JPSE (Journal of Physical Science and Engineering), Vol. 7, No. 2, 2022, Page 134–141.
DOI: 10.17977/um024v7i22022p134

JPSE
(Journal of Physical Science and Engineering)

http://journal2.um.ac.id/index.php/jpse
EISSN: 2541-2485

Physical and Mechanical Properties of Fiber Board from Corn Husk Fiber

Received
10 October 2022

Revised
10 November 2022

Accepted for Publication
26 November 2022

Published
30 December 2022

R Desiasni[1*], F Widyawati[1], Y F Sarsaningsih[1], S Bahtiar[1], and A Kusmiran[2]

[1] Metallurgical Engineering Study Program, Faculty of Environmental and Mineral Technology, Sumbawa University of Technology, Jl. Raya Olat Maras, Sumbawa, 84371, Indonesia.
[2] Departement of Physics, Faculty of Science and Technology, UIN Alauddin Makassar, Jl. H. M. Yasin Limpo 36, Gowa, 92111, Indonesia.

***E-mail:** rita.desiasni@uts.uts.ac.id

Abstract
Using agricultural waste materials, namely corn husk fiber (CHF), to reduce agricultural waste and recycle corn husk waste into sustainable engineering materials is relatively significant due to the decreasing number of woods. This study aims to analyze the effect of the volume fraction of CHF with polyester (PE) on the physical and mechanical strength of fiberboard composites with variations in volume fraction of 25% fiber : 75% PE, 50% fiber : 50% PE, and 75% fiber : 25% PE. Composites are made by the hand layup method. Fibers were pretreated by immersing 5% NaOH for 2 hours. The results of testing the physical properties of the highest density composite board at a volume fraction of 25% fiber : 75% PE of 0.85 g/cm³ and the lowest moisture absorption value was at 0.49%. The results of the mechanical board test in the form of the modulus of elasticity (MOE) test got the highest test value at the fiber volume fraction 25% fiber : 75% PE, which was 1179.2 MPa as well as the highest modulus of rupture (MOR) test value was found in the volume fraction 25% fiber: 75% PE that is equal to 9.4 MPa. Based on this result research, the average strength of the mechanical properties increases with the increase in the number of matrices. That indicates a reasonably good bond between the fiber and the matrix. The results of the water content test also increased as the density value increased.
Keywords: Corn husk fiber, polyester resin, hand layup method, physical and mechanical properties.

1. Introduction

Researchers have begun to develop natural fiber-based fillers. Fibers are divided into two, namely synthetic fibers and natural fibers. Synthetic fiber is a composite base material used in various categories, including aviation, car, marine, military, and recreation industries. However, synthetic fibers are environmentally harmful and not readily biodegradable. According to [1], using natural fibers is a wiser alternative, considering that natural fibers are superior to synthetic fibers because they are harmless, recyclable, and abundantly available. In nature, the fiber surface can be easily modified and is biodegradable, renewable, has lower production costs, and is environmentally friendly. Research has been carried out on a wide variety of non-wood plant fibers and agricultural wastes, such as kenaf fiber [2], coconut husk and bagasse [3], sorghum [4], rice straw [5], and rice husk [6]. This research used corn husk fiber (CHF) as a fiber composite board. CHF also provide excellent strength, high elongation, flexibility, moderate durability, and are readily biodegradable. The fiber obtained from corn gave a specific strength and a specific modulus of 2.7 tenacity/g·den^{-1} and 70 modulus/g·den^{-1}, respectively [7]. Therefore, corn husk can be used as a natural fiber in fiber composite boards.

Data on total corn production from 2013 to 2015 from the Central Statistics Agency of West Nusa Tenggara (NTB), corn production increased from 633,773 tons in 2013 to 959,972.92 tons in 2015 [8]. The more corn production increases, followed by corn waste increases. One part of corn waste that could be utilized more optimally is corn husk. However, environmental waste, such as CHF, can now become valuable industrial materials [9]. CHF is a sustainable, low-cost option for reinforcing composites, and environmentally friendly. That makes it a very competitive fiber for product use [10]. The research found that CHF subjected to enzymatic treatment has direct quality and tall dampness maintenance [11]. The water-wetted CHF obtained from the innermost leaves is found to have superior mechanical properties, low water content, low water absorption, and obtained from the outer leaves [10]. The chemically treated CHF was more efficient than untreated CHF. So, the advantages of CHF compared to other fibers are that it has good elasticity properties, namely (224.05 ± 22.14) MPa to (368.25 ± 78.97) MPa and modulus of elasticity (MOE) value from (4.57 ± 0.54) GPa to (15.87 ± 1.87) GPa. One factor that increases the MOE is the treatment process using 0.5–8% sodium hydroxide (NaOH) for two hours. Another research found that CHF composites had significant physical and mechanical properties [12]. According to the report, the mechanical properties of CHF-reinforced polypropylene composites are higher than those of polypropylene alone.

