Jurnal Ilmu Fisika (JIF)
Vol. 14, No. 1, March 2022, pp. 21–27
ISSN: 1979-4657 (Print); 2614-7386 (Online)
https://doi.org/10.25077/jif.14.1.21-27.2022

Jurnal Ilmu Fisika
Open Access

Analysis of Fill Weight, Water Absorption and Density of Plasterboard Ceiling Made of Banana Midrib Fiber

Ana Yuli Komariyah[1], Sisy Anggelina Aulia Aska Mei[1], Arifa Insani Navalia[1], Lydia Rohmawati[1*], and Woro Setyarsih[1]

[1]Physics Study Program, Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, Surabaya 60231, Indonesia

Article Info

Article History:

Received August 23, 2021
Revised October 12, 2021
Accepted October 14, 2021

Keywords:

Fiber
Plasterboard Ceiling
Fill weight
Water Absorption
Density

Corresponding Author:

Lydia Rohmawati
Email: lydiarohmawati@unesa.ac.id

ABSTRACT

The plasterboard ceiling is one of the applications of fiber-based composite materials. Asbestos fibers, usually used to make plasterboard ceilings, are unfortunately harmful to humans. We propose using banana midrib fibers that are environment-friendly to replace asbestos fibers. This research investigates the influence of the percentage of banana midrib fibers on the fill weight, water absorption, and density of plasterboard ceilings. The fibers extracted from banana midrib were immersed in 40 mL of 1 M NaOH and then used to prepare plasterboard ceiling samples with different fiber percentages, namely 0.0%; 1.0%; 1.5%; 2% 2.5%. The fill weight, water absorption, and density of plasterboard samples were measured and then compared to Indonesian National Standard. The highest fill weight of 1.52 g/cm^3 was obtained with a 1.0% percentage of banana midrib fibers for the plasterboard sample. In contrast, the highest water absorption of 11.84% was obtained at 2.5% banana midrib fibers. The more fibers added, the better the seepage of the plasterboard ceilings.

1. INTRODUCTION

A class of material that has attracted significant interest from researchers in the last decade is composite materials. Composites consist of two or more materials showing properties that are not achievable using their component material only (Aramide et al., 2012). Composites comprise two parts: a matrix that acts as a binder or protector and a filler that improves the mechanical or thermal properties of the resulting composite (Alamsyah & Gundara, 2020). Compared to other natural materials, composites offer some advantages: low-cost, soundproof, environment-friendly, low-density, and corrosion-resistant (Nurhidayat, 2013). The applications of composite materials are immense, including aerospace, architecture, automotive, energy, marine, and military. Composites are also used as building materials, for example, plasterboard ceilings.

Plasterboard ceilings inhibit environmental heat from entering the house through the roof (Ang et al., 2020). Plasterboards can be used used to cover roofs or as a room divider. Commercial plasterboards consist of a mixture of gypsum, calcium, and fiber. Asbestos fibers, usually used to make plasterboards, are no longer recommended because they have a considerable health risk, such as respiratory problems or cancer.

Currently, industries have experienced technological developments, especially in material production. Renewable and environment-friendly materials are being sought for many applications, including building materials (González-Vallejo et al., 2015); (Cabeza et al., 2014). Natural fibers are in the spotlight of many companies and researchers to develop new composite materials (Alves et al., 2010). Many kinds of research on using natural fibers as an alternative material for plasterboard ceiling manufacture have been carried out. Natural fibers are more affordable, biodegradable, renewable, and advantageous in terms of physical-mechanical properties (Rukini, 2019).

Prasetyo (2017) reported that plasterboard ceiling made of 2% corn husk fiber as a filler had a flexural strength of 110.862 kg/cm2. This finding shows that plasterboards made of fibers from plants have high mechanical strength. Several studies have shown that the use of natural materials, especially fibers, reduces negative impacts in the automotive industry (Cicala et al., 2016; dos Santos Pegoretti et al., 2014; La Rosa et al., 2013), electronics industry (Deng et al., 2016) and in other fields as well. However, only a few studies have been conducted on products or materials for applications as building materials (Asdrubali et al., 2012).

