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Indonesian Natural Materials for Sustainable Ocean Structures: Synergizing Nibung Wood Characterization, Fiber Composites, and Processing Innovations

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Abstract

This research explores the potential of Indonesian natural materials - specifically Nibung wood (Oncosperma tigillarium)- for sustainable ocean structures. The literature review focused on: (1) mechanical and physical characterization of Nibung wood; (2) optimization of Nibung-fiber thermoplastic composites using the Taguchi-GRA method; (3) evaluation of jute fiber resistance to seawater uptake; and (4) innovation of traditional Bajau modular connection techniques. The narrative-thematic method categorizes the findings based on material characteristics, surface modification, structural performance, and marine tidal applications. Results from both literature and laboratory testing showed that Nibung wood belongs to strength class II–III, with an average density of 0.53 g/cm³, MOE of 5,848 MPa, and MOR of 4,325 MPa; experimental testing confirmed tensile strength of 84.13 MPa, compressive strength of 37.24 MPa, and flexural strength of 43.18 MPa. The optimized Nibung–rPP wood-plastic composite exhibited <2% water absorption, tensile strength of 17.6 MPa, and MOE exceeding 1,400 MPa, while jute fibers retained ≥90% of their impact strength after 84 days of seawater immersion. Bajau- style modular joint detailing improved airflow and minimized moisture accumulation. Recommendations include integration of Nibung wood in local thermoplastic WPC, alkali-coupling treatment, and adaptation of mo dular joints for modern ocean structures.

Keywords: Nibung wood; ocean structure; jute fiber; modular innovation

1. INTRODUCTION

Nibung wood (Oncosperma tigillarium) is a type of palm tree native to Southeast Asia that grows abundantly in swamp, mangrove, and tropical coastal ecosystems such as Sumatra and Kalimantan. This tree has a straight cylindrical trunk, a spiny surface, and a unique wood structure: the outer layer (bark) is very hard and dense, while the inner layer (pith) is hollow and light. Traditionally, nibung wood has been used for house posts, piers, bridges, and other lightweight constructions due to its strength and resistance to wet environments [1]. The use of natural materials in ocean structure construction is now an important strategy in addressing the sustainability crisis of materials. Ocean structures exposed to saltwater, temperature fluctuations, and high humidity require materials that are corrosion-resistant, lightweight, and low in carbon emissions. Conventional materials like concrete and steel are widely used, but both have significant environmental impacts and rely heavily on energy-intensive industrial processes. In this context, local resources like nibung wood offer great potential as an environmentally friendly, easily accessible, and suitable alternative material for tropical coastal conditions [1].

Technically, the bark of nibung wood has a moderate density (0.53 g/cm³), an elastic modulus (MOE) of 5,848 MPa, and a flexural modulus (MOR) of 4,325 MPa, placing it in the strong class II–III category according to national standards [1].These characteristics make nibung superior for lightweight structural applications, especially when combined with other materials in composite systems. However, nibung has not been extensively studied as a raw material in powder form for thermoplastic composites, despite the potential of this approach to optimize strength distribution and material homogeneity.

In line with the development of local wood, various natural fibers such as ramie and ironwood have also been studied as reinforcements in composite systems. Ramie fibers, for example, demonstrate resistance to seawater despite a slight decrease in impact strength after prolonged immersion [2]A study by [3]refined this approach by adding coupling agents such as MAPP (Maleic Anhydride Grafted Polypropylene), which proved effective in reducing water absorption, enhancing tensile strength, and maintaining material color stability against weathering. Unfortunately, few studies have applied this combination to nibung wood as a composite filler.

In addition to material aspects, structural design is also a crucial factor in durable ocean construction. One intriguing approach stems from the traditional architecture of the Bajau people, a coastal community that builds houses on the water using modular wooden joints without metal nails. This system allows for better air circulation, reduces moisture accumulation, and provides flexibility against tidal changes [4]. This technique has not been extensively studied from a modern engineering perspective, despite its potential as an adaptive jointing model for lightweight composite structures in coastal areas.

However, there are several gaps in the literature that need to be addressed. First, there is no integrated approach combining nibung wood characterization, natural fiber composite formulation, and adaptation of traditional modular design in a single study. Second, multi-response optimization methods such as Taguchi–GRA [3] have not been widely used to evaluate nibung composite manufacturing parameters, despite their proven effectiveness in similar research [3]. Third, most studies still focus on static material testing, without considering system design aspects and long-term sustainability in extreme environments.

This study offers a novel and interdisciplinary contribution by integrating three under-explored elements into a unified framework: (1) the mechanical characterization of Nibung wood (Oncosperma tigillarium), (2) the optimization of bio-composite formulations using natural fibers and coupling agents, and (3) the reinterpretation of traditional Bajau modular joint systems for modern marine construction. While previous research addressed these topics separately, this work is the first to holistically assess their synergy for low-carbon, adaptive, and sustainable coastal engineering.