The previous report also found that a 5% CHF weight fraction composite provides the best tensile and flexural strengths [13]. Several studies reprocessed that polystyrene (PS) froth or recycled polystyrene (RPS) and CHF can produce composite products. Adding fiber to the RPS or CHF composite from the fiber interval of 30% to 60% caused an increase in the tensile strength and modulus values of 26% and 13%, respectively. The increase in the value of the strength of mechanical properties is supported by alkalizing treatment of the fiber. The decomposition temperature decreases as the fiber content of a CHF composite increases [14]. One of the uses of CHF in the industrial sector is as a composite board. The manufacture of composite boards from non-wood materials is very significant. That is due to the need for more wood as the primary raw material for manufacturing fiberboard. This research utilizes corn husk waste by using synthetic and natural adhesives. The results show that the particleboard of CHF is used for building materials [15]. From the description above, further studies are needed regarding the best composition between the percentage of filler (corn husk fiber) and matrix (resin) to produce the best physical and mechanical properties of composite boards that can be applied commercially based on the Indonesian National Standard (SNI 01-4449-2006) [16].

2. Method

2.1. Treatment of Corn Husk Fiber (CHF)

The material used is CHF from corn plantations in Rhee district, Sumbawa, NTB province. The corn husks were soaked for 10 days in water, and the fiber was removed using an iron comb. Some CHF are dried in the sun to evacuate the damp substance. The dry CHF is not used directly as a fiber but is given a surface treatment first, namely soaking the fiber with NaOH (5%) for 2 hours to remove the lignin content in the CHF. The use of 5% NaOH for 2 hours in the treatment of CHF process is based on some previous research [17]–[19]. Then the fiber is removed and rinsed with clean water at a neutral pH of the NaOH solution. Next, the corn fiber is dried in the sun to dry and cut to a fiber size of ±1 cm, the material preparation as Figure 1.

(a) (b) (c)

Figure 1. (a) Corn husk soak for 10 days, (b) corn husk combing, and (c) corn husk treated with NaOH concentration of 5%.

Table 1. Sample size for physical and mechanical properties.

Composition (% Fiber : % Resin)	Test		Dimensions (cm)	Number of Specimen
25 : 75 50 : 50 75 : 25	Physical Test	Density	10 × 10 × 1	6
		Water Content		
	Mechanical Test	Modulus of Elasticity (MOE)	20 × 5 × 1	6
		Modulus of Rupture (MOR)		

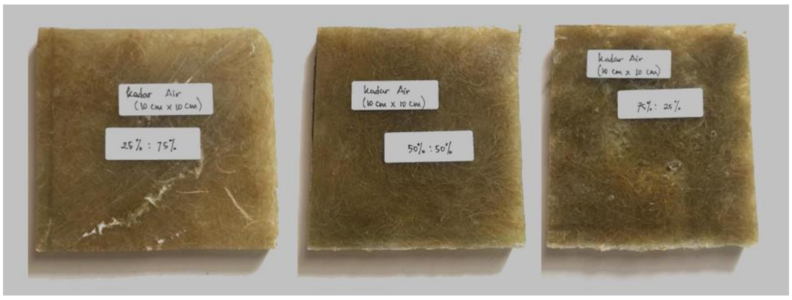

Figure 2. Specimen for density and water content tests.

