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# Enhancing the mechanical strength of *petung* bamboo (Dendrocalamus asper) composites using brackish water immersion

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**Abstract**

This study investigates and analyzes the effect of brackish water immersion on the mechanical properties of woven Petung bamboo (Dendrocalamus asper) reinforced epoxy composites. The bamboo, aged 5 years and 10 feet in length, was split, woven, and soaked in brackish water with varying salinity levels (10–30%) for 2, 4, 6, and 8 weeks. The composites were fabricated using epoxy resin and dried for two weeks before testing. Mechanical properties were evaluated through tensile and bending tests, following ASTM D3039 and ASTM C393 standards, respectively. The results show that immersion significantly improves mechanical strength under specific conditions. The highest tensile strength (74.75 MPa) was achieved by a 2-layer composite soaked for 2 weeks in 10% brackish water, while a 3-layer composite soaked for 4 weeks in 20% brackish water achieved the maximum bending strength of 84.73 MPa. Compared to untreated specimens, strength increases ranged from 30% to 60%, depending on the number of layers and immersion conditions. These findings suggest that brackish water immersion acts as an effective pre-treatment method, enhancing the fiber–matrix bonding and stiffness of bamboo composites. These results suggest that pre-treatment with brackish water can significantly enhance the mechanical performance of natural fiber composites, offering low-cost, sustainable composite materials applicable in construction, furniture, and eco-friendly product development.

**Keywords:**
Composite material, tensile strength, bending, woven bamboo blades, epoxy resin, brackish water.

## 1 Introduction

The development of material engineering technology, especially composite materials, has recently experienced significant progress, especially in the field of application in the manufacturing industry. One of the engineering technologies and innovations of composite materials is the use of natural materials as reinforcement [1]. The use of natural materials as reinforcement materials for composite materials, generally in the form of fibers, such as hemp fiber, pineapple, coconut belt, kenaf, palm, banana stems, and bamboo.

Bamboo is a plant that belongs to the Poaceae tribe (grasses). Bamboo is a very abundant resource and has a fairly high diversity [2]. According to researcher [3] in Indonesia there are allegedly 157 types of bamboo. This amount is more than 10% of the world's bamboo species, 50% is a type of bamboo that has been used by the population and has great potential to be developed for the community's economy, both for daily needs, such as water pipes, fishing gear and to make furniture that can be used in addition to being able to be traded.

One type of bamboo that is used for various purposes is Petung bamboo (Dendrocalamus Asper). Bamboo Petung has a much larger stem size than other types with shorter segments. Petung bamboo is commonly used as a food ingredient while Petung bamboo stems are widely used for construction materials because of their large stem size and thick walls. Petung bamboo is a type of bamboo with a rather dense clump, the height of the bamboo can reach 20 m with a center line of up to 20 cm. In books there are often short and clustered roots, the length of the segments ranges from 40-60 cm, and the bamboo walls are quite thick 1-1.5 cm. Bamboo, particularly Petung bamboo (Dendrocalamus Asper), is a promising natural material for composite reinforcement due to its high tensile strength and environmental benefits. The mechanical properties of bamboo composites can be enhanced through various treatment methods, including immersion processes.

Bamboo, particularly Petung bamboo (Dendrocalamus asper), has emerged as a promising natural fiber for composite reinforcement due to its abundance, low cost, and environmental benefits . But unfortunately, bamboo reinforced fibers are still low in tensile and bending

Some previous studies on the influence of bamboo mechanical properties on the immersion method include: The alkalization process, by immersion of bamboo fibers in NaOH solution, can increase the bond between the fiber and the matrix, potentially increasing tensile strength. However, excessive immersion time can lead to a decrease in strength [4]. Brackish water immersion, which is a method of immersion of bamboo pieces in brackish water with varying levels of salinity and duration, has shown a significant increase in tensile strength. Optimal results were observed with salinity of 20 ppm for 4 weeks, leading to an increase in tensile strength by 21.537% [5]. Sulfur water immersion, i.e. by immersion of bamboo in sulfur water, has been found to increase tensile strength by up to 89.17%, with additional benefits observed when followed by seawater immersion [6].

One of the mechanical tests that have been carried out by researchers is tensile Strength: Mechanical testing ensures the quality of the material. Various studies have demonstrated that treated bamboo composites exhibit increased tensile strength. For instance, composites soaked in brackish water showed tensile strength improvements ranging from 5.317% to 21.537% depending on the salinity and duration [5]. In addition to tensile strength, immersion treatment has also been shown to improve flexural and impact strength, making bamboo composites stronger and more versatile for structural applications [6].

