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Modification of Water Hyacinth Fiber Composite in The Production of Decorative Particle Boards using Spray Coating Method and Silane Coupling Agent

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Abstract. Water hyacinth is a waste in waters that can damage the balance of aquatic ecosystems because of its rapid growth, which can reach 3% in a day. One utilization of water hyacinth waste is to be used as filler material for decorative particleboard. This study aims to look at the physical and mechanical characteristics of particleboard with surface coating treatment using silane coupling agent solution.. Water hyacinth fiber was selected as an alternative filler material for the particle board composite due to its abundant availability and potential fiber properties. The surface of the particle boards was modified using a silane coupling agent (KH550) to enhance the bond quality between components. The water hyacinth powder was first alkalized with NaOH and distilled water (1:5) for 1 hour, then mixed with epoxy resin in a 40:60 weight ratio. The compaction process was carried out using a hydraulic hot press at 2 bar pressure and 50°C temperature for 10 minutes. The resulting particle boards were tested for density, moisture content, water absorption, and thickness swelling. Flexural testing was conducted in accordance with ASTM D790-03, and tensile strength testing followed ASTM D638-14. Surface morphology was observed using a scanning electron microscope (SEM). The results showed that the application of a silane coupling agent improved the bond between the matrix and filler, and the produced particle boards met the quality standards for density, moisture content, water absorption, thickness swelling, flexural strength, and tensile strength.

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1. Introduction

Decorative particle boards are composite materials that are increasingly in demand as alternatives to decorative wood in various industrial applications, particularly in furniture making and interior construction. Decorative boards are widely used as advanced interior decorative materials in places where people may come into direct contact, such as doors, frames, window sills, wooden floors, heating mantels, and various furniture pieces. According to SNI 03-2105-2006, decorative particle boards are composite materials that can serve as alternatives to decorative wood with superior physical and mechanical properties (Rofaida et al., 2021).

The advantage of decorative particle boards lies in their physical and mechanical properties, which can be adjusted through the selection of raw materials and production techniques. In an effort to increase added value and production efficiency, various studies have been conducted to explore the use of natural materials as filler components in particle boards. One material with potential is water hyacinth fiber.

Water hyacinth fiber is a more potential composite reinforcement because it is widely available in Indonesia (Prasetyaningrum et al., 2009). The high fiber content and flexibility of water hyacinth make it promising for development in fiber-based composite applications (Putri & Mahyudin, 2019). The use of water hyacinth as a composite reinforcement can help reduce environmental pollution (Anggriani, 2018). Water hyacinth plants have a relatively high lignocellulose content, high fiber content, abundant, cheap, easy to obtain, and non-toxic (Bagir, 2008). Esearch on composites using water hyacinth fibers as particle boards has been conducted (Simanjuntak, 2013). It has also been studied for concrete composites (Jirawattanasomkul et al., 2021).

However, to produce particle boards with optimal performance, modifications are needed in the interaction between the fibers and adhesive matrix. One way to improve the bond quality between the matrix and fibers is by adding silane coupling agents (SCA), which act as a binder between natural fibers and the matrix (Dittenber & Gangarao, 2012). SCA can increase the bond between the fiber and the matrix due to the change in the properties of hydrophilic fibers (love to water) to hydropobic bonds (do not like water SCA improve the bond between the fibers and matrix by altering the fiber's hydrophilic properties (water-attracting) to hydrophobic bonds (water-repelling) (Xie et al., 2010). SCA are additives used to increase fiber adhesion to the matrix. The principle of silane in improving the bond between adhesives and fibers involves a chemical cross-linking reaction that forms covalent bonds between silanol and hydroxyl groups on the fiber. This covalent bond helps resist water ingress (Wu & Wang, 2018).

This research aims to evaluate the physical and mechanical characteristics of particle boards using water hyacinth fibers as filler with surface coating treatment using SCA. With this development, it is expected that the produced particle boards will meet the required quality standards and provide a more sustainable solution in the composite material industry.