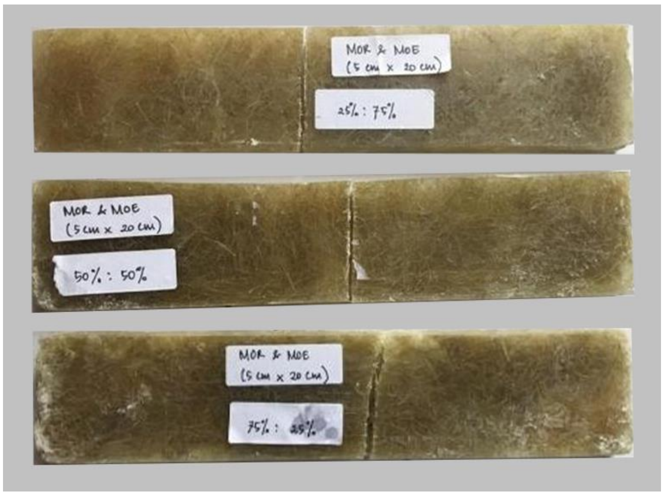

Figure 3. Specimen for MOE and MOR tests.

2.2. Preparation of Composites

Manufacture of CHF composite board specimens using the hand lay-up method. The first thing to do in making this specimen is to prepare tools and materials such as CHF, epoxy resin, catalyst, mold, and others. The next step is to mix resin, catalyst, and CHF and stir slowly until a homogeneous mixture is formed. Then pour the three mixtures slowly into a mold smeared with a release agent. Then the mold is closed and pressure is applied to the composite. CHF composite specimens were allowed to dry. Then it is removed from the mold for further cutting according to the sample size for physical and mechanical properties testing based on the SNI 01-4449-2006 standard [16], as shown in Table 1, and composite sample products are presented in Figure 2 and Figure 3.

2.3. Testing and Analysis

2.3.1. Physical Test

Density testing measures the mass of each unit volume of an object. The voids can influence the high and low density of the composite. Density can also be affected by the interfacial bond between fiber and matrix. The density value decreases when the matrix and fiber cannot bond properly. Meanwhile, the water content is a composite board property that reflects the water content property of the composite board. Specimen testing was carried out using density and water content tests with the Indonesian

National Standard SNI 01-4449-2006 [16]. A density test was conducted by weighing the mass of the dry sample and the volume of the specimen to obtain the density of the CHF board composite. The density calculation (ρ) was calculated using Equation 1 [16].

$$\rho = \frac{m}{V} \tag{1}$$

Where ρ is density (kg/m^3), m is mass (kg), and V is the volume (m^3). Meanwhile, the moisture content test is obtained based on the results of measuring the specimen's initial and dry mass after being in the oven to obtain the moisture content in percent. Water content was calculated using Equation 2 [16],

$$\text{KA} = \frac{m_{\text{KU}}}{m_{\text{KO}}} \times 100\% \tag{2}$$

where KA is water content (%), m_{KU} is the dry mass of sample air (kg), and m_{KO} is the dry mass after the oven sample (gr).

2.3.2. Mechanical Test

Specimen testing was carried out using the MOE and MOR tests with the Indonesian National Standard (SNI 01-4449-2006) [16]. MOE is the proportional slope of the linear line and the stress and strain curves on the sample. MOR is a fiber strength that occurs at the maximum load when the sample fails and is said to be maximum strength. The MOE and MOR tests were carried out using the Universal Tensile Machine (UTS) RTG-1310 with a load cell capacity of 10 kN, a specimen width (L) of 0.05 m (5 cm), specimen thickness (T) of 0.01 m (1 cm), and buffer distance (S) 0.15 m (15 cm) applicable to all samples. Based on the data obtained from the UTS RTG-1310 tool, the MOE and MOR were calculated using Equation 3 and Equation 4 [16].

$$\text{MOR} = \frac{3PL}{2bh^2} \tag{3}$$

$$\text{MOE} = \frac{\Delta PL^3}{4\Delta Ybh^3} \tag{4}$$

Where MOR is modulus of rupture (MPa), MOE is modulus of elasticity (MPa), P is maximum load (N), L is buffer distance (m), b is the width of the test sample (m), h is the thickness of the test sample (m), ΔP is the increasing load in the range of linear line of graph (N) buffer distance, and ΔY is the increasing banding distance in the range of linear line of graph (N) [16].

3. Result and Discussion

3.1. Physical Test

Volume fraction has a significant effect on the physical properties of the composite. Composite quality can be known based on physical testing. This test aims to determine the quality of the composite in water and humid environments [20]. Density and water absorption are factors that affect composite quality [21].