Studies have shown that bamboo fiber-reinforced composites exhibit improved mechanical properties, especially tensile strength, when subjected to various treatments. Alkali treatment with NaOH can enhance fiber-matrix bonding, while sulfur water immersion has been found to significantly increase tensile strength [7][8]. Manufacturing processes, such as hot pressing, can further improve tensile strength compared to hand lay-up methods [8]. However, water absorption can negatively impact composite strength [8]. Chemical treatments are often employed to address issues related to poor fiber-matrix adhesion caused by natural fiber constituents like cellulose and lignin [9].

Based on the publications that have been explained above, nothing has been focused on analyzing the mechanical properties of woven reinforced composite materials of bamboo blades soaked in brackish water and the variation of immersion. The age of the bamboo used is 5 years old, with a height of 10 feet while the trunk circumference reaches 20 cm. Bamboo that has been cut and split and then woven, then soaked with brackish water. The composite material is made of a mixture of epoxy resin and woven blades that are dried for 2 weeks indoors without light. Specimens are made based on ASTM D3039 for tensile tests, and ASTM C393 for bending tests. The research aims to analyze the mechanical properties of composite materials reinforced with woven bamboo blades, specifically Petung bamboo (Dendrocalamus Asper), after immersion in brackish water. The focus is on examining the impact of varying immersion durations (2, 4, 6, and 8 weeks) on tensile and bending strength. Specimens are prepared in accordance with ASTM standards, using a combination of epoxy resin and woven blades, to determine how the immersion treatment influences the performance of these bamboo-based composites in structural applications

## 2 Research methods/ materials and methods

This study is experimental research to test the mechanical strength of bamboo Petung, including tensile strength and bending strength by providing a pre-treatment [5][10], namely immersion in laboratory-scale river water taken from the Tello River in Makassar. This research was conducted at the Mechanical Engineering Laboratory at Hasanuddin University.

### 2.1 Research materials

The bamboo used in this study is Petung bamboo (Dendrocalamus asper) shown in Fig. 1, often used as an alternative material to replace wood to overcome the scarcity of wood raw material supply for the furniture and building materials industry. The life of the bamboo used is 5 years, with a height of 10 feet while the trunk circumference reaches 20 cm.

Fig. 1. Petung bamboo tree

### 2.2 River water

The material used for immersion bamboo is Tello river water in Makassar City with a salinity standard of 10 ppm. The studies Petung(Fig. 2) bamboo strip composites demonstrated varying tensile strengths when immersed in brackish water, with the highest strength observed after 2 weeks of immersion at 10 ppm [11]. Bamboo's high silica content (5-30% dry weight) suggests a potential role in enhancing chemical weathering, though the efficiency of Si recycling from bamboo litter remains unclear [12]. Stream water analyses from bamboo forests indicated a slight increase in silicate-derived dissolved ion concentrations, hinting at bamboo's possible contribution to chemical weathering [12]. However, further research is needed to fully understand bamboo's impact on chemical weathering processes.The material is used as a water enhancer and maintains salinity levels when river water evaporates during the immersion process

Fig. 2. River water

### 2.3 Resin epoxy

In the manufacture of composite panels, the resin used is epoxy resin and also hardener, with a ratio of 60:40. The composite material uses an epoxy resin as the matrix. To be more specific, the resin employed is a thermosetting epoxy, which is known for its high strength, low shrinkage, excellent adhesion to fibers, and chemical resistance. By combining the tensile strength of bamboo fibers with the rigidity and durability of epoxy resin, the study aims to explore the synergistic enhancements achieved through immersion treatments. Specimen preparation follows ASTM D3039 for tensile tests and ASTM C393 for bending tests, ensuring adherence to standardized mechanical evaluation protocols.

The choice of epoxy-to-hardener ratio significantly influences the mechanical properties and performance of epoxy systems. While resin suppliers often specify ratios for full cure, research shows that slight variations can alter tensile strength and curing time [13]. For polymer concrete, a resin-to-filler ratio of 60:40 was found optimal for uniform aggregate distribution, balancing performance and cost [14]. Studies on epoxy systems reveal that resin-rich compositions exhibit brittle behavior due to rigid macromolecular structures, while hardener-rich systems demonstrate greater deformation capacity [15]. Interestingly, increasing the hardener-to-resin ratio can enhance impact energy absorption, contrary to the usual expectation of increased brittleness. This is attributed to non-reacted sites on hardener molecules, allowing for greater strain accommodation through molecular rotation [15]. These findings underscore the importance of carefully considering and justifying epoxy-to-hardener ratios in various applications.

### 2.4 Research tools

The research tools used in this study are chainsaws, machetes, meters, immersion containers (aquariums), refractometers, aquarium and room thermometers, measuring cups, aquarium pumps, 20 Ton hydraulic jacks, scales, shovels, and curtain rails.