2. The Methods

2.1 Materials

Water hyacinth fibers were used as filler in the manufacture of decorative particle boards. The fibers were obtained from ditches near residential areas along Riau street and the banks of the Siak River, Pekanbaru, Riau Province. Epoxy resin, consisting of epoxy resin and hardener, was used as the binder. The solvent for fiber alkalization consisted of NaOH and distilled water. Particle boards were made using water hyacinth fibers as filler with epoxy resin as the adhesive, and a silane coupling agent (SCA) solution was added during surface coating using the spray coating method.

Natural fiber composites with SCA show higher tensile strength compared to composites without SCA when using the same amount of fiber (Ginting et al., 2019). SCA prevent water from entering the bond between the fiber and matrix by converting the bond from hydrophilic to hydrophobic (Akil et al., 2011).

2.2 Preparation of water hyacinth fiber

Preparation is a process that must be done to make the material ready for analysis. Water hyacinth fibers obtained from the riverbanks were separated from their leaves and roots, leaving only the stems. The stems were dried under sunlight for 4-5 days (Ginting et al., 2019).

The dried stems were then cut into approximately 2 cm lengths using scissors. The chopped fibers were alkalized by soaking in a 5% NaOH solution. To obtain 5% NaOH, 250 grams of NaOH crystals were dissolved in 5000 ml of distilled water (Ginting et al., 2019.). The fibers were then washed with running water and dried using an electric oven until the moisture content was less than 8%. The preparation process of water hyacinth fibers can be seen in Figure 1.

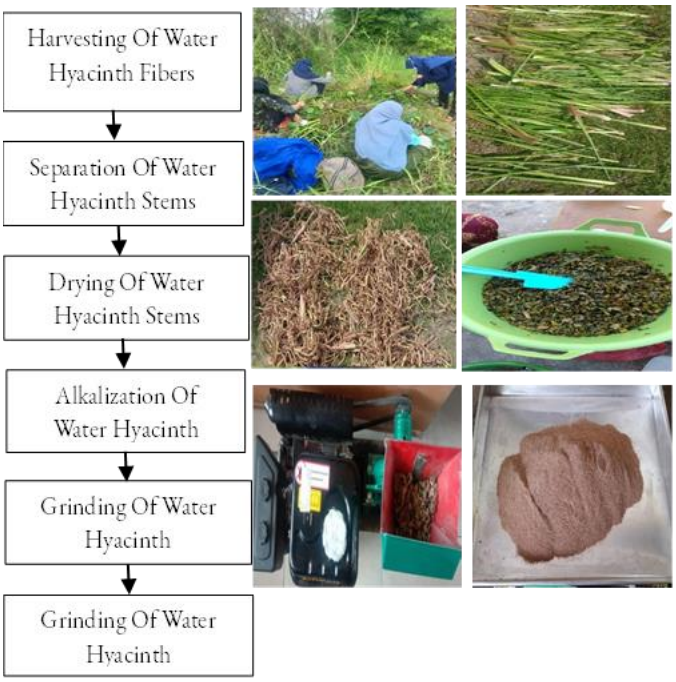


Figure 1. Preparation of water hyacinth powder

2.1 Fabrication of the particle board

The water hyacinth fiber and epoxy resin were mixed in a 40:60 ratio (Simanjuntak, 2013). he materials were stirred with a mixer at 300 rpm for 10 minutes. The mixed materials were then placed in a mold (20x15x2 cm) and subjected to hot pressing at 2 bar for 10 minutes at 50°C. The particle board was removed from the mold and conditioned for 7 days before undergoing surface coating. The physical and mechanical characteristics of the particle board were tested to meet the standards of SNI 03-2105-2006.

2.2 SCA coating

After the particle boards were molded, they were cut to ensure even surface coating on all sides. KH550 used as SCA solution at 10% of the total composite mass with concentrations of SCA: solvent (ethanol and distilled water) ratio of 25%, 50%, 75%, and 100%. The KH550 solution was prepared in a spray gun and applied to the surface of the board at 7 bar pressure from a distance of 300 mm. The drying process was done at 21°C for 48 hours.

2.3 Characterization

The particle board samples were evaluated through physical and mechanical tests. The physical tests included measurements of density, moisture content, water absorption, thickness swelling/expansion, and morphological analysis. The mechanical tests consisted of bending strength and tensile strength evaluations.