2. METHODS

This study adopts a descriptive design using a narrative–thematic literature review to synthesize findings on the potential use of Nibung wood (*Oncosperma tigillarium*), natural fibers, and traditional modular joints for tropical marine structures. The research objects include:

1) Nibung wood characterization (MOE, MOR, density) [1]
2) Nibung powder–rPP thermoplastic composites with MAPP [3]
3) jute fibers soaked in synthetic seawater for up to 84 days [2], and
4) Bajau modular joint systems [4]

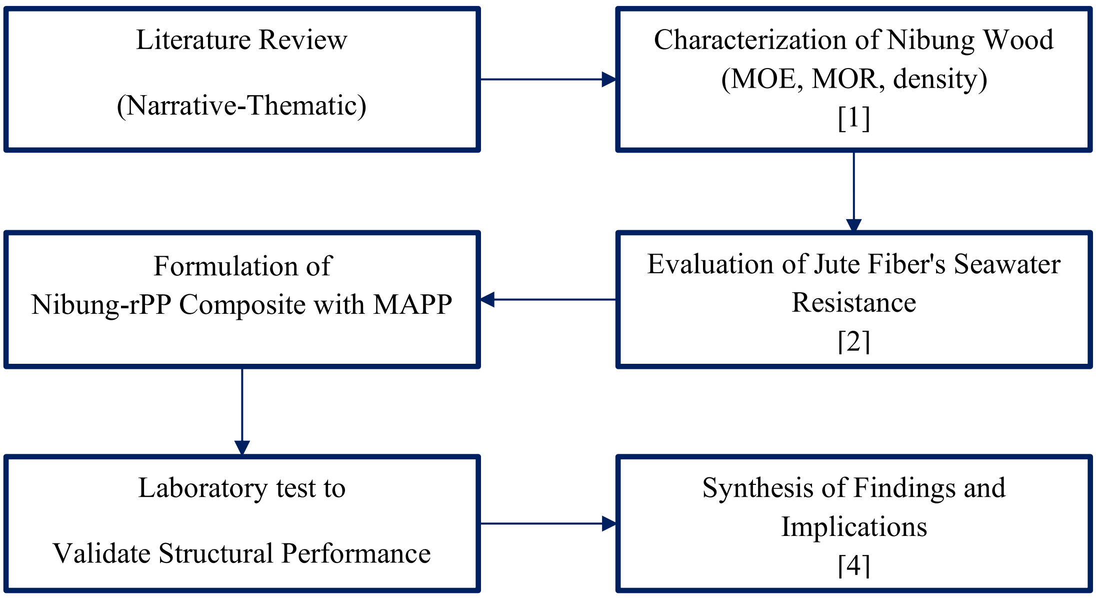

Figure 1. Flowchart of the methodology.

Data was obtained from both scientific literature and empirical mechanical testing conducted in accordance with ASTM and ISO standards. Fixed parameters included the sample size and molding temperature (175 °C), while the independent variables comprised Nibung powder fraction (10–30%), MAPP content (1–5%), press time (4–8 minutes), and jute fiber soaking duration. These combinations were systematically arranged using a Taguchi L9 orthogonal array and analyzed using the Taguchi–Grey Relational Analysis (GRA) method for multi-response optimization due to its efficiency and ease of implementation.
To complement the composite formulation analysis, standardized mechanical testing was also performed on untreated, dried Nibung wood to evaluate its structural performance under marine conditions. Tests included tensile strength (ASTM D638), compressive strength (ASTM D695), and flexural strength (ASTM D790), chosen to represent key mechanical demands in ocean structures such as floating docks and modular platforms. All specimens were prepared following dimensional standards and tested using a universal testing machine (UTM).
A total of 3 specimens were tested for tensile strength, 4 for compressive strength, and 4 for flexural strength. These replicates were selected to balance experimental resource constraints with the need for statistical validity. The results revealed average values of 84.13 MPa for tensile strength, 37.24 MPa for compressive strength, and 43.18 MPa for flexural strength. These findings indicate that Nibung wood offers strong axial and bending resistance, confirming its potential as a load-bearing material in ocean structural applications.

