, S., & Faresta, R. A. (2023). Physical and Mechanical Characteristics Analysis of Partition Composite Board Made of Coconut Shell Material. *Jurnal Penelitian Pendidikan IPA*, *9*(5). https://doi.org/10.29303/jppipa.v9i5.3221

Sari, K., Isnen, Y. Z., Utomo, A. B. S., & Sunardi, S. (2022). Properties of Pineapple Leaf Fibers with Paper Waste as An Absorbing-Composite to Reduce Nois. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, *11*(2), 175-184. http://dx.doi.org/10.24042/jipfalbiruni.v11i2.12356

Sharma, S, K., Shukla, S. R., & Sethy, A. K. (2020). Acoustical Behaviour of Natural Fibres-Based Composite Boards as Sound-Absorbing Materials. *Journal of the Indian Academy of Wood Science*, *17*(1). https://doi.org/10.1007/s13196-020-00255-z

Syahputra, P., & Elvaswer, E. (2023). Karakteristik Koefisien Absorpsi Bunyi dan Impedansi Akustik dari Serat Alam Menggunakan Metode Tabung. *Jurnal Fisika Unand (JFU)*, *12*(4). https://doi.org/10.25077/jfu.12.4.548-553.2023

Taban, E., Khavanin, A., Jafari, A. J., Faridan, M., & Tabrizi, A. K. (2019a). Experimental and Mathematical Survey of Sound Absorption Performance of Date Palm Fibers. *Heliyon*, *5*. https://doi.org/10.1016/j.heliyon.2019.e01977

Taban, E., Khavanin, A., Ohadi, A., Putra, A., Jafari, A. J., Faridan, M., & Soleimanian, A. (2019b). Study on the Acoustic Characteristics of Natural Date Palm Fibres: Experimental and Theoretical Approaches. *Building and Environment*, *161*(106274), 1–8. https://doi.org/https://doi.org/10.1016/j.buildenv.2019.106274

Ulrich, T., & Arenas, J. P. (2020). Sound Absorption of Sustainable Polymer Nanofibrous Thin Membranes Bonded to a Bulk Porous Material. *Sustainability*, *12*, 2361. https://doi.org/10.3390/su12062361

Waryati, W., Fritami, L. T., & Sarwono, E. (2017). Pemanfaatan Serabut Kelapa (Coco Fiber) dan Lem Kanji (Cassava Starch) Menjadi Papan Serat Komposit sebagai Material Pengendali Kebisingan. *Teknik Lingkungan Universitas Mulawarman*, *1*(1), 27-35. Retrieved from https://ejournals.unmul.ac.id/index.php/TL/article/view/1568/1215

Xu, X., Wang, H., Sun, Y., Han, J., & Huang, R. (2018). Sound Absorbing Properties of Perforated Composite Panels of Recycled Rubber, Fiberboard Sawdust, and High Density Polyethylene. *Journal of Cleaner Production*, *187*(6), 215–221. https://doi.org/https://doi.org/10.1016/j.jclepro.2018.03.174

Yang, T., Hu, L., Xiong, X., Petru, M., Noman, M. T., Mishra, R., & Militký, J. (2020). Sound Absorption Properties of Natural Fibers: A Review. *Sustainability*, *12*, 8477. https://dx.doi.org/10.3390/su12208477

Zulhiyah, F., Sholeh, M., Susanti. R. W, Subagiyo, L., Nuryadin, A. (2022). Analisis Perbandingan Nilai Efektivitas Koefisien Absorbsi pada Pelepah Pisang dan Eceng Gondok. *Kappa Journal*, *6*(2), 119-129. https://doi.org/10.29408/kpj.v6i2.5881