3. Result and Discussion

3.1 Decorative particle board

This research produced particle boards using water hyacinth fibers with epoxy resin adhesive, applying Silane Coupling Agent (SCA) solution to the surface of the decorative particle boards using the spray coating method. The water hyacinth fiber used was 50 mesh in size. The ratio variation used in the production of decorative particle boards was 40% water hyacinth fiber and 60% epoxy resin (Simanjuntak, 2013).

The molding process for decorative particle boards used a hot press with a pressure of 2 bar at 50°C for 10 minutes. This research tested physical properties, including density, moisture content, water absorption, and thickness swelling. Additionally, the mechanical properties, such as flexural and tensile strength, and morphological tests were conducted. A picture of the particle board is shown in figure 2.

Figure 2. Fabricated decorative particle board.

3.2 Density of particle board

The density testing of the particle board was conducted according to the SNI 03-2105-2006 standard. The test results show that the density increased with the addition of SCA variations. The density test results of decorative particle boards made from water hyacinth fibers using epoxy resin adhesive can be seen in Figure 3.

The highest particle board density was observed with 100% SCA coating without any solvent, with a density of 1.2 g/cm³, while the lowest density was found in sample 1, which was a particle board without any coating, with a density of 0.88 g/cm³. This is because there was no SCA solution coating applied to that particle board.

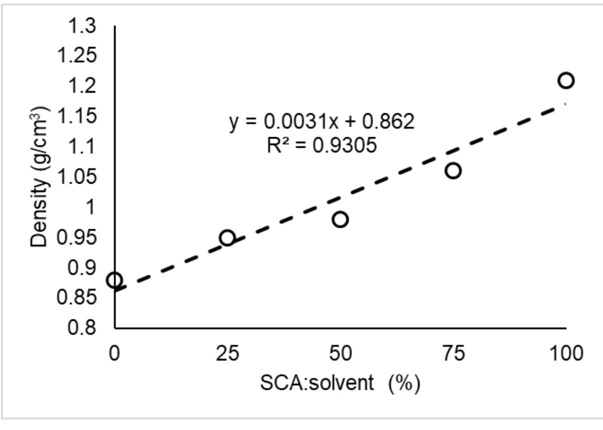


Figure 3. The effect of SCA treatment on particle board density.

Figure 3 shows that the greater the SCA value applied, the higher the density value; this is due to the function of the SCA solution, which can enhance the bonding between the matrix, namely epoxy resin, and the filler, which is water hyacinth fiber (Akil et al., 2011). The correlation coefficient of the effect of coating on the density value of the particleboard is 0.9305, indicating that the effect of the coating using SCA on the density value is strong.

Based on the research conducted, it can be concluded that for the production of water hyacinth fiber particle boards with the addition of SCA, the physical property of density has met the SNI 03-2105-2006 standard, which requires a density of 0.40-0.90 g/cm³ (National Indonesia, 2006).

3.3 Moisture content

Moisture content refers to the amount of water that can be removed from the particle board by heating in an oven. According to SNI 03-2105-2006, the moisture content for particle boards should be ≤14% (National Indonesia Standard, 2006).

The average moisture content of the particle board ranged from 0.72% to 1.35%. The highest moisture content, 1.35%, was found in sample 1, which had no SCA treatment. The lowest moisture content, 0.72%, was found in sample 5, which had 100% SCA without any solvent and the highest density.

The graph showing the relationship between the effect of varying amounts of SCA on the moisture content of the particle board can be seen in Figure 4. The results indicate that surface coating treatment using a silane coupling agent (SCA) has a significant effect on the moisture content of the particle board. The higher the amount of SCA applied, the lower the moisture content. This is because the SCA solution improves the bond between the matrix (epoxy resin) and the filler (water hyacinth fiber). The larger the amount of SCA applied, the lower the moisture content, which is due to the SCA solution improving the bond between the matrix (epoxy resin) and the filler (water hyacinth fiber). The correlation coefficient of the coating's effect on moisture content is 0.9723, meaning that the impact of the SCA coating on moisture content is very strong. The moisture content of the particle board has already met the SNI 03-2105-2006 standard (less than 14%).