Natural fibers that are promising as a composite reinforcer are banana midrib fiber. Banana stem fiber can also be combined with other raw materials to increase mechanical strength (Endriatno et al., 2015). Banana midrib fiber is extracted mainly from the skin layer of banana trees. The shape of banana midrib fiber is very similar to bamboo or hemp fibers but with a much finer diameter. The main chemical compositions of banana midrib fiber are cellulose, hemicellulose, and lignin. The banana midrib fibers are lightweight and environment-friendly and have high mechanical strength, negligible elongation, and good thermal insulation. Therefore, it is suitable for composite applications (Chinta et al., 2012).

Irawan & Sukania (2015) showed that the tensile strength and the modulus of elasticity of the composite materials reinforced using banana midrib fibers are 62.3 ± 0.67 MPa and 8.72 ± 1.12 GPa, respectively. Waghmare et al. (2017) reported that the mechanical properties of the biocomposite made of banana midrib fiber show a tensile strength of 54 MPa, an elongation of about 4 - 6%, and Young's modulus of 3.48 GPa. Malau et al. (2016) also investigated the effect of the content of phenol-formaldehyde adhesive on the quality of banana stem particleboards. The authors reported that the best adhesive concentration is 16% due to a more even distribution of filler than lower adhesive concentration. The flexural strength and the compressive strength of the particleboards are 27.6 kg/cm2 and 70.7 kg/cm2 that unfortunately do not meet the standard of SNI 03-2150-2006 (Badan Standardisasi Nasional, 2006).

Banana fiber is an alternative composite reinforcer due to its low density, high mechanical strength, and cost-effectiveness. With some of the characteristics of banana fiber, the utilization of banana midrib fiber may serve as a promising alternative solution for the community and researchers in developing renewable building materials. We investigate the effect of fiber percentage on the fill weight, water absorption, and density of the plasterboard ceilings.

2. METHOD

The tools and materials used in this study were Gypsum (A-PLUS), Calcium (Unicarb NRS – 5000), NaOH 1 M, banana midrib fiber, water, ceiling molds, scales, oven, beakers, mechanical test equipment Microcomputer Autograph Universal Testing Control with a maximum test force of 400 N and others. The research started from the fiber extraction process from the banana midrib to get the fibers. Next, the fibers were soaked in 40 mL of 1M NaOH for one hour, then dried for seven days under sun illumination. The ceiling-making process was started by mixing 100 g gypsum, 100 g calcium, and water (with a weight ratio of 1: 1: 1). The dough was put into a mold with a dimension of 20 cm x 10 cm x 1 cm by adding different fiber percentages (0.0%, 1.0%, 1.5%, 2%, and 2.5%) from a total weight of the ceiling 200 g and continued with the drying process of the ceiling samples at room temperature for three days. Next, the fill weight, water absorption, and density of the plasterboard ceiling samples were measured. A density test was used to determine the pore content. The maximum water content that the ceiling can absorb was obtained from the water absorption test, while the specific gravity of the plasterboard ceiling was obtained from the density test.

JIF, 14 (1), March 2022, pp. 21–27

2.1 Fill Weight Test

The fill weight of plasterboard ceilings can be determined using the formula given in the Indonesian National Standard: 15-0233-1989 document as follows:

$$\text{Fill weight} = \frac{A}{B-C} \tag{1}$$

where *A* is the oven-dry weight (g), *B* is the weight after 24-hour immersion in water (g), and *C* is the weight at room temperature water (g).

2.2 Water Absorption Test

According to Indonesian National Standard 15 – 0233 – 1989, the allowed maximum water absorption of a ceiling must not above 35 %. Water absorption was calculated as follows:

$$K\ (\text{water}) = \frac{A-B}{B} \times 100\% \tag{2}$$

where *K* (water) is the water absorption capacity (%), *A* is the wet weight of the sample (g), and *B* is the dry weight of the sample (g).

2.3 Density Test

According to Indonesian National Standard 15-0233-1989 concerning fiber cement sheets, the density on the ceiling is that no seepage may occur for 5 x 24 hours. Only 30% of the test objects are allowed seepage to arise from the test objects.