### 2.5 The process of taking bamboo petung

Bamboo picking in the Tana Toraja (Makale) area. The selection of bamboo petung with an age range of 3-5 years. The collection of Petung bamboo materials uses a chainsaw. The part of the bamboo segment that will be used is 2 meters away from the base of the bamboo stem. Cutting bamboo segments without picking up bamboo bones, completely as in fig. 3.

Fig. 3. Bamboo pieces

### 2.6 Webbing making process

The first step is to make the bamboo slats perpendicular to the bamboo skin. Next, measure the bamboo slats using a caliper with the size: thickness =1 mm, width 10 mm, and length 250 mm Then the last step is to make a plain weave with high density using bamboo slats that have been made as many as 78 sheets with a size of 250 mm x 250 mm, completely as in fig. 4.

Fig. 4. Woven shape

### 2.7 The process of making immersion media

Prepare an aquarium as a container with a water capacity of 50 liters as many as 3 pieces. Taking water from the Tello river in Makassar City as much as 120 liters. Preparing salt as an increase in salinity in river water. Prepare aquadest. Prepare aquarium pumps, aquarium thermometers, curtain rails and chicken drinking places. Mix water and salt with 3 variations of immersion salinity levels, namely: 10 ppm, 20 ppm and 30 ppm. Installing all bamboo immersion equipment.

### 2.8 Immersion process

The bamboo immersion process varies between 2, 4, 6 and 8 weeks of removal done every 2 months. Before immersion, the bamboo webbing is weighed. In 1 aquarium there are 24 pieces of woven bamboo. Every 1x in 1 day, the room temperature and water temperature in the aquarium are checked. Every 1x in 2 days, salinity levels and water evaporation are checked, as seen in fig. 5.

Fig. 5. Immersion container

### 2.9 Composite panel manufacturing process

In the manufacturing process is very important to pay attention to the steps [16]. The steps of the manufacturing process are as follows (Fig. 6):

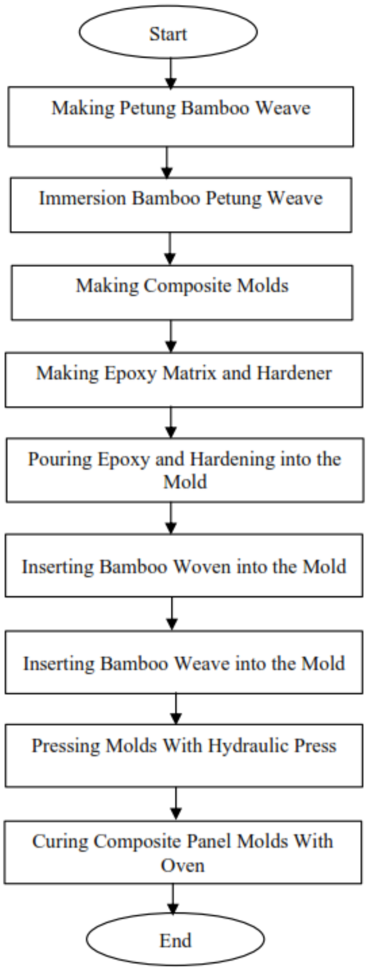


Fig. 6. Manufacturing process flow diagram composite panel

The size of the composite panel to be made is: 250 mm x 250 mm, 4 mm thick. The total panels to be made are 36 with a variety of layers, namely 1, 2, and 3 layers of woven fabric in 1 panel. Use the PPE (Personal Protective Equipment) provided. Prepare bamboo webbing that has been lifted from the immersion. Make a matrix of epoxy and hardener with a ratio of 60: 40 (90 ml: 60 ml). Prepare the mold and apply Mirror glazes on the mold until it is evenly distributed so that it can make it easier during the process of removing the composite panel on the mold. (The mold used is made of steel plate). Pour the mixture into a mold and then flatten it. Insert the bamboo weaving according to the number of layers. Cover the mold with a cover that is also made of steel plate, then apply pressure using a hydraulic press so that the thickness of the panel is in accordance with the ASTM standard, which is 4 mm. The pressing process is carried out for 8 hours. After that, the panel can be removed from the mold. Weigh the panels before curing. The panel curing process uses an electric oven with a temperature of 110 $^{o}$C for 60 minutes.

### 2.10 Specimen manufacturing process

Specimen cutting is performed on the basis of (ASTM D638-02) [17] for tensile tests, and (ASTM D790-03) [18] for bending tests, with room temperature 21 0C, relative humidity: 88.36%. for tensile tests, Tensile Testing Machine: Type Universal Testing Machine; Manufacturer by Instron; Made in USA. For bending tests (ASTM D790-03) [11] Bending Testing Machine: Type Bending Tester; Manufacturer by Shimadzu Corporation; Made in Japan The specimen to be made is based on the variation of the layer, the immersion time and the moisture content of the soak (Fig. 7).