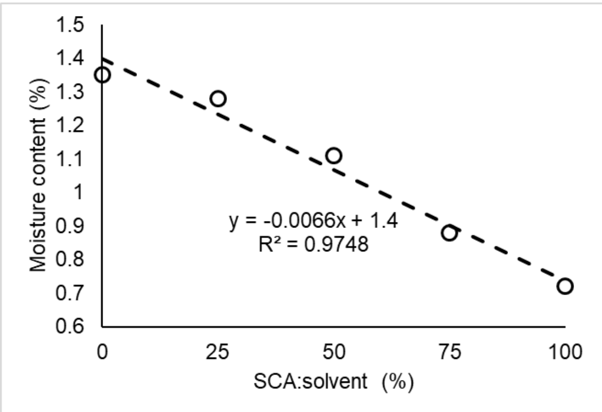


Figure 4. The effect of SCA treatment on moisture content particle board boards

3.4 Water absorption

The water absorption test aims to assess the material's ability to absorb water after being immersed in water for 24 hours at room temperature, expressed as a percentage. The water absorption test follows the ASTM D570 standard. The results of the water absorption test with three repetitions can be seen in Figure 5.

Based on Figure 5, it can be observed that the highest water absorption value is in sample 1, which has no coating of SCA solution, with a value of 19.78%. The lowest water absorption value is in sample 5, which has a 100% concentration of SCA solution, with a value of 2.49%. The correlation coefficient of the effect of coating on the water absorption value of particleboard is 0.9037, indicating that the effect of coating on the water absorption value using SCA is classified as very strong.

The amount of SCA solution affects the density value. The higher the density value, the lower the water absorption. The improvement in the quality of the bond between the fibers and the matrix is due to the change in the properties of hydrophilic fibers to hydrophobic, which can prevent the absorption of water into the bond between the matrix and the fibers, resulting in better bonding between the matrix and the fibers. SNI 03-2105-2006 does not specify a required water absorption value. The water absorption value of the particleboard already meets the SNI 03-2105-2006 standard.

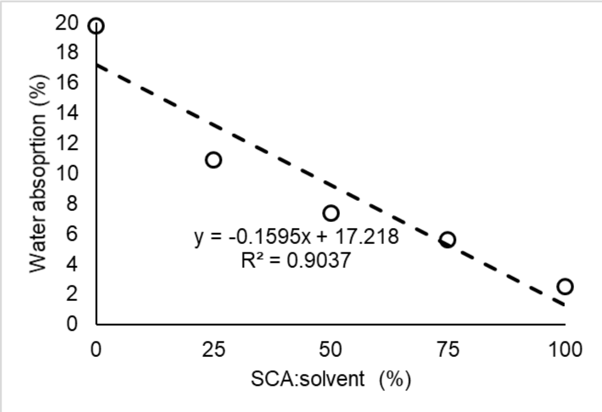


Figure 5. The effect of SCA treatment on water absorption of particle board.

3.5 Thickness expansion testing

The thickness expansion test aims to observe the expansion of particleboard thickness by measuring the thickness of the board after being immersed for 24 hours, expressed as a percentage. The density test follows the SNI 03-2105-2006 standard. The results of the thickness expansion testing of the particleboard can be seen in Figure 6.

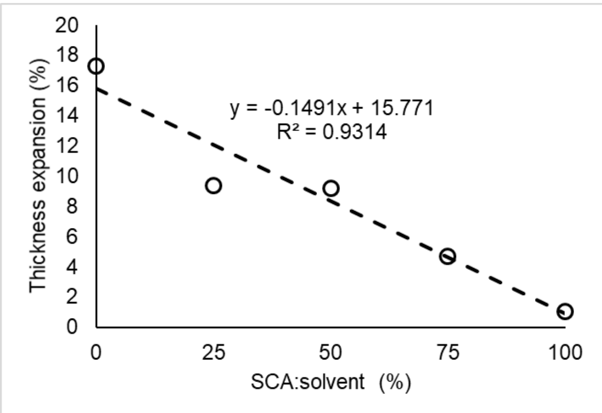


Figure 6. The effect of SCA treatment on the thickness expansion of particle board.