3. RESULTS AND DISCUSSION

3.1 Fill Weight of Plasterboards

The addition of banana midrib fiber in this study dramatically affects the fill weight of the plasterboard ceiling. The fill weight test was carried out to determine the density and pore content of the plasterboard ceiling. The fill weight of the plasterboard ceiling as a function of the percentage of banana midrib fiber is shown in Figure 1. It can been seen the dependence of fill weight of plasterboard ceiling on fiber percentage. The fill weight of the plasterboard ceiling made without banana midrib fibers (control sample) is 1.54 g/cm^3. For plasterboard made with the addition of banana midrib fiber, the highest fill weight of 1.52 g/cm^3 was obtained at the percentage of banana midrib fiber of 1%. The fill weight of plasterboards decreases with the percentage of the banana midrib fiber. The lowest fill weight of 1.27 g/cm^3 is obtained at the percentage of 2.5%. According to the Indonesian National Standard 15-0233-1989 concerning fiber cement sheets, the minimum fill weight must be above 1.2 g/cm^3. All samples have a fill weight of more than 1.2 g/cm^3, so all of the plasterboard ceiling samples meet the Indonesian National Standard 15-0233-1989.

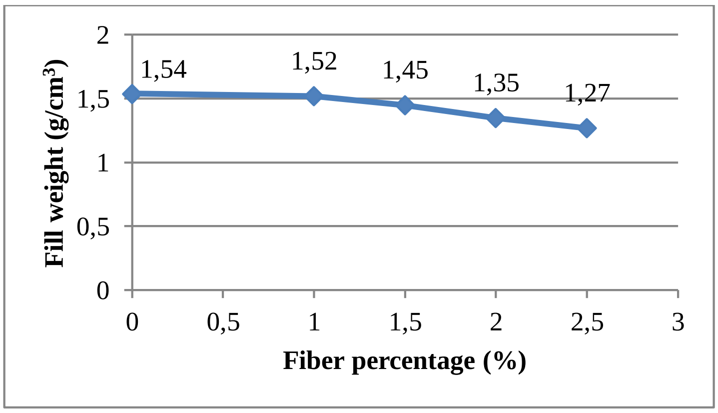

Figure 1. Dependence of fill weight of the plasterboard ceiling on the percentage of banana midrib fibers

The more percentage of fiber added in the manufacture of the ceiling, the lighter the plasterboard ceiling. The decrease of fill weight is because the volumes of gypsum and calcium are constant, while the volume of banana midrib fiber increases. The banana midrib fiber has a lower density, therefore reducing the fill weight of the resulting plasterboard ceiling. Surbakti (2020) reported that the more fiber used, the less matrix there will be and, consequently, the smaller the mass of the resulting composite. Sukoko (2017) studied the effect of bamboo bark fibers on gypsum ceiling with polyester Adhesive and obtained the highest fill weight of 0.608 g/cm that does not meet the Indonesian National Standard 15-0233-1989. Petandung (2018) stated that the addition of coco fiber in the manufacture of ceilings resulted in the highest density of 1.82 g/cm^3. Compared to bamboo bark and coco fibers, banana midrib fibers result in better plasterboard ceiling and fulfill the standard.

3.2 Water Absorption Capacity

The water absorption test on the plasterboard ceiling with banana midrib fibers showed that higher fiber percentage results in higher water absorption. The highest water absorption of 11.84% is obtained from 2.5% banana midrib fibers samples, while the lowest absorption (7.82%) is at the percentage of 1.5%. According to the Indonesian National Standard 15-0233-1989, the maximum water absorption at the ceiling is 35%. In this study, the water absorption capacity of the plasterboard ceiling is below 35%. So it is said that all prepared samples meet the Indonesian National Standard 15-0233-1989.

Figure 2 shows the relationship between variations in the percentage of the banana midrib fiber on the water absorption value of the plasterboard ceiling. The addition of fiber causes higher water absorption. However, at 1.5% fiber percentage, there was a decrease in water absorption value, which was possible due to the uneven distribution of fibers in the plasterboard ceiling manufacturing process. This study also shows that water absorption and fiber percentage are directly proportional. The lower the fiber percentage, the lower the water absorption, and vice versa. The higher the fiber percentage, the higher the water absorption. The higher water absorption indicates that the pores on the plasterboard ceiling are a lot of as the fiber increases.