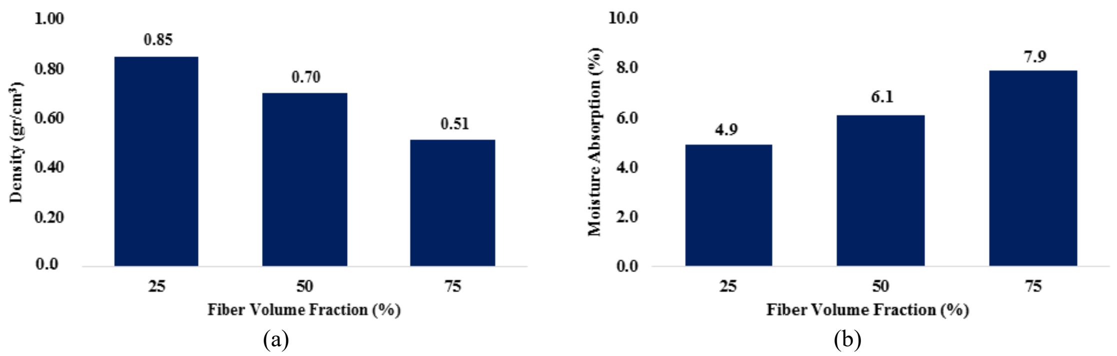

Figure 4. (a) Density and (b) moisture absorption of composite with variation of fiber volume fraction.

Figure 4 shows each composite's density value and percentage of moisture by variation of fiber volume fraction. The density value has decreased with increasing weight percent of CHF. It was indicated that the density increased with decreased weight of the percent of the CHF (Figure 4a). The highest density (0.85%) is achieved by the composite reinforced with 25% of CHF, and the composite contains the highest amount of CHF. The density of the composite reinforced with 75% CHF is the lowest at 0.51%. Adding CHF to the mix can increase the rate at which moisture is absorbed (Figure 4b). The composite with the highest value of CHF absorbs the most moisture (7.91%). It shows that less dense composites have more void spaces than dense ones so that more water can be absorbed. A similar type of result was found for CHF/polyester (PE) composites [22], explaining that the effect of CHF/PE that the best composite composition with physical properties absorption the research that lowest absorption with value 2.39% was detected in 20% CHF and 80% PE composite. It means that the lower CHF content and the more resin content in the composite, the lower absorption and the higher density vice versa. Other research similar to previous research [23] shows that increasing filler corn and jute fiber composite loading decreases the density value. On the other hand, the increase in fiber causes increased water absorption in the composite. It is due to the presence of cavities in the composite process.

The moisture absorption is directly related to the density composite. A large number of voids and weaker bonds between the fiber and matrix cause more water to accumulate in the void. According to [24], water molecules penetrate the composite material when natural fiber composites are exposed to wet conditions. They comprise small cracks that allow the material to flow through them, affecting the adhesion between the fibers and resin. Swelling of the fibers causes microcracks in the matrix and can eventually lead to debonding events of the fiber-polymer matrix. Debonding event is the damage to the composite caused by the non-adherence of the fiber with a binder or resin. This debonding can impact reducing the composite's strength and the lack of fiber function as a reinforcing material in the binder [25]. Conversely, less moisture absorption and density increase when there is an increase in adhesion to the composite.

3.2. *Mechanical Test*

The mechanical testing of composite materials is essential for determining their properties in product design and analysis, quality control, application performance requirements, and production processes [26]. Mechanical testing is used to determine the strength and stiffness of polymer composts to investigate their potential use in the design of a composite structure [27]. The MOR and MOE of various combinations of the CHF and PE resin composite are presented in Figure 5.

Based on Figure 5, the MOE has the same trend as the MOR. The MOE increased when the fiber volume fraction decreased. The MOE and MOR values increased fiber content by 25% and decreased fiber content by 50–75%. The averages of MOE of the fiberboard composite with a fiber content of 25%, 50%, and 75% are 1179.2 MPa, 458.8 MPa, and 178.2 MPa, respectively. According to the standard SNI 01-4449-2006 [16], the value of MOE is ≥ 804.1 MPa. Based on the standard, a value that