Based on Figure 6, it can be seen that the thickness expansion of the particleboard after 24 hours of immersion has decreased. Figure 6 shows that the greater the amount of SCA solution used for coating the particleboard, the lower the thickness expansion value. In this study, the thickness expansion values range from 17.31% to 1.034%. The largest thickness expansion value is found in sample 1, which is the sample without SCA solution treatment, with a value of 17.31%. The smallest thickness expansion value is found in sample 5, which uses 100% SCA solution coating, with a value of 1.034%.

The correlation coefficient for the effect of coating on the thickness expansion value of the particleboard is 0.9314, which means that the effect of coating on the thickness expansion value using SCA is classified as very strong.

The expansion value of the control particleboard does not meet the SNI 03-2105-2006 standard. The thickness expansion values for each sample using SCA solution coating have met the SNI 03-2105-2006 standard.

3.7 Bending strength testing

The bending strength test aims to determine the resistance of particleboard to the applied load. This bending test uses the HUNG TA HT-8503 apparatus. The test follows the ASTM D-638 standard. The graph showing the relationship between the strength values and the samples is presented in Figure 7.

Figure 7 identifies the effect of SCA concentration on the bending strength of the particleboard. The lowest bending strength is found in sample 1, which is the control sample, with a value of 75.86 Kgf/cm². This is due to the fact that the control sample did not undergo any SCA addition treatment. The highest bending strength test result is found in sample 5, with a value of 186.38 Kgf/cm².

The research by Simanjuntak (2013) studied the Mechanical Properties of Composites with a Volume Fraction of Water Hyacinth Fiber in a Polyester Matrix. The results showed that the lowest bending strength occurred at a fiber volume fraction of 40%:60%, with a value of 16.4 MPa. This study was conducted using a fiber volume fraction of 40%:60%, and the lowest bending strength was modified by adding an SCA solution coating, with the expectation that the addition of SCA would increase the bending strength.

The addition of SCA to the particleboard shows an interaction with the flexural properties of the particleboard; the percentage of SCA added is directly proportional to the flexural value. The results of the bending strength tests increased with the concentration of SCA. The bending test results for the water hyacinth fiber particleboard without treatment meet the SNI 03-2105-2006 standard for decorative particleboard type 8. The particleboard coated with SCA meets the SNI 03-2105-2006 standard for structural particleboard type 10, with a dry bending strength above 102 Kgf/cm². Based on the correlation coefficient value in the graph, which is 0.9697, it indicates that the effect of coating on the bending strength value using SCA is classified as very strong.

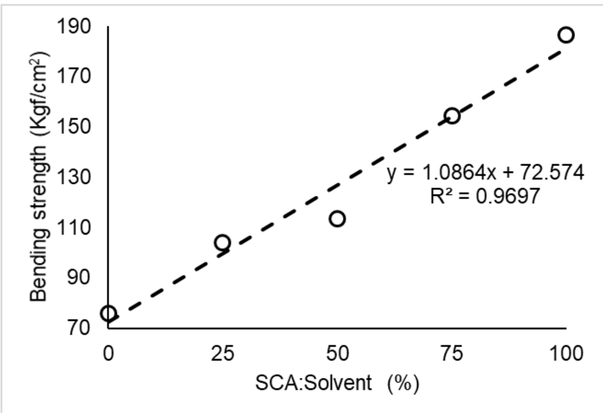


Figure 7. The effect of SCA treatment on strong bending hyacinth particle board

3.8 Tensile strength testing

The tensile strength test uses the HUNG TA HT-8503 apparatus. This test follows the ASTM D-638-14 standard. The graph showing the relationship between the strength values and the samples is presented in Figure 8. The results of the tensile strength tests meet the SNI 03-2105-2006 standard for particleboard of all types.

Based on the results shown in Figure 8, it can be seen that sample 5 has the highest tensile strength, which is 52.7193 Kgf/cm², while the control sample has the lowest tensile strength at 50.17 Kgf/cm². This is due to the fact that the control sample did not undergo any SCA coating treatment. The research by Simanjuntak (2013) states that the lowest tensile strength value occurs at a fiber fraction of 40%:60%, with a value of 40.92 Kgf/cm².