Almost all test objects experienced an increase in water absorption. Prasetyo (2017) showed that the water absorption capacity of the plasterboard ceilings made of corn coir fibers ranges between 11% - 13%. Silalahi et al. (2015) showed that water absorption of corn fiber composite ranges between 1.38% and 2.46%. Thus, this research indicates that banana midrib fiber is better than the other natural fibers, resulting in water absorption values from 5% - 11.84%.

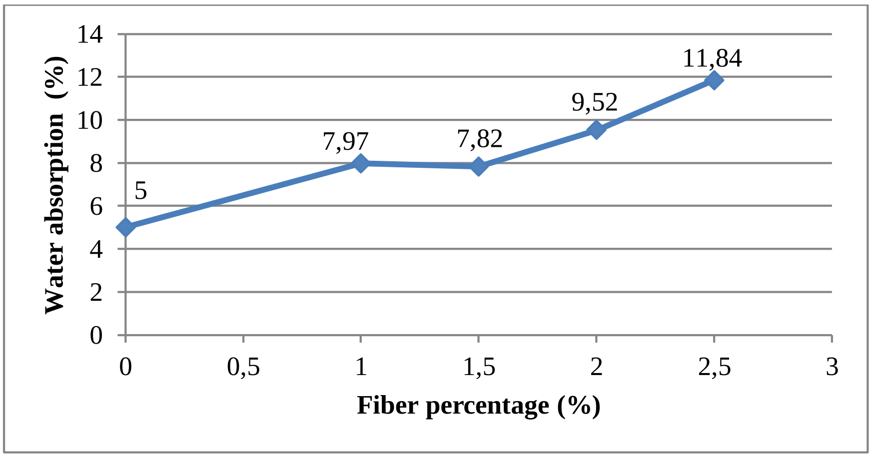

Figure 2. The effect of fiber Percentage on the water absorption of the plasterboard ceiling.

3.3 The density of Plasterboard Ceiling

The density of the ceiling is not allowed to seep for 5 x 24 hours. Only 30% samples show seepage. The control sample and 1% fiber percentage sample experienced seepage at 36 hours and 96 hours, respectively. As for the fiber percentage above 1%, no seepage occurs within the time limit given in the Indonesian National Standard 15-0233-1989, which is for five days. It shows that the addition of banana midrib fiber has a positive effect on water seepage on the plasterboard ceiling. The results showed that with the increase in the percentage of the banana midrib fiber, the seepage on the plasterboard ceiling was getting better. Figure 3 shows the relationship between variations in the percentage of banana midrib fibers on density, especially seepage time on the plasterboard ceiling.

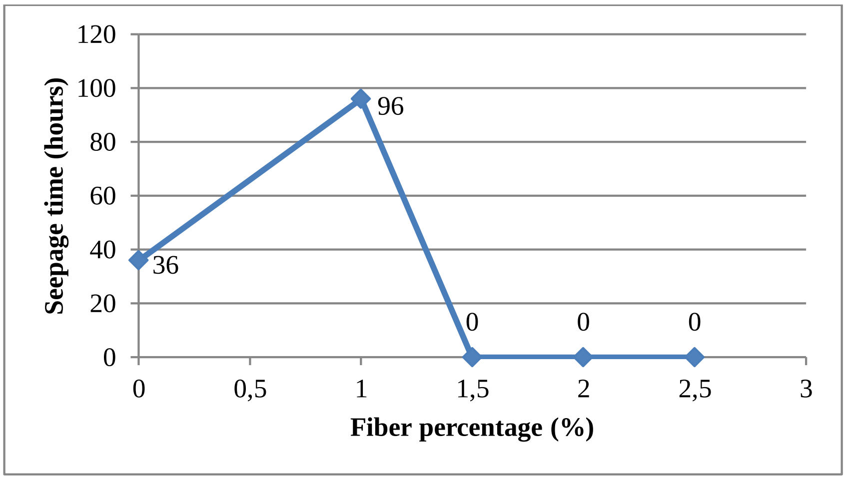

Figure 3. The effect of the percentage of banana midrib fiber on the water seepage time of plasterboard ceiling.