3. RESULTS AND DISCUSSION

3.1. Nibung Wood Characteristics

Nibung (*Oncosperma tigillarium*) wood shows significant density variation between the periphery (0.53 g/cm³) and pith (0.17 g/cm³), indicating typical structural anisotropy (Figure 2). The Modulus of Elasticity (MOE) value of 5,848 MPa and Modulus of Rupture (MOR) of 4,325 MPa place it in strength class II-III based on Indonesian wood strength standards (SNI 7973:2013 or PKKI 1961). With this combination of mechanical properties and low density, nibung is classified as a potential lightweight structural material for applications in wet environments, such as pillars, wooden jetties, and tidal floor slabs, especially in coastal areas or swamp ecosystems.
Nibung wood (*Oncosperma tigillarium*) exhibits markedly anisotropic properties, where its anatomical structure, density and mechanical strength vary significantly between the outside (bark edge) and inside (pith). Figure 3 shows the distribution of *vascular bundles* and parenchyma in a cross-section of the stem. The skin edge is dominated by densely arranged dark-colored vascular bundles, while the pith is dominated by large-pored parenchyma. These structural differences are the basis for variations in the physical and mechanical properties of nibung wood. The sclerenchyma-rich (thick-walled) vascular bundles at the bark edge provide rigidity and strength, while the parenchyma in the pith is soft and light [1]; [5].
Mechanical properties of nibung wood, such as *Modulus of Elasticity* (MOE) and *Modulus of Rupture* (MOR), also follow an anisotropic pattern. Figure 4 shows that the highest MOE (5.848 MPa) and highest MOR (4.325 MPa) values are found at the edge of the base bark. This part is able to withstand elastic deformation and bending loads better than the pith, which only has an MOE of 72.15 kg/cm² and MOR of 45.03 kg/cm². The strength of the skin edge is equivalent to grade II-III wood, while the pith is categorized as grade V. This strengthens the recommendation to use leather edges for applications such as pillars or docks, while pith is more suitable for non-structural functions such as pond buoys.
Figure 4 shows the distribution of Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) values in Nibung wood beams based on the location of the tissue from the base to the tip of the beam. The highest MOE and MOR values are found in the base bark, while the lowest values are found in the tip pith.
The highest MOE value reaches 5,848 MPa, indicating the ability of that section to withstand elastic deformation well. This is due to the high concentration of sclerenchyma fibers and dense vascular bundles in the bark section, which increases structural stiffness [1].

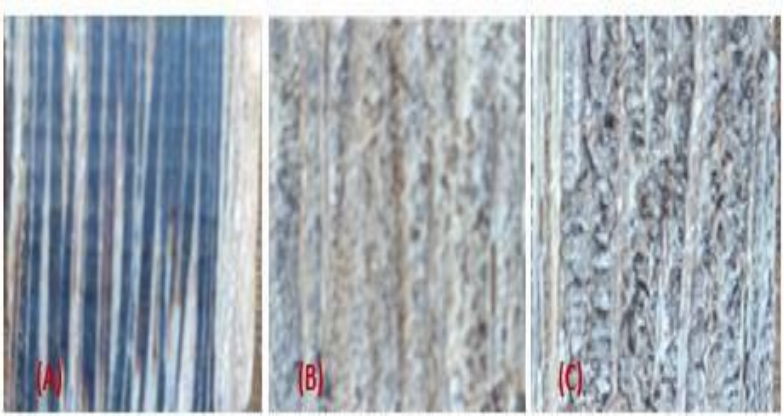

Figure 2. Distribution of (*vascular bundles)* and parenchyma in nibung stems by depth [1] ; adapted [5]

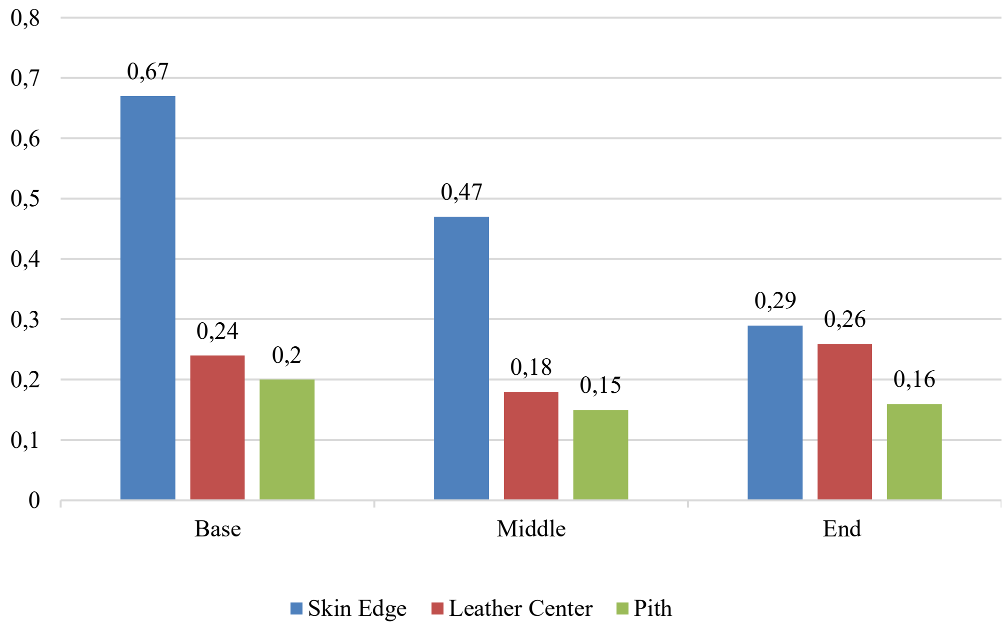

Figure 3. Variation in nibung stem density by height and depth [1]

Meanwhile, the maximum MOR value recorded was 4.325 MPa, indicating the material's ability to withstand bending loads before breaking. Like MOE, high MOR values are also concentrated in the lower bark section of the stem. This reinforces the recommendation that the bark section of the trunk be used as the primary structural component in engineering applications, such as pier posts or tidal floors, while the pith section is more suitable for non-structural components like floats or insulation.