Fig.. 7. Specimen ready for testing

The research delves into the mechanical properties of composite materials reinforced with woven blades of Petung bamboo (Dendrocalamus Asper), focusing on tensile and bending strengths after immersion in brackish water for varying durations (2, 4, 6, and 8 weeks). Bamboo fibers are known for their excellent mechanical properties, such as high tensile strength (ranging from 140–230 MPa) and elasticity, which make them a strong contender for composite reinforcement

## 3 Results and discussion

The results obtained from this study generally consist of Tensile Strength and Bending Strength.

### 3.1 Tensile strength

Tensile strength is often used to determine the strength of a material by measuring the force required to pull the material to the point where the material breaks. Based on the results of the tensile test of composite material reinforced with woven bamboo slats with variations in brackish water immersion time, variations in salinity percentages of 10, 20, and 30% and layers 1, 2, and 3-layer bamboo weaving that has been done can be seen in the Fig. 8.

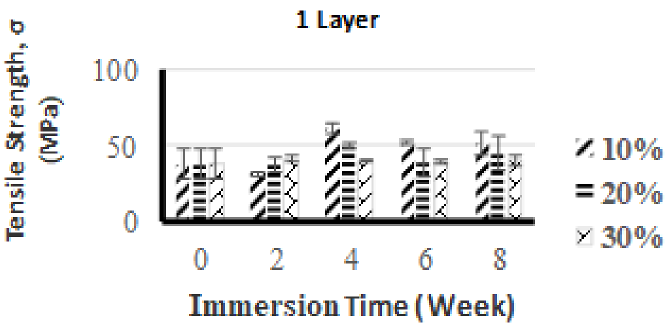


Fig. 8. Graph of 2, 4, 6, 8 weeks of immersion time variation on the tensile strength of 1-layer bamboo blade woven reinforced composite material and 10, 20, 30% salinity percentage variation

Figure 8 shows the value of the tensile test results on the 1-layer Petung bamboo composite, where the normal value in the test results is (37.66 MPa) which is the basic value to see the effect that occurs on bamboo immersion. The value of the 2-week immersion results decreased at 10% and 20% brackish levels (31.14 MPa and 36.64 MPa) and increased by 30% (40.74 MPa). At 4 weeks of immersion, there was an increase for all variables of brackish level and 10% brackish content which experienced the highest increase (61.25 MPa) or around 62.64%. Furthermore, for 6 weeks, there tends to be a continuous decrease until 8 weeks of immersion. These results align with several previous studies, including:Researchers [19] studies show that increasing the volume percentage of bamboo strips improves tensile strength, with 60% volume yielding the highest strength of 39.139 N/mm²). So did the researcher [11] optimal tensile strength was achieved with 2-3 weeks of immersion in brackish or sulfurous water, reaching up to 78.71 MPa for 3-layer composites Manufacturing methods impact strength, with hot press improving tensile strength by 37% compared to hand lay-up [8]. However, water absorption can decrease tensile strength by up to 29%. Alkali treatment of fibers reduces water absorption and its negative effects on strength [8]. These findings demonstrate the potential of petung bamboo as a reinforcement material in epoxy resin composites, offering an environmentally friendly alternative to synthetic fibers.

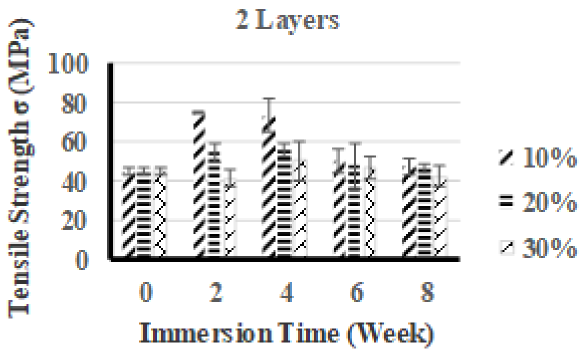


Fig 9. Graph of 2, 4, 6, 8 weeks of immersion time variation on the tensile strength of 2-layer bamboo woven reinforced composite material and 10, 20, 30% salinity percentage variation

In Figure 9 showed the results of the tensile strength test of the 2-layer Petung bamboo composite, where the normal value was (44.77 MPa) which was the basis for seeing the effect on the results of the immersion treatment carried out. The value in 2 weeks of immersion increased in value at 10% & 20% brackish level where the 10% brackish level experienced the highest increase in value (74.75 MPa) and for 30% brackish content decreased. For 4 weeks of immersion tends to increase at 20% and 30% brackish rates and decreases at 10% brackish rates but higher than other brackish levels. For 6 weeks, it tends to decrease for all percentages of brackish levels up to 8 weeks of immersion.