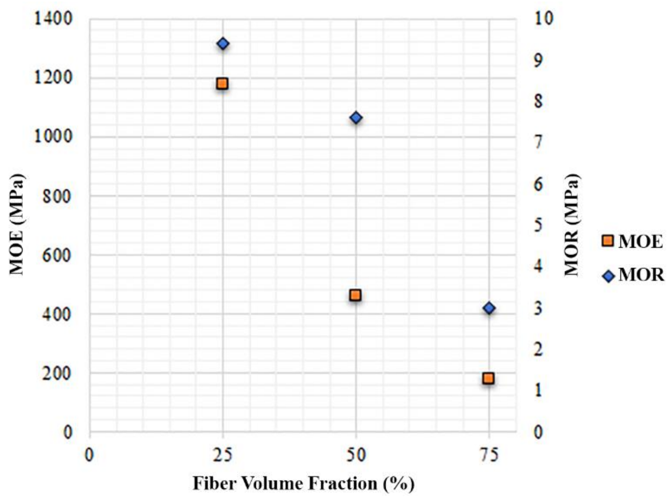

Figure 5. Effect variation of fiber volume fraction corn husk fiber on the MOR and the MOE.

qualifies the standards are the composition of 25% fiber and 75% resin. At the same time, the averages of MOR of the fiberboard composite with a fiber content of 25%, 50%, and 75% are 9.4 MPa, 7.6 MPa, and 3.0 MPa, respectively. According to the standard SNI 01-4449-2006 [16], the value of MOR is ≥ 5.0 MPa. Experiment values that qualify the standards are 25% fiber and 50% fiber, while 75% of the fiber is unqualified.

Based on previous research [22] explains the increase in the value of the MOE together with the increment in fiber substance up to 30%. However, when CHF volume is more than 30%, there is a decrease in MOE. The reduction in MOE can be caused by fiber damage and fiber pulling in the composite structures. A similar study using different matrices was stated by [28]. Its research explains that Young's modulus gradually increases mechanical properties with increasing fiber content. These values increased up to 10% fiber content and then decreased. This event is associated with the flow process and the formation of a film from the matrix on the composite structure, which can increase the strength of the composite [29]. Whereas based on a similar study using flax fiber and epoxy has been carried out. The composite's mechanical strength is reduced because more water molecules enter the material through the fiber channels and capillaries. They act along the interface between the epoxy and the flax fiber, causing swelling of the sample, which can cause the bond between resin and fiber to break. It may also explain why the MOE and MOE strength of the composite between CHF and PE resin in this study increased at 25% fiber content, then decreased with fiber addition to 75%.

4. Conclusion

Based on the results and discussion, it can be concluded that the volume fraction of fiber affects the physical and mechanical properties of composites. Increasing the fiber volume fraction will increase the moisture absorption of the composite but will decrease the density of the composite. The standard SNI 01-4449-2006 requires a fiberboard density value of 0.40 to 0.84 gr/cm³ and moisture absorption value ≤ 13%. The best results from moisture absorption and density of the composites were obtained for 25% fiber volume fraction and 75% PE, namely 0.49% and 0.85 g/cm³, respectively. Based on these standards, this composite is categorized as high-density fiberboard because it has a density of more than 0.84 g/cm³. While for the mechanical properties of the composite, the MOE and MOR value increased in fiber content by 25% and decreased in fiber content by 50–75%, respectively. The average MOR value of the fiberboard composite was obtained at 9.4 MPa with 25% fiber content, 7.6 MPa with 50% fiber content, and 3.0 MPa with 75% fiber content and requires a fiberboard MOR value ≥ 5.0 MPa. At the same time, the average MOE value of the fiberboard composite was obtained at 1179.2 MPa with 25% fiber content, 458.8 MPa with 50% fiber content, and 178.2 MPa with 75% fiber content and requires a fiberboard MOR value ≥ 804.1 MPa. Based on the mechanical properties results, the composites from this research values that qualify the standards SNI 01-4449-2006 are 25% fiber and 50% fiber for MOR, whereas MOE requires 25% fiber.

References

[1] R. A. Ilyas, S. M. Sapuan, and M. R. Ishak, "Isolation and characterization of nanocrystalline cellulose from sugar palm fibres (Arenga Pinnata)," *Carbohydr. Polym.*, vol. 181, pp. 1038–1051, Feb. 2018, doi: 10.1016/j.carbpol.2017.11.045.