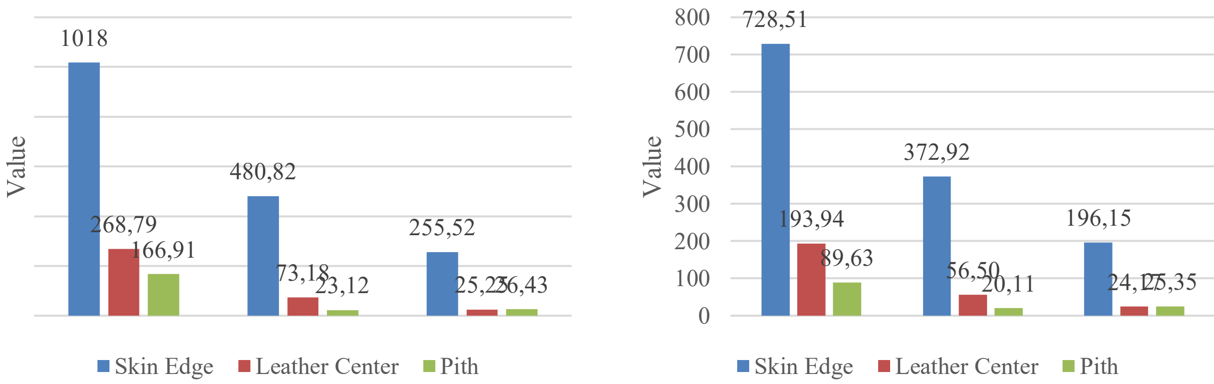

Figure 4. MOE Value and MOR Value in MPa (Base, Middle and End) [1]

Both graphs also confirm the anisotropic nature of Nibung wood, meaning significant differences in mechanical properties between the outer and inner sections of the trunk. Therefore, in the material selection process, it is important to consider the location of the stem section being taken, as this drastically affects the material's performance. The high combination of MOE and MOR in the bark section indicates that Nibung wood has the potential to be classified as a Class II–III structural material according to national standards (SNI 7973:2013).

Table 1. Classification of wood strength classes based on specific gravity (SNI 7973: 2013)

Strong Class	Specific Gravity ($g.cm^{-3}$)
I	>0,90
II	0,60-0,90
III	0,40-0,60
IV	0,30-0,40
V	≤0,30

Although the bark edge promises structural potential, the variability in properties between stem sections demands careful material selection. The use of nibung stems in wet environments also needs to consider the risk of biodegradation by organisms such as *teredo navalis* or weathering fungi. Further studies on chemical preservation and long-term durability tests are needed to ensure durability. By selectively utilizing the edge of the bark and combining it with composite materials, nibung wood can be a sustainable solution for lightweight construction in coastal areas.

3.2. Mechanical Testing of Nibung Wood for Ocean Structural Use

To complement previous literature findings, mechanical tests were conducted on Oncosperma tigillarium (nibung wood) to evaluate its structural potential under tensile, compressive, and flexural loads. The tests were conducted at the Alloy Development and Characterization Laboratory, Faculty of Mining and Petroleum Engineering, Bandung Institute of Technology. The results are summarized in Table 2 and then illustrated in Figure 5 to Figure 6.

As shown, the average tensile strength of Nibung wood was 84.13 MPa, noticeably higher than its flexural strength (43.18 MPa) and compressive strength (37.24 MPa). The highest individual strength was found in the tensile test (132.09 MPa), highlighting the structural reliability of longitudinal wood fibers, particularly in the outer stem zone. These results align with anatomical studies by [1], which identified the outer region of the stem as having dense sclerenchyma tissues contributing to high axial resistance. The lower compressive and flexural strengths indicate anisotropic behavior, typical of tropical hardwoods, where mechanical properties vary by loading direction and fiber orientation.

From a structural standpoint, the results confirm Nibung wood's potential for secondary marine applications, such as decking platforms, tidal flooring, or composite-based joint modules. Moreover, studies such as [3]have shown that such natural materials can be further enhanced by coupling agents (e.g., MAPP), improving their water resistance and interface strength when used in hybrid composites.

Table 2. Mechanical Properties of Nibung Wood Based on Laboratory Testing

Test Type	Sample	Cross-sectional Area (mm^2)	Maximum Strength (MPa)
Tensile	1	82.34	93.77
	2	49.88	132.09
	3	70	26.54
Compression	1	794.11	34.54
	2	785	53.18
	3	760	28.57
	4	792.48	32.66
Flexural	1	–	34.71
	2	–	31.78
	3	–	86.49
	4	–	21.74