Fig 10 shows the results of the tensile strength test of 3-layer bamboo composite, where the normal value is (68.95 MPa) which is the basis for seeing the effect on the results of the immersion treatment carried out. Values at 2 weeks of immersion, 20% & 30% decreased in value and did not increase for up to 8 weeks. For the brackish level of 10%, it increased to 14.16% in 2 weeks of immersion with a value of (78.71 MPa) and then decreased to 8 weeks.

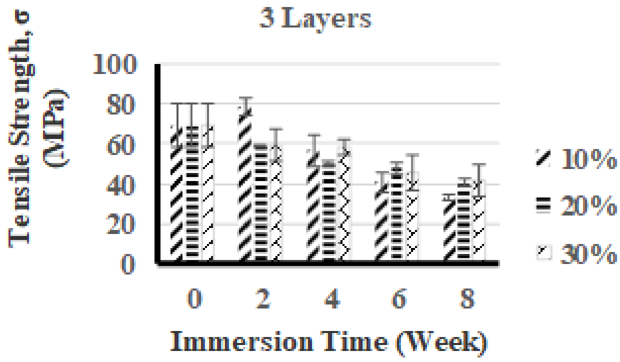


Fig 10. Graph of 2, 4, 6, 8 weeks of immersion time variation on the tensile strength of 3-layer bamboo woven reinforced composite material and 10, 20, 30% salinity percentage variation

This is in line with the researcher [20] they conducted a study on the degradation of the tensile strength of Petung bamboo composite with random fibers due to the treatment of immersion in hot water for 4 hours, the results obtained from the strength of bamboo decreased the strength of the treatment given because the absorption of bamboo occurs very quickly and absorption occurs at an unreachable level as the immersion time increases. The tensile strength of the Petung bamboo composite, which has a higher percentage of bamboo fiber than the matrix of the composite, which has a higher percentage of bamboo fiber than the composite matrix, is the lowest tensile value. The above research is in line with the results of the tensile test that has been carried out on bamboo woven composites, following the large percentage of reinforcing fibers and a long immersion time that degrades the tensile strength of bamboo.

### 3.2 Bending strength

Bending testing is often used to determine the strength and ductility of materials. The bending test results are as follows: 1-layer bamboo woven reinforced composite material and 10, 20, 30% salinity percentage variation. Fig. 11 shows the results of the bending strength test of 1-layer bamboo composite, where the normal value is (51.40 MPa) which is the basis for seeing the effect on the results of the immersion treatment carried out.

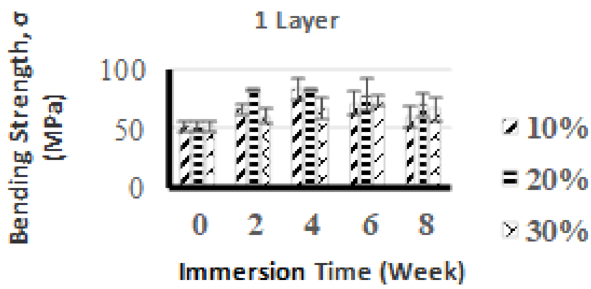


Fig 11. Graph of 2, 4, 6, 8 weeks of immersion time variation on the bending strength of 1-layer bamboo woven reinforced composite material and 10, 20, 30% salinity percentage variation

The strength of the 1-layer bending is above the normal value, the value in the figure above shows at 2 weeks and 4 weeks of all brackish levels, the value of the test specimen rises to 61.61% with a strength of around (83.07 MPa) which is at 20% brackish level, 6 weeks shows a degradation of the value up to 8 weeks. Research on Petung bamboo (Dendrocalamus asper) composites has shown promising results for their use as engineering materials. Studies have investigated the effects of various treatments on the tensile strength of these composites. Immersion in brackish water for different durations and concentrations affected the tensile strength, with some treatments showing improvement [11]. NaOH treatment also influenced the tensile strength, with a 6% concentration yielding the best results [21]. Increasing the volume percentage of bamboo strips in the composite led to higher tensile strength, with 60% volume showing the best performance [22]. Pretreatment with sulfur water and seawater immersion significantly improved tensile strength and strain, with longer immersion times yielding better results [23]. These findings demonstrate the potential of Petung bamboo composites as alternatives to synthetic materials in various applications.