[2] M. R. Pelaez-Samaniego, V. Yadama, E. Lowell, and R. Espinoza-Herrera, "A review of wood thermal pretreatments to improve wood composite properties," *Wood Sci. Technol.*, vol. 47, no. 6, pp. 1285–1319, Jul. 2013, doi: 10.1007/s00226-013-0574-3.

[3] S. Schiavoni, F. Bianchi, and F. Asdrubali, "Insulation materials for the building sector: A review and comparative analysis," *Renew. Sustain. Energy Rev.*, vol. 62, pp. 988–1011, Sep. 2016, doi: 10.1016/j.rser.2016.05.045.

[4] A. Khazaeian, A. Ashori, and M. Y. Dizaj, "Suitability of sorghum stalk fibers for production of particleboard," *Carbohydr. Polym.*, vol. 120, pp. 15–21, Apr. 2015, doi: 10.1016/j.carbpol.2014.12.001.

[5] L. Zhang and Y. Hu, "Novel lignocellulosic hybrid particleboard composites made from rice straws and coir fibers," *Mater. Des.*, vol. 55, pp. 19–26, Mar. 2014, doi: 10.1016/j.matdes.2013.09.066.

[6] A. A. Adediran *et al.*, "Properties of agro-based hybrid particleboards," *Procedia Manuf.*, vol. 35, pp. 442–446, 2019, doi: 10.1016/j.promfg.2019.05.064.

[7] M. R. Sanjay *et al.*, "A comprehensive review of techniques for natural fibers as reinforcement in composites: Preparation, processing and characterization," *Carbohydr. Polym.*, vol. 207, pp. 108–121, Mar. 2019, doi: 10.1016/j.carbpol.2018.11.083.
[8] Badan Pusat Statistik Nusa Tenggara Barat, "Luas Panen, Produksi, dan Produktivitas Jagung 2013-2015." ntb.bps.go.id. https://ntb.bps.go.id/indicator/53/182/1/luas-panen-produksi-dan-produktivitas-jagung.html (accessed Oct. 1, 2022)
[9] J. T. Aladejana, Z. Wu, M. Fan, and Y. Xie, "Key advances in development of straw fibre bio-composite boards: An overview," *Mater. Res. Express*, vol. 7, no. 1, p. 012005, Jan. 2020, doi: 10.1088/2053-1591/ab66ec.
[10] N. H. Sari, I. N. G. Wardana, Y. S. Irawan, and E. Siswanto, "Characterization of the chemical, physical, and mechanical properties of NaOH-treated natural cellulosic fibers from corn husks," *J. Nat. Fibers*, vol. 15, no. 4, pp. 545–558, 2018, doi: 10.1080/15440478.2017.1349707.
[11] N. D. Yilmaz, M. Sulak, K. Yilmaz, and F. Kalin, "Physical and chemical properties of water-retted fibers extracted from different locations in corn husks," *J. Nat. Fibers*, vol. 13, no. 4, pp. 397–409, Jul. 2016, doi: 10.1080/15440478.2015.1029201.
[12] N. R. Kumar, C. R. Rao, P. Srikant, and B. R. Rao, "Mechanical properties of corn fiber reinforced polypropylene composites using Taguchi method," *Mater. Today: Proc.*, vol. 2, no. 4–5, 2015, pp. 3084–3092, doi: 10.1016/j.matpr.2015.07.251.
[13] K. S. Chun *et al.*, "Wood plastic composites made from corn husk fiber and recycled polystyrene foam," *J. Eng. Sci. Technol*, vol. 13, no. 11, pp. 3445–3456, Nov. 2018.
[14] A. Maghfirah, L. Hakim, and M. Hamid, "Manufacturing and characterization process of polymer concrete with aggregate from pumice stone and corn husk fiber as a filler," *J. Technomater. Phys.*, vol. 1, no. 1, pp. 6–14, Feb. 2019, doi: 10.32734/jotp.v1i1.819.
[15] K. W. Prasetiyo, L. Zalukhu, L. Astari, F. Akbar, and D. Hermawan, "The potential of using agricultural waste: Corn husk for particleboard raw material," in *IOP Conf. Ser.: Earth Environ. Sci.*, vol. 591, no. 1, Nov. 2020, p. 012011, doi: 10.1088/1755-1315/591/1/012011.
[16] *Papan Serat*, SNI 01-4449-2006, Indonesian National Standard, Jakarta, 2006. [Online]. https://bsilhk.menlhk.go.id/standarlhk/2022/09/13/sni-01-4449-2006-papan-serat/
[17] A. Oushabi *et al.*, "The effect of alkali treatment on mechanical, morphological and thermal properties of date palm fibers (DPFs): Study of the interface of DPF–Polyurethane composite," *S. Afr. J. Chem. Eng.*, vol. 23, pp. 116–123, Jun. 2017, doi: 10.1016/j.sajce.2017.04.005.
[18] N. Venkateshwaran, A. E. Perumal, and D. Arunsundaranayagam, "Fiber surface treatment and its effect on mechanical and visco-elastic behaviour of banana/epoxy composite," *Mater. Des.*, vol. 47, pp. 151–159, May 2013, doi: 10.1016/j.matdes.2012.12.001.
[19] T. Partuti, U. H. Fariyan, Y. Dwiyanti, A. Trenggono, and E. Yustanti, "Effect of fibre volume fraction and sodium hydroxide treatment on mechanical properties of palm fibre/unsaturated polyester composite," *JPSE (J. Phys. Sci. Eng.)*, vol. 7, no. 1, pp. 39–45, Apr. 2022, doi: 10.17977/um024v7i12022p039.
[20] R. Yahaya, S. M. Sapuan, M. Jawaid, Z. Leman, and E. S. Zainudin, "Effect of fibre orientations on the mechanical properties of kenaf–aramid hybrid composites for spall-liner application," *Def. Technol.*, vol. 12, no. 1, pp. 52–58, Feb. 2016, doi: 10.1016/j.dt.2015.08.005.
[21] N. Saba, M. T. Paridah, K. Abdan, and N. A. Ibrahim, "Physical, structural and thermomechanical properties of oil palm nano filler/kenaf/epoxy hybrid nanocomposites," *Mater. Chem. Phys.*, vol. 184, pp. 64–71, Sep. 2016, doi: 10.1016/j.matchemphys.2016.09.026.
[22] N. H. Sari *et al.*, "The effect of water immersion and fibre content on properties of corn husk fibres reinforced thermoset polyester composite," *Polym. Test.*, vol. 91, p. 106751, Nov. 2020, doi: 10.1016/j.polymertesting.2020.106751.
[23] J. B. Ali, A. B. Musa, A. Danladi, M. M. Bukhari, and B. B. Nyakuma, "Physico-mechanical properties of unsaturated polyester resin reinforced maize cob and jute fiber composites," *J. Nat. Fibers*, vol. 19, no. 9, pp. 3195–3207, 2022, doi: 10.1080/15440478.2020.1841062.
[24] O. Faruk, A. K. Bledzki, H. P. Fink, and M. Sain, "Progress report on natural fiber reinforced composites," *Macromol. Mater. Eng.*, vol. 299, no. 1, pp. 9–26, Jan. 2014, doi: 10.1002/mame.201300008.