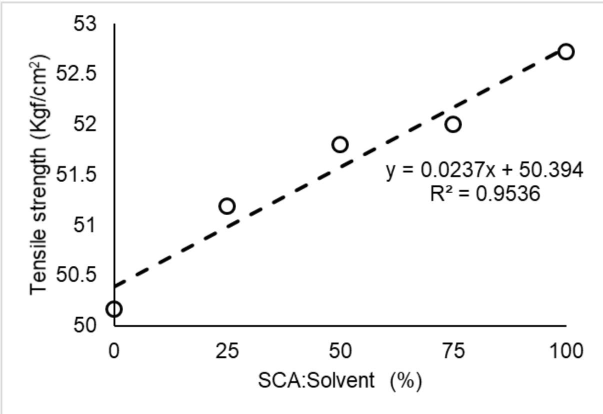


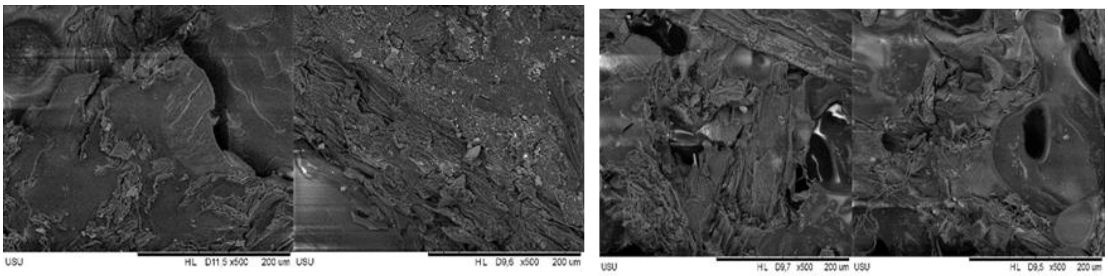
Figure 8. The effect of SCA on the tensile water hyacinth particle board.

The results of this study, when compared to the research by Simanjuntak (2013), can be concluded that the addition of SCA to the particleboard shows an interaction with the tensile values of the particleboard. Simanjuntak's (2013) research reported the highest tensile strength value at 45.78 Kgf/cm², with a correlation coefficient of 0.49.

The percentage of SCA added is directly proportional to the tensile value. The higher the percentage of SCA, the better the tensile value will be. The results of the tensile strength tests meet the SNI 03-2105-2006 standard for particleboard of all types.

3.9 Surface morphology

Morphological testing to observe the bonding of decorative boards with a Silane Coupling Agent solution was conducted using Scanning Electron Microscopy (SEM). The SEM test results can be seen in Figure 10. The imaging results from the Scanning Electron Microscope (SEM) show the cross-sectional surface of particleboard fractures after the bending test. The imaging results were selected for two samples: particleboard without coating and with 100% SCA coating.



(a) (b) (c) (d)

Figure 10. Morphological SEM photograph of the particle board cross section: (a) without coating, (b) surface fracture of without coating after bending test, (c) with 100% KH550 (SCA) coating, and (d) surface fracture with 100% KH550 (SCA) coating after bending test.

The results of the Scanning Electron Microscope (SEM) imaging of the cross-sectional surface of particleboard fractures before and after the bending test can be seen in Figure 10. Two samples were selected for imaging: particleboard without coating and with 100% KH550 coating. The imaging results show that the cross-sectional bonding of the uncoated composite has more grains; as known, grains can be a cause of reduced bonding strength between the filler and the matrix.

Looking at the bending strength test results in Figure 7, the lowest value is found in the uncoated particleboard, which is due to the abundance of grains in the particleboard. The imaging of the particleboard with 100% KH550 coating shows that there are not many grains on the composite surface.

4. Conclusion

The results of this study show that the effect of SCA (KH550) treatment on the physical and mechanical properties has successfully enhanced the bonding between water hyacinth fibers and epoxy, effectively aligning with the increases in density, moisture content, and bending strength. The physical properties testing of the particleboard has met the SNI 03-2105-2006 standard. The bending test results for the water hyacinth fiber particleboard without treatment meet the SNI 03-2105-2006 standard for decorative particleboard type 8. The particleboard coated with SCA (KH550) meets the SNI 03-2105-2006 standard for structural particleboard type 10, with a dry bending strength above 102 kgf/cm^2. The tensile strength test results meet the SNI 03-2105-2006 standard for particleboard of all types.