In Fig 12 shows the results of the bending strength test of the 2-layer Petung bamboo composite, where the normal value was (72.46 MPa) which was the basis for seeing the influence on the results of the immersion treatment carried out. The value for the brackish content of 20% is above the normal value for up to 8 weeks of immersion and has the highest value at 4 weeks of immersion, which is (84.63 MPa). For 10% and 30% tend to have values below normal, but at 2 weeks and 4 weeks have values above normal.

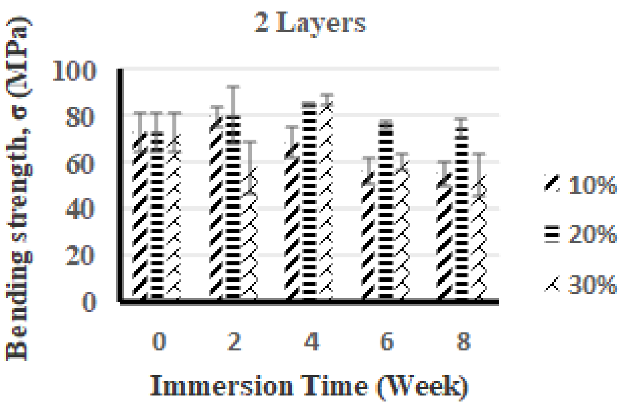


Fig 12. Graph of 2, 4, 6, 8 weeks of immersion time variation on the tensile strength of 2-layer bamboo woven reinforced composite material and 10, 20, 30% salinity percentage variation

In Fig 13 showed the results of the bending strength test of 3-layer Petung bamboo composite, where the normal value was (68.78 MPa) which was the basis for seeing the effect on the results of the immersion treatment carried out. The value in the graph above tends to have a value above normal and has the highest value (84.73 MPa) occurring at 4 weeks – 20% brackish and at 8 weeks – 30% brackish level has the lowest value (53.10 MPa).

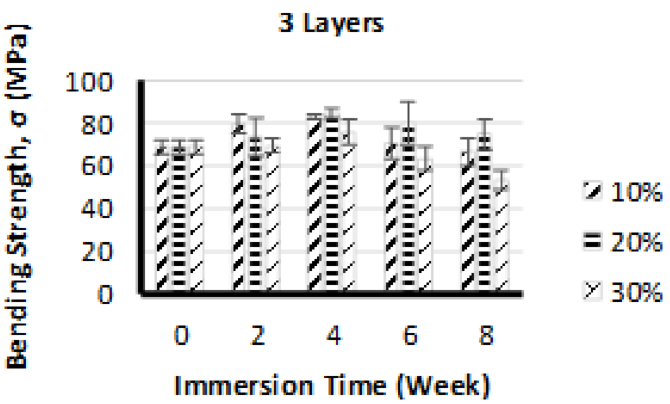


Fig 13. Graph of 2, 4, 6, 8 weeks of immersion time variation on the tensile strength of 3-layer bamboo woven reinforced composite material and 10, 20, 30% salinity percentage variation

This is in line with the researcher [20] they conducted a study on the degradation of the tensile strength of Petung bamboo composite with random fibers due to the treatment of immersion in hot water for 4 hours, the results obtained from the strength of bamboo decreased the strength of the treatment given because the absorption of bamboo occurs very quickly and absorption occurs at an unreachable level as the immersion time increases. The tensile strength of the Petung bamboo composite, which has a higher percentage of bamboo fiber compared to the composite matrix, is the lowest tensile value. The above research is in line with the results of the tensile test that has been carried out on bamboo woven composites, following the large percentage of reinforcing fibers and a long immersion time that degrades the tensile strength of bamboo.

Research on Petung bamboo (Dendrocalamus asper) composites has shown promising results for their mechanical properties. Studies have investigated the effects of various treatments on tensile and bending strength. Immersion in brackish water for different durations and concentrations can influence the composite's performance [28][7]. The highest tensile strength was observed after 2 weeks of immersion for 2- and 3-layer composites, with increases of up to 20.69% compared to untreated samples [27]. Sulfur water immersion also improved tensile strength, with longer immersion times yielding better results [23]. The composite's volume percentage of bamboo strips affects its strength, with 60% volume showing the highest tensile strength of 39.139 N/mm² [7]. These findings suggest that Petung bamboo composites have potential as alternative materials in various applications.

## 4 Conclusion

Brackish water immersion significantly increased the tensile strength of the bamboo composite. The most notable result was observed in a 2-layer composite soaked for 2 weeks in 10% salinity, reaching 74.75 MPa compared to the untreated value of 44.77 MPa. The highest bending strength (84.73 MPa) was recorded for a 3-layer composite after 4 weeks of immersion in 20% brackish water, showing a substantial improvement from the untreated value of 68.78 MPa. The most optimal treatment for tensile strength was 2 weeks of immersion at 10% salinity, while for bending strength, it was 4 weeks of immersion at 20% salinity.