Based on the density test, three of five samples meet the Indonesian National Standard 15-0233-1989 that no seepage occurs for five days, namely the addition of 1.5%, 2%, and 2.5% fiber. However, some samples experienced seepage, namely in samples without the addition of fiber that had experienced seepage after 36 hours and the addition of 1% fiber seepage after 96 hours. The plasterboard ceilings of 1.5%, 2%, and 2.5% banana midrib fibers satisfy the Indonesian National Standard.

The test results also show an inverse relationship between density and water absorption. The greater the density of fiber in ceilings, the lower the water absorption capacity. Vice versa, the lower the density of plasterboard ceilings, the greater the water absorption capacity. The result of this research was also in agreement with that of Sukoko (2017). However, almost all of their samples experienced seepage after 24 hours. Prasetyo (2017) stated that seepage for percentage using corn husk fiber also occurred at 1% 1.2% corn husk fiber in less than 120 hours. The increase in fiber content makes the compaction process inadequate so that it induces cavities in the ceiling (Al-Rifaie & Al-Niami, 2016).

The fill weight, water absorption, and density results show that the addition of banana midrib fiber has a good effect on its use as a mixture in making plasterboard ceilings, where the obtained results on average have met the test standards. The following table compares the results of research testing with standardized testing parameters according to the Indonesian National Standard shown in Table 1.

Table 1. Comparison of Standard Parameters with Research Test Results

Parameter	Test Type	Standard Parameter	Test Result
Indonesian National Standard 15-0233-1989	Fill Weight	Minimum 1.2 g/cm^3	Highest 1.52 g/cm^3
	Water Absorption	Maximum 35% seepage	Highest 11.84%
	Density	Five days	Good (more than five days)

4. CONCLUSION

The addition of banana midrib fiber affects the value of fill weight, water absorption, and density of the plasterboard ceiling. The results show that the highest fill weight was obtained at a percentage of 1% banana midrib fiber of 1.52 g/cm^3, the highest water absorption was at a percentage of 2.5% of 11.84%. The more fibers added, the better the seepage on the ceiling. Thus, according to the Indonesian National Standard 15- 0233-1989 concerning fiber cement sheets, all test objects have met the standard.

REFERENCES

Al-Rifaie, W. N., & Al-Niami, M. (2016). Mechanical performance of date palm fibre-reinforced gypsums. *Innovative Infrastructure Solutions*, *1*(1), 1–7.

Alamsyah, M. H., & Gundara, G. (2020). Analisis Sifat Mekanik Komposit Bahan Kampas Rem Dengan Penguat Serbuk Kayu Jati Dan Serbuk Kuningan. *REM (Rekayasa Energi Manufaktur) Jurnal*, *5*(1), 9–13.

Alves, C., Silva, A. J., Reis, L. G., Freitas, M., Rodrigues, L. B., & Alves, D. E. (2010). Ecodesign of automotive components making use of natural jute fiber composites. *Journal of Cleaner Production*, *18*(4), 313–327.

Ang, P. S. E., Ibrahim, A. H. I., & Abdullah, M. S. (2020). Preliminary Study of Ceiling Board from Composite Material of Rice Husk, Rice Husk Ash and Waste Paper. *Progress in Engineering Application and Technology*, *1*(1), 104–115.

Aramide, F. O., Atanda, P. O., & Olorunniwo, O. O. (2012). Mechanical properties of a polyester fibre glass composite. *International Journal of Composite Materials*, *2*(6), 147–151.

Asdrubali, F., Schiavoni, S., & Horoshenkov, K. V. (2012). A review of sustainable materials for acoustic applications. *Building Acoustics*, *19*(4), 283–311.

Badan Standardisasi Nasional. (2006). Papan partikel. *Standar Nasional Indonesia (Papan Serat)*, 1–23.

Cabeza, L. F., Rincón, L., Vilariño, V., Pérez, G., & Castell, A. (2014). Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings and the building sector: A review. *Renewable and Sustainable Energy Reviews*, *29*, 394–416.