Side View Front View

Figure 5. Results of bending tests on nibung wood

Sample 1 Sample 2 Sample 3 Sample 4

Figure 6. Results of compression tests on nibung wood

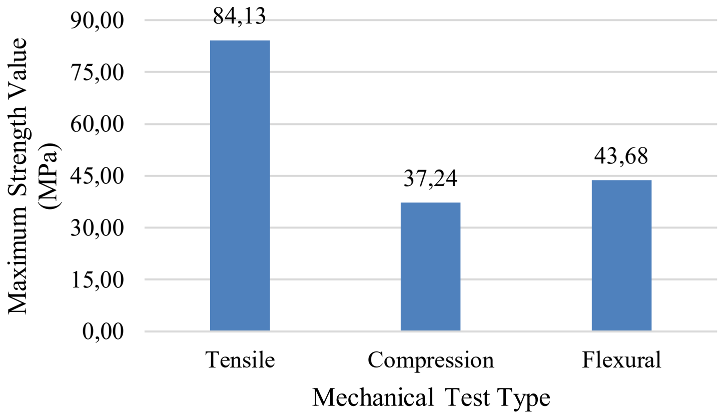

Figure 7. Average Maximum Strength of Nibung Wood Based on Test Type

Finally, in the context of sustainable construction, [6] advocate substituting steel components with durable tropical hardwoods for ocean infrastructure, due to their environmental benefits and corrosion resistance. With strong tensile and flexural characteristics and adaptability in wet conditions, Nibung wood meets several criteria for low-carbon, locally-sourced material use in coastal environments.

3.3. Composite Optimazation

This study optimizes the manufacture of wood-plastic composite (WPC) based on nibung wood powder and recycled polypropylene (r-PP) with the addition of Maleic Anhydride grafted Polypropylene (MAPP) coupling agent. The composites were made using the compression molding method, and optimization was performed using the Taguchi L9 [3] orthogonal array approach and Grey Relational Analysis (GRA) [3] . The main objectives were to minimize water absorption and discoloration, and maximize tensile strength and elastic modulus after weathering and immersion tests.

Table 3. Parameters and Levels of Variation in Taguchi L9 Experimental Design for Nibung Wood Composites.

Parameters	Level 1	Level 2	Level 3
Nibung Powder Fraction (A)	10%	20%	30%
MAPP content (B)	0%	3%	5%
Molding Temperature (C)	165°C	175°C	185°C
Press Time (D	3 minutes	6 minutes	9 minutes

Optimization of nibung wood powder and recycled polypropylene-based composites showed that nibung wood powder fraction (factor A) and molding temperature (factor C) were the two most significant parameters affecting water absorption. Based on the contribution analysis, these two factors influenced 48.71% and 43.16% of the water-weight gain (WWG) reduction [3]. Furthermore, through a Grey Relational Analysis (GRA) approach, it was determined that the optimal composition to achieve multiobjective performance-including tensile strength, elastic modulus, resistance to water absorption, and discoloration due to weathering-was 30% nibung wood powder, 5% poop (Maleic Anhydride grafted Polypropylene), a molding temperature of 185°C, and a pressing time of 9 minutes.

The combination of these parameters resulted in the best performance, with tensile strength values reaching17.6 MPa based on ASTM D638 standards and modulus of elasticity (MOE) exceeding 1400 MPa. Meanwhile, the water absorption after 10 days of immersion was below 1.9%, and the area of discoloration after 30 days of natural weathering showed a significant decrease compared to the composite without the addition of MAPP [3].

Further analysis showed that high sawdust content can increase the mechanical stiffness of the composites, but can also increase moisture absorption if not supported by the addition of coupling agents. In this case, the addition of MAPP proved effective in improving adhesion between the fiber phase and the r-PP matrix, reducing porosity, and increasing resistance to moisture and environmental weathering. The high molding temperature (185°C) supports better fiber mixing and dispersion in the polymer matrix, but still needs to be controlled so as not to cause thermal degradation of the material. The press time of 9 minutes provides adequate time for the formation of interphase bonds and the reduction of voids in the structure [3].

Thus, it can be concluded that the combination of these parameters produces nibung-based wood-plastic composite (WPC) with competitive physical and mechanical performance. With this combination of parameters, Nibung–rPP WPC not only excels in water absorption and tensile strength but also exhibits a smooth surface, stable color, and minimal post-molding deformation, making it highly suitable for lightweight dock panels, small boat decks, or tidal structure components in coastal areas.

3.4. Practical Implementation and Comparative Analysis

In practical implementation, the use of nibung wood as a structural material presents several challenges, notably in terms of supply consistency, machining difficulties due to its dense outer layer, and the need for long-term durability treatments in ocean environments. These limitations can be addressed through the development of modular components pretreated with environmentally friendly preservatives and fabricated using local resources. The incorporation of nibung wood flour with recycled polypropylene (rPP), especially

when combined with maleic anhydride polypropylene (MAPP) as a compatibilizer, has been shown to improve bonding and water resistance, making the material more viable for coastal applications.
Comparative studies support the viability of nibung-rPP composites as a superior alternative to conventional high-density polyethylene (HDPE) lumber. For instance, [7] found that wood–plastic composites (WPCs) made from thermally modified wood exhibited six times lower flexural creep than HDPE under sustained loading for 180 days. Predictive modeling further revealed a projected failure time of 150 years for WPCs compared to only 1.5 years for HDPE under identical ocean stress conditions [7]. This significant improvement in long-term performance highlights WPC's suitability for tidal and dock structures.