[25] Z. N. Azwa, B. F. Yousif, A. C. Manalo, and W. Karunasena, “A review on the degradability of polymeric composites based on natural fibres,” *Mater. Des.*, vol. 47, pp. 424–442, 2013, doi: 10.1016/j.matdes.2012.11.025.
[26] N. Saba, M. T. Paridah, and M. Jawaid, “Mechanical properties of kenaf fibre reinforced polymer composite: A review,” *Constr. Build. Mater.*, vol. 76, pp. 87–96, Feb. 2015, doi: 10.1016/j.conbuildmat.2014.11.043.
[27] K. Senthilkumar *et al.*, “Mechanical properties evaluation of sisal fibre reinforced polymer composites: A review,” *Constr. Buildi. Mater.*, vol. 174, pp. 713–729, Jun. 2018, doi: 10.1016/j.conbuildmat.2018.04.143.
[28] A. M. Youssef, A. El-Gendy, and S. Kamel, “Evaluation of corn husk fibers reinforced recycled low density polyethylene composites,” *Mater. Chem. Phys.*, vol. 152, pp. 26–33, Feb. 2015, doi: 10.1016/j.matchemphys.2014.12.004.
[29] Z. Luo *et al.*, “Comparison of performances of corn fiber plastic composites made from different parts of corn stalk,” *Ind. Crops Prod.*, vol. 95, pp. 521–527, Jan. 2017, doi: 10.1016/j.indcrop.2016.11.005.