Chinta, S. K., Katkar, P. M., & Mirji, M. J. (2012). Natural fibres-reinforced in false ceiling. *International Journal of Advanced Research in IT and Engineering*, *1*(5), 47–55.

Cicala, G., Rosa, D. La, Musarra, M., Saccullo, G., Banatao, R., & Pastine, S. (2016). Recyclable epoxy resins: An example of green approach for advanced composite applications. *AIP Conference Proceedings*, *1736*(1), 20027.

Deng, Y., Paraskevas, D., Tian, Y., Van Acker, K., Dewulf, W., & Duflou, J. R. (2016). Life cycle assessment of flax-fibre reinforced epoxidized linseed oil composite with a flame retardant for electronic applications. *Journal of Cleaner Production*, *133*, 427–438.

dos Santos Pegoretti, T., Mathieux, F., Evrard, D., Brissaud, D., & de França Arruda, J. R. (2014). Use of recycled natural fibres in industrial products: a comparative LCA case study on acoustic components in the Brazilian automotive sector. *Resources, Conservation and Recycling*, *84*, 1–14.

Endriatno, N., Kadir, K., & Alim, A. (2015). Analisis Sifat Mekanik Komposit Sandwich Serat Pelepah Pisang dengan Core Kayu Biti. *Dinamika: Jurnal Ilmiah Teknik Mesin*, *6*(2).

González-Vallejo, P., Marrero, M., & Solís-Guzmán, J. (2015). The ecological footprint of dwelling construction in Spain. *Ecological Indicators*, *52*, 75–84.

Irawan, A. P., & Sukania, I. W. (2015). Tensile strength of banana fiber reinforced epoxy composites materials. *Applied Mechanics and Materials*, *776*, 260–263.

La Rosa, A. D., Cozzo, G., Latteri, A., Mancini, G., Recca, A., & Cicala, G. (2013). A comparative life cycle assessment of a composite component for automotive. *Chemical Engineering*, *32*.

Malau, J. C., Sucipto, T., & Iswanto, A. H. (2016). Kualitas Papan Partikel Batang Pisang Barangan Berdasarkan Variasi Kadar Perekat Phenol Formaldehida. *Peronema Forestry Science Journal*, *5*(1), 1–9.

Nurhidayat, A. (2013). *Kajian Ketangguhan Impak Komposit Sandwich Serat Aren-Polyester dengan Core Gedebog Pohon Pisang*.

Patandung, P. (2018). Pengembangan Pembuatan Plafon Dari Abu Sekam Padi Dengan Menggunakan Serat Sabut Kelapa. *Jurnal Penelitian Teknologi Industri*, *8*(1), 39–50.

Prasetyo, D. A. (2017). Pemanfaatan Serat Kulit Jagung sebagai Bahan Campuran Pembuatan Plafon Eternit. *Rekayasa Teknik Sipil*, *1*(1/REKAT/17).

Rukini, A. (2019). Analisis Kelayakan Sifat Fisik dan Mekanik Komposit Gipsum Berpenguat Serat Alam Sisal Sumbawa sebagai Papan Plafon. *Jurnal Tambora*, *3*(3), 20–23.

Silalahi, R., Sinuhaji, P., & Simbolon, T. R. (2015). Pembuatan dan Karakterisasi Komposit Serat Kulit Jagung-Poliester dengan Metode Chopped Strand Mat. *Medan: Universitas Sumatera Utara*.

Sukoko, T. E. (2017). Pengaruh Penambahan Serat Kulit Bambu pada Plafon Gipsum dengan Perekat Poliester. *Rekayasa Teknik Sipil*, *1*(1/REKAT/17).

Surbakti, E. J. (2020). *Pembuatan Dan Karakterisasi Komposit Serat Kulit Jagung Dengan Matriks Epoksi*.

Waghmare, P. M., Bedmutha, P. G., & Sollapur, S. B. (2017). Review on mechanical properties of banana fiber biocomposite. *Int. J. Res. Appl. Sci. Eng. Technol*, *5*(10), 847.