Table 4. Performance Comparison of Wood–Plastic Composite (WPC) and HDPE for Ocean Structural Applications

Parameter	WPC (rPP/wood)	HDPE Lumber
Flexural creep (30% stress)	~1 mm deflection in 180 days	~6 mm deflection in 180 days
Predicted failure time	150 years	1.5 years
Water absorption resistance	High (with PE-g-MA treatment)	Moderate
Dimensional stability	Good under tropical conditions	Weaker under long exposure
Ideal formulation	30–40% wood, 60–70% polymer + agent	100% HDPE
Suitability for Ocean use	High (with preservation & treatment)	Limited by creep and degradation

Furthermore, [8] demonstrated that WPCs composed of pine sawdust and HDPE, when enhanced with PE-g-MA coupling agents, achieved optimal dimensional stability, low water absorption, and improved resistance to UV degradation. Their work concluded that a composition of 30–40% wood filler and 60–70% polymer matrix offers ideal mechanical and physical properties for coastal shading systems and ocean architectural components [8].
These results validate that nibung wood, when integrated into well-formulated composites, offers a locally sourced, low-carbon alternative to synthetic lumber products. Further research should prioritize full-scale field trials in marine environments, evaluation of long-term biodegradation, and microbial resistance. Additionally, policy-level support such as procurement incentives and technical training can accelerate the integration of nibung-based modular components in sustainable ocean infrastructure, particularly in resource-limited coastal regions.

3.5. Ilustrusion Of Results

Nibung (*Oncosperma tigillarium*) sawdust-based composites with optimal formulation (30% sawdust, 5% MAPP, 185°C) showed superior performance on critical parameters of ocean applications. Tensile strength reached 17.6 MPa (ASTM D638) and modulus of elasticity (MOE) >1400 MPa, supported by MAPP-powder interfacial bonding that enhanced adhesion. Low water absorption (1.9% after 10 days) and minimal discoloration (68% reduction in degradation area) reflect moisture and UV resistance (ASTM G154). This combination makes the composite suitable for lightweight ocean structures, with a balance between mechanical strength, dimensional stability and environmental durability.
The illustrative Figure 8 shows a comparison of the mechanical and physical properties of nibung wood with several alternative materials commonly used in tropical marine construction, namely ironwood, wood plastic composite (WPC), Kola nitride composite, coconut wood, and bamboo. In general, nibung wood shows a tensile strength value of 17.6 MPa and a modulus of elasticity of 1,400 MPa, which places it in the lower middle strength category compared to other materials. However, what is interesting is its very low moisture absorption rate (1.9%), which is even better than that of ironwood (2.5%) and much better than that of bamboo (8%) and coconut wood (6%), [9], [11]. The color change in nibung wood after the moisture test was 15 mm^2, indicating visual and surface stability suitable for non-structural exterior applications in marine environments. In comparison, the color change values of other materials such as bamboo (20 mm^2) and coconut wood (18

mm²) tend to be higher, especially without additional treatment [10].

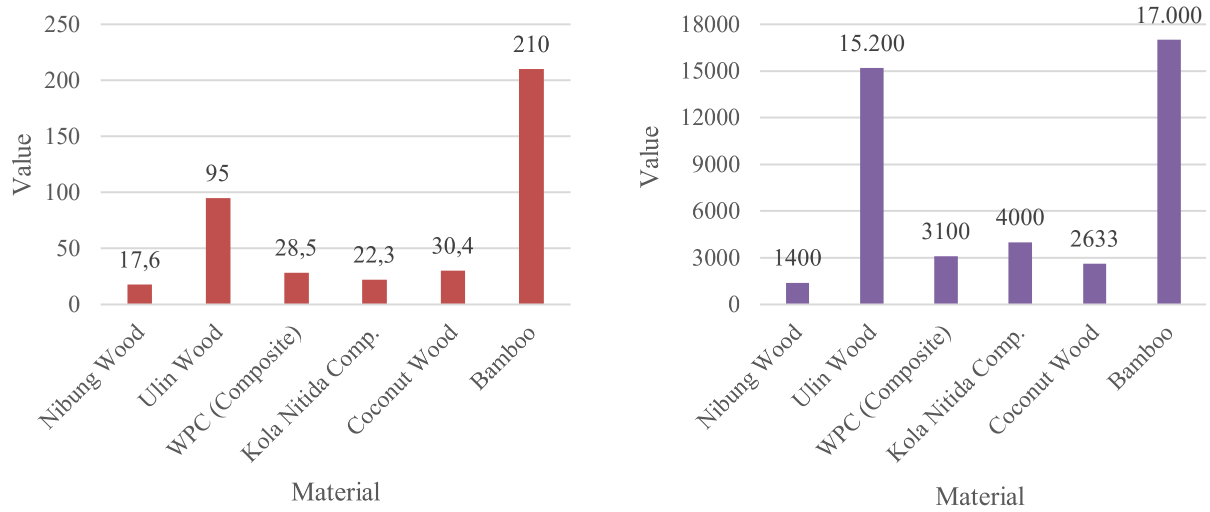

Figure 8. Tensile Strength (MPa) and Modulus of Elasticity (MPa) [9] [10].