References

Akil, H. M., Omar, M. F., Mazuki, A. A. M., Safiee, S., Ishak, Z. A. M., & Abu Bakar, A. (2011). Kenaf fiber reinforced composites: A review. In *Materials and Design* (Vol. 32, Issues 8–9, pp. 4107–4121). https://doi.org/10.1016/j.matdes.2011.04.008

Anggriani, D. (2018). Manufacture of Composite Board of Bagasse Powder and Hyacinth Fiber with Polypropylene Matrix. *Journal of Scientific Physics*, *Vol. 11 No.*

Bagir, A. and G. E. P. (2008). *The use of water hyacinth fiber as raw materials for the manufacture of composite Achmad Bagir (L2C005218) and Gigih Eka Pradana (L2C005260).*

Dittenber, D. B., & Gangarao, H. V. S. (2012). Critical review of recent publications on use of natural composites in infrastructure. In *Composites Part A: Applied Science and Manufacturing* (Vol. 43, Issue 8, pp. 1419–1429). https://doi.org/10.1016/j.compositesa.2011.11.019

Ginting, D., Putra Wirman, S., & Muharman Lubis, Y. (2019). *Modification of Kenaf Fibers Composite and Empty Oil Palm Bunch With Silane Coupling Agent Addition*.

Jirawattanasomkul, T., Minakawa, H., Likitlersuang, S., Ueda, T., Dai, J. G., Wuttiwannasak, N., & Kongwang, N. (2021). Use of water hyacinth waste to produce fibre-reinforced polymer composites for concrete confinement: Mechanical performance and environmental assessment. *Journal of Cleaner Production*, *292*. https://doi.org/10.1016/j.jclepro.2021.126041

Liu, Y., Guo, L., Wang, W., Sun, Y., & Wang, H. (2019). Modifying wood veneer with silane coupling agent for decorating wood fiber/high-density polyethylene composite. *Construction and Building Materials*, *224*, 691–699. https://doi.org/10.1016/j.conbuildmat.2019.07.090

National Indonesia Standard. (2006). *"Particle board" Indonesia National Standard (Fiber Board) 1-23.*

Prasetyaningrum, A., Rokhati, N., & Rahayu, K. (2009). Optimization of the process of making water hyacinth fiber to produce fiber composites with high physical and mechanical quality. *Riptek*, *3*(1), 45–50.

Putri, L. D., & Mahyudin, A. (2019). Analysis of the Effect of Volume Percentage of Hyacinth Fiber and Areca Nut Fiber on the Mechanical Properties and Biodegradation of Epoxy Matrix Hybrid Composites. *Journal of Physics Unand*, *8*(3), 288–294. https://doi.org/10.25077/jfu.8.3.288-294.2019

Rofaida, A., Pratama, R. M., Sugiartha, I. W., & Widianty, D. (2021). The Physical And Mechanical Properties Of Particle Board Due To The Addition Of Bamboo Fiber Filler. *Civil Spectrum*, *8*(1), 1–11. https://doi.org/10.29303/spektrum.v8i1.187

Simanjuntak, M. P. (2013). Mechanical Properties of Composites to Volume Fraction of Polyester Matrix Hyacinth Fibers. *Einstein e-journaL, 1*(2), 76–87. https://doi.org/10.24114/einstein.v1i2.5062

Wu, W., & Wang, J. (2018). Effect of KH550 on the Preparation and Compatibility of Carbon Fibers Reinforced Silicone Rubber Composites. *Silicon*, *10*(5), 1903–1910. https://doi.org/10.1007/s12633-017-9700-4

Xie, Y., Hill, C. A. S., Xiao, Z., Militz, H., & Mai, C. (2010). Silane coupling agents used for natural fiber/polymer composites: A review. In *Composites Part A: Applied Science and Manufacturing* (Vol. 41, Issue 7, pp. 806–819). https://doi.org/10.1016/j.compositesa.2010.03.005.