The study implied that these immersion treatments can enhance the mechanical performance of natural fiber composites, although further research is needed on the microstructure of each of the most influential treatments.

## References


[1] M. Y. Khalid, A. Al Rashid, Z. U. Arif, W. Ahmed, H. Arshad, and A. A. Zaidi, “Natural fiber reinforced composites: Sustainable materials for emerging applications,” *Results Eng.*, vol. 11, no. April, p. 100263, 2021, doi: 10.1016/j.rineng.2021.100263.

[2] A. R. Paembonan, E. Tambaru, M. R. Umar, and A. I. Latunra, “Analisis kemampuan bambu ater (Gigantochloa atter (Hassk.) Kurz dalam mengabsorpsi karbon dioksida di kecamatan buntao’ rantebua kabupaten toraja utara,” pp. 1–9, 2014, [Online]. Available: http://repository.unhas.ac.id/handle/123456789/10923

[3] E. A. Widjaja And K. Karsono, “Bamboo diversity in Sumba island,” *Biodiversitas J. Biol. Divers.*, vol. 6, no. 2, pp. 95–99, 1970, doi: 10.13057/biodiv/d060205.

[4] T. D. Widodo *et al.*, “Effect of alkalization treatment on the tensile strength and interface character matrix-fibber of bamboo Petung (Dendrocalamus Asper) Reinforced Polyester Resin Composite,” in *IOP Conference Series: Materials Science and Engineering*, Institute of Physics Publishing, Mar. 2019. doi: 10.1088/1757-899X/494/1/012081.

[5] F. R. Bethoni, C. Johan, M. Pineng, and S. Suluh, “Analysis of mechanical and physical properties of composite materials of reinforced epoxy reinforced woven bamboo strips (Dendrocalamus Asper),” *ARPN J. Eng. Appl. Sci.*, vol. 17, no. 15, pp. 1513–1519, 2022.

[6] R. Martini Bako *et al.*, “Optimization of sulfur soaking water

on mechanical properties and physical properties of woven Petung bamboo (Dendrocalamus asper Backer ex Heyne) Strips," in *E3S Web of Conferences*, EDP Sciences, Sep. 2020. doi: 10.1051/e3sconf/202019000031.

[7] F. R. B. F. R. Bethony and Tjprc, "Volume Percentage of Petung Bamboo (Dendrocalamus Asper) Woven Stripas a Reinforcementof Epoxy Resin Composites to the Tensile Strength," 2020. [Online]. Available: https://api.semanticscholar.org/CorpusID:226630903

[8] G. Refiadi, Y. Syamsiar, and H. Judawisastra, "The tensile strength of Petung bamboo fiber reinforced epoxy composites: the effects of alkali treatment, composites manufacturing, and water absorption," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 547, no. 1, 2019, doi: 10.1088/1757-899X/547/1/012043.

[9] S. A. Roslan, Z. A. Rasid, and M. Z. Hassan, "Bamboo reinforced polymer composite - A comprehensive review," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 344, 2018, [Online]. Available: https://api.semanticscholar.org/CorpusID:139907493

[10] Ariyanto, M. S. Sukardin, I. Renreng, H. Arsyad, M. Syahid, and M. Alwi, "Optimization of resistance spot welding with surface roughness dissimilar mild steel with stainless steel," *Eastern-European J. Enterp. Technol.*, 2023.

[11] F. R. Bethony, H. Abbas, Z. Djafar, and M. Syahid, "Tensile strength analysis of composite reinforced Petung bamboo woven (Dendrocalamus Asper)," *www.tjprc.org SCOPUS Index. J. Ed.*, vol. 10, no. 3, pp. 8227–8232, 2020, [Online]. Available: www.tjprc.org

[12] T. Akagi *et al.*, "Dissolved ion analyses of stream water from bamboo forests : Implication for enhancement of chemical weathering by bamboo," *Geochem. J.*, vol. 46, pp. 505–515, 2012, [Online]. Available: https://api.semanticscholar.org/CorpusID:129562931

[13] R. Torres, R. L. Tanaka, R. G. Morini, O. O. O. Filho, and T. Vilela, "Flexible Pipe Anchoring System: Resin Ratio Effects on Mechanical Properties," IOP Publishing, 2015. [Online]. Available: https://api.semanticscholar.org/CorpusID:138088968

[14] W. Ferdous *et al.*, "Optimal design for epoxy polymer concrete based on mechanical properties and durability aspects," *Constr. Build. Mater.*, vol. 232, p. 117229, 2020, doi: 10.1016/j.conbuildmat.2019.117229.