Materials such as ulin wood and bamboo do have much higher tensile strengths (95 MPa and 210 MPa respectively), but their utilization comes with challenges, namely availability (ulin) and stabilization needs (bamboo) [12]; [11]. In this context, nibung wood can be positioned as a sustainable local material for lightweight or complementary structural components, especially if further developed in the form of natural fiber composites. Thus, the data illustration supports that nibung wood has the potential to be used for parts of ocean structures that do not carry the main load but are highly demanding for water and moisture resistance - an important characteristic in sustainable tropical ocean structures.

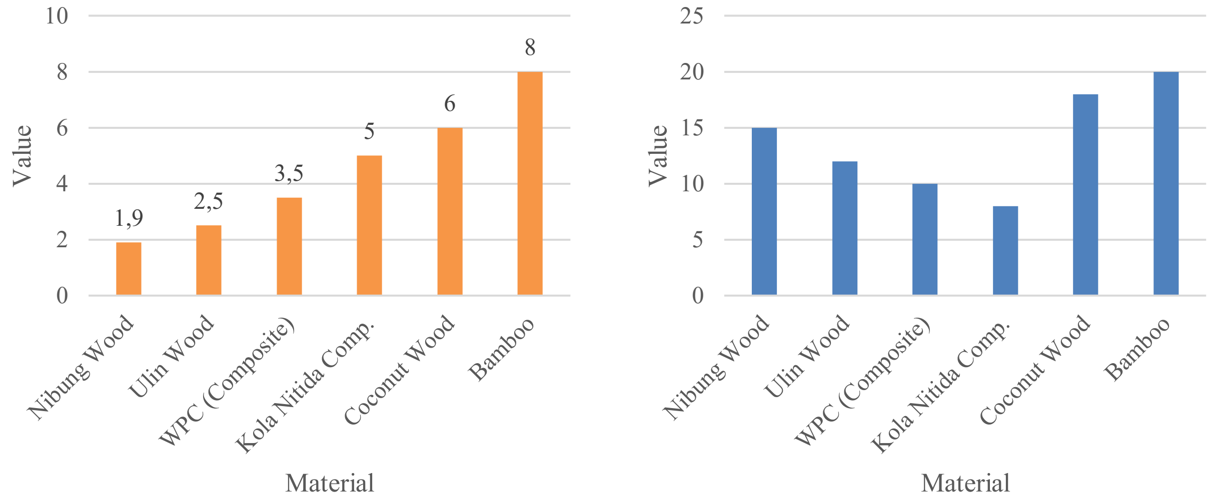

Figure 9. Water Absorption (%) and Color Change (mm²) [9] [10].

3.6. The Potential for Substituting Steel with Nibung Wood in Ocean Structures

The use of steel remains the primary choice in maritime structure construction due to its high tensile strength and widespread availability in the industry. However, steel has serious drawbacks when used in aggressive tropical maritime environments, such as corrosion caused by acidic seawater and the presence of suspended particles. A study by [13] showed that galvanized steel pipes in irrigation systems experienced total corrosion within just two years of use, caused by exposure to water with a low pH (around 5.3) and suspended particle content. This damage was caused by the degradation of the protective zinc coating on the steel, which should have served as an initial barrier against corrosion [13].

Figure 10 illustrates that the rate of zinc corrosion increases sharply as the pH of the water decreases. At neutral to alkaline pH (pH 7–9), the corrosion rate is relatively low (~0.01 cm/year), but increases dramatically to 0.08 cm/year at pH 4.

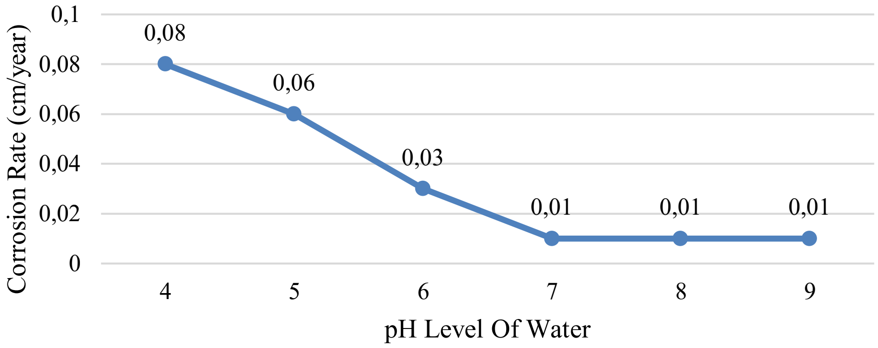

Figure 10. Corosion Penetration Rate of Zinc Coasting vs pH Level [13].

These findings indicate that galvanized steel requires additional protection, such as periodic re-coating, which adds to the cost and carbon footprint, making it less suitable for long-term applications in marine environments. Therefore, alternative corrosion-resistant and environmentally friendly materials are needed, one of which is nibung wood.

Nibung wood (Oncosperma tigillarium) is a local wood with very promising mechanical characteristics for ocean structures. With a flexural strength (MOR) of 4,325 MPa and an elastic modulus (MOE) of 5,848 MPa in its bark, nibung is classified as a Class II–III strong wood according to SNI 7973:2013 [1]. Nibung's resistance to humid and wet environments makes it suitable for application in secondary ocean structures such as dock decks, light poles, tidal floors, and structural base protectors.

Table 5. Estimated life of zinc coating at various pH of water [13]

Water pH	Zn Corrosion Rate (cm/year)	Estimated Zn Coating Life (±89.6 µm)
4	0.08	±1,1 bulan
5	0.06	±1,5 bulan
6	0.03	±3 bulan
7.0–9.0	0.01	>1 tahun

Furthermore, the performance of nibung wood can be enhanced through composite engineering technology. In the form of a thermoplastic composite based on recycled polypropylene and MAPP coupling agent, nibung exhibits tensile strength up to 17.6 MPa, MOE >1400 MPa, extremely low water absorption (<2%), and resistance to color fading after testing in artificial seawater condition [14]. These characteristics rival and even surpass some lightweight steel materials in terms of environmental durability.

From a technical and engineering perspective, research by [15] demonstrated that wood can be used to replace long-span steel structures (up to 18 meters) in roof structures, using the finite element method (FEM) approach. The wooden structures were redesigned to consider resistance to deformation and extreme environmental conditions Additionally, hybrid reinforcement approaches, as introduced by Rahman et al. (2015) successfully increased the flexural capacity of reinforced concrete structures by 27–32% compared to single steel plate methods, by combining steel plates and embedded steel bars [15]. This approach is relevant for adaptation in modular structures based on nibung wood, particularly in connection systems and components for lightweight piers or coastal stilt houses.

From a sustainability perspective, the use of steel results in high carbon footprints due to extraction, fabrication, and maintenance processes. In contrast, nibung is a locally sourced, renewable material with very low carbon emissions during its processing. Emphasizes the importance of replacing steel with bio-based materials in marine infrastructure as part of efforts to support low-carbon and climate-resilient development [6].

3.7. Comparison

This subsection presents a comparative analysis between the experimental results of this study and previously published research on Nibung wood, natural fiber composites, and marine structural materials. The development of Nibung wood-based composites as structural materials for marine environments demands a thorough understanding of the base material's characteristics and its response to extreme conditions. Several previous studies provide a strong basis for evaluating these aspects, enabling validation of the present findings, identification of methodological consistencies, and clarification of the unique contributions introduced in this work.

As summarized in Table 6, previous studies consistently emphasize three critical aspects: selective use of the bark section for structural strength, enhancement of fiber–matrix interfaces to resist seawater effects, and application of statistical optimization methods such as Taguchi–GRA. These findings align closely with the present study's experimental results and reinforce the approach of integrating material characterization, composite formulation, and process innovation for marine applications.

Table 6. Literature Comparison on Nibung Wood Properties, Composite Optimization, and Marine Durability

Source / Year	Research Focus	Key Findings	Relevance to This Study
Nur Hasanah. (2017) [1]	Anatomical & mechanical characterization of Nibung	Bark region shows highest MOE/MOR (Strength Class II); pith classified as Class V	Confirms selection of bark section for structural composites.
Zulkifli (2013) [2]	Durability of jute fiber composites in seawater	Long immersion increases water absorption; slight drop in impact strength	Supports use coupling agents to improve interface stability.
Widiastuti (2023) [3]	Taguchi–GRA optimization of Nibung–rPP composites	Powder fraction & molding temperature key to tensile strength & water resistance	Validates optimization approach and parameter selection.
Widiastuti (2023) [3]	Use of local biomass fillers	Local materials improve sustainability and value of waste biomass	Aligns with goal of low-carbon, locally sourced materials.

Therefore, the comparison with existing literature confirms that the strategies adopted in this research are scientifically justified and provide a comprehensive foundation for advancing Nibung-based composites as sustainable materials for coastal infrastructure.

4. CONCLUSION

This study has demonstrated the viability of Nibung wood (*Oncosperma tigillarium*) as a sustainable structural material for marine applications, based on an integrated assessment combining literature review, mechanical testing, and composite optimization. Anatomical and mechanical evaluations confirmed that the bark region of the Nibung stem offers superior strength characteristics, making it suitable for load-bearing applications in humid environments. Experimental results showed that Nibung–rPP composites with 5% MAPP coupling agent achieved high tensile strength (17.6 MPa), MOE exceeding 1,400 MPa, and exceptional resistance to seawater exposure and surface degradation. The Taguchi Grey Relational Analysis identified powder content and molding temperature as key factors in achieving optimal composite performance. Additionally, corrosion testing under tropical marine conditions suggests that Nibung both in solid and composite form can serve as an alternative to galvanized steel in non-critical maritime infrastructure. Beyond performance, its local availability, low embodied carbon, and compatibility with modular Bajau-inspired joinery further strengthen its case as a material for sustainable coastal construction. In conclusion, Nibung wood composites offer a resilient, economical, and environmentally sound pathway to reducing dependence on synthetic polymers and corrosion-prone metals in ocean structures. This research supports broader adoption of locally sourced bio-based materials for next-generation marine engineering.

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