[15] J. R. M. D'Almeida, S. N. Monteiro, G. W. Menezes, and R. J. S. Rodriguez, "Diamond-epoxy composites," *J. Reinf. Plast. Compos.*, vol. 26, no. 3, pp. 321–330, 2007, doi: 10.1177/0731684407072516.

[16] Ariyanto *et al.*, "Design and manufacturing of Welded Vacuum Testing (WVT) tool," *J. Polimesin*, vol. 22, no. 3, pp. 334–337, 2024.

[17] ASTM, astm e8-04 standard test methods for tension testing of metallic materials, vol. i. Amerika: ASTM International, 2004. [Online]. Available: www.astm.org

[18] ASTM Int., "ASTM E23-07ae1 - Standard Test methods for notched bar impact testing of metallic materials," *Astm*, no. C, pp. 1–28, 2007, doi: 10.1520/E0023-07AE01.2.

[19] F. R. Bethoni, C. Johan, M. Pineng, and S. Suluh, "Analysis of mechanical and physical properties of composite materials of reinforced epoxy reinforced woven bamboo strips (dendrocalamus asper)," *ARPN J. Eng. Appl. Sci.*, vol. 17, no. 15, 2022, [Online]. Available: www.arpnjournals.com

[20] H. Judawisastra, R. D. R. Sitohang, and M. S. Rosadi, "Water absorption and tensile strength degradation of Petung bamboo (Dendrocalamus asper) fiber—reinforced polymeric composites," *Mater. Res. Express*, vol. 4, no. 9, p. 94003, Sep. 2017, doi: 10.1088/2053-1591/aa8a0d.

[21] M. H. Hamidon, M. T. H. Sultan, A. H. Ariffin, and A. U. M. Shah, "Effects of fibre treatment on mechanical properties of kenaf fibre reinforced composites: A review," *J. Mater. Res. Technol.*, vol. 8, no. 3, pp. 3327–3337, 2019, doi: 10.1016/j.jmrt.2019.04.012.

[22] R. M. Abhilash, G. S. Venkatesh, and S. S. Chauhan, "Development of bamboo polymer composites with improved impact resistance," *Polym. Polym. Compos.*, vol. 29, no. 9_suppl, pp. S464–S474, 2021, doi: 10.1177/09673911211009369.

[23] R. M. Bako, Z. Djafar, I. Renreng, C. W. Wullur, and Hariyanto, "Analysis of mechanical strength of woven strip composite at petung bamboo (Dendrocalamus asper) epoxy resin tape: Tensile strength properties of bamboo strips," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 343, no. 1, 2019, doi: 10.1088/1755-1315/343/1/012192.

[24] T. Endramawan, Adi Kusmayadi, D. Suwandi, and A. Hudayef, "Fabrication and mechanical properties of copper and sili- con carbide-reinforced aluminum metal matrix composi- tes processed by powder metallurgy," *J. Polimesin*, vol. 20, no. 2, pp. 121–127, 2023, [Online]. Available: https://e-jurnal.pnl.ac.id/polimesin/article/view/3626/3230

[25] Q. B. Bui, A. Grillet, and H.-D. Tran, "A bamboo treatment procedure: effects on the durability and mechanical performance," *Sustainability*, vol. 9, p. 1444, 2017, [Online]. Available: https://api.semanticscholar.org/CorpusID:36554160

[26] I. Widiastuti, Y. R. Pratiwi, and D. N. Cahyo, "A study on water absorption and mechanical properties in epoxy-bamboo laminate composite with varying immersion temperatures," *Open Eng.*, vol. 10, no. 1, pp. 814–819, 2020, doi: 10.1515/eng-2020-0091.

[27] F. R. Bethony, M. Pineng, F. Paliling, and C. G. Simon, "Tensile analysis of epoxy resin composite material with petung bamboo strip reinforcement," *INTEK J. Penelit.*, vol. 10, no. 2, pp. 126–130, 2023, doi: 10.31963/intek.v10i2.4578.

[28] Z. Djafar, "Petung bamboo strips woven reinforced epoxy composite (PeBaSWoREC), Tensile Strength Analysis," *Int. J. Mech. Prod. Eng. Res. Dev.*, vol. 10, pp. 8643–8652, Jan. 2020, doi: 10.24247/ijmperdjun2020822.

[29] R. Raharjo, D. B. Darmadi, F. Gapsari, P. H. Setyarini, and F. A. Alamsyah, "Modification of woven dendrocalamus asper in composite applications," *Int. J. Mech. Eng. Technol. Appl.*, 2024, [Online]. Available: https://api.semanticscholar.org/CorpusID:271233462