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Exploring the adverse environmental effects of bio teakwood as filler in bio-degradable PU hybrid: A sustainable and systematic approach

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ABSTRACT

The present worldwide scenario is characterized by a significant environmental challenge pertaining to the appropriate management of PU waste disposal. The potential utilization of hybrid composites in Structural applications has been the subject of investigation, wherein discarded PU and teakwood particles have been explored as viable filler materials. The present study focused on the fabrication of hybrid composites through the blending of different proportions of discarded PU and teakwood particles s with a polyester resin matrix. Subsequently, an analysis was conducted to evaluate the mechanical characteristics of these composites. The mechanical properties of the composites were evaluated by the utilization of tensile, flexural, and impact tests. The findings of this study indicate that the inclusion of discarded PU and teakwood particles in the hybrid composites leads to improved mechanical properties. Nevertheless, the mechanical properties saw enhancement only until a loading of 60wt% of PU and teakwood particles waste, beyond which they started to deteriorate. According to research findings, the incorporation of teakwood particles waste as filler into hybrid composites, together with PU, has been shown to enhance the resistance of these materials to environmental degradation. Consequently, this composite formulation presents an appealing choice for application in maritime environments.

Keywords: PU; Teakwood; Tensile; Flexural; SEM.

1. INTRODUCTION

Rising water and land pollution, the prospect of raw material exhaustion, and the durability of plastics have all increased the urgency with which we must develop systems for recycling, recovering, and ecologically suitable disposal of synthetic polymer waste. Hybrid composites, which combine the properties of two or more materials, can have enhanced qualities such as strength, durability, and resistance to environmental deterioration [1, 2]. In recent years utilization of PU hybrid composites was increasing, in order to obtain a combination of low density, high strength, and resistance to corrosion and moisture. Using conventional fillers like glass fibers or carbon fibers to make hybrid composites can be expensive and wasteful [3]. The utilization of synthetic polymers finds widespread application in the present scenario. PU is a type of synthetic polymer that can be used for a wide range of PU. These polymers are the result of a reaction between polyisocyanates and polyalcohols. PU account for more than 8% of all plastics manufactured and are thus the sixth most used polymer worldwide. Two of the most common applications for PU are in foams and CASE (Coatings, Adhesives, Sealants, Elastomers) [4]. You can find soft foams in beds and vehicle seats, and stiff foams in soundproofing and industrial freezers. CASEs are commonplace in the manufacture of athletic shoes, athletic surfaces, electrical devices, and ships. Lightweight materials with high specific stiffness are in high demand in the automotive, aerospace, and avionics industries [5, 6]. Many industries, including packaging and cushioning, have taken an interest in PU foam because of its adaptability. The bulk of these structures are networks of robust struts and cell walls with voids or pockets where gas could become trapped [7, 8]. PUs have found broad usage in industry due to their many desirable properties, such as their resistance to tearing and wear, their resilience to stretching and compression, and their ability to absorb shock. Therefore, PUs are widely used to extend many structural products and reduce resource use, both of which have positive effects on the environment. The composite's enhanced its mechanical performance, interfacial bonding between reinforcements and matrix [9, 10].

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Improper disposal of used PUs fibers can have harmful consequences in the natural environment. Landfilling is still the most typical way to dispose of PU trash due to the material's low vulnerability to physical, chemical, and biological elements and the toxicity of specific combustion products. However, as re-sources like petroleum grow more limited and landfills become more expensive, treating PU waste has taken on greater significance on a global scale [11]. Structural animals become injured or even die from becoming entangled in PU fibers (i.e in terms of ropes used for fishing), and the fibers themselves contribute to pollute the structural ecosystem [12]. As a result, researchers have been considering using this PU waste as a matrix material in their hybrid composites manufacturing process [13, 14].

PUs are a type of synthetic polymer that can be used in a wide variety of applications. Lightweight materials with high specific stiffness are in high demand in many industries, but none more so than the automotive, aerospace, and avionics. Many industries, including packaging and cushioning, have taken an interest in PU foam because of its adaptability. The bulk of these structures are networks of robust struts and cell walls with voids or pockets where gas could become trapped [15–17]. PU is versatile enough to be utilized either as a hard, impermeable construction material or a soft, soothing coating. Polymers' have the ability to dissipate heat, combined with their light weight, low cost, corrosion resistance, and ease of manufacture, has piqued the interest of the electronics, engineering, energy, and aerospace industries. PUs have found broad usage in industry due to their many desirable properties, such as their resistance to tearing and wear, their resilience to stretching and compression, and their ability to absorb shock. In terms of lowering resource use and increasing product longevity, PUs provide substantial environmental benefits [18–20]. The shape of the fiber surface, the type of impregnation used, and the interfacial bonding between the reinforcements and the matrix all play significant roles in the mechanical performance of composites. Disposal of PU is a serious environmental concern around the world since it is non-biodegradable and has harmful impacts on the environment [21, 22]. PU waste, generated through manufacturing processes contributes to environmental deterioration and depletes natural resources when disposed of in landfills. Because of this, researchers are considering using this waste as a material in the development of hybrid composites, which combine the benefits of two or more materials to create an improved end product [23–25]. Due to its advantageous mix of high strength to weight ratio, low density, and corrosion and moisture resistance, hybrid composites have been increasingly PU in recent years. Conventional fillers, such as glass fibers or carbon fibers, can be expensive and environmentally unsustainable when making hybrid composites [26–28].

The use of discarded PU material in the development of hybrid composites for structural applications has been studied by scientists as a possible solution to these limitations. Discarded PU is a viable alter-native to conventional fillers due to its many useful properties, including its high strength, stiffness, and resistance to moisture [29–31]. The addition of PU and teakwood particles has been shown to improve a number of mechanical properties of composites, including tensile strength, flexural strength, and impact strength. However, there is still some debate about what optimum percentage of PU scrap is for optimizing the composites' mechanical properties. Studies have investigated the mechanical properties of hybrid composites made from discarded PU for the use in maritime environments [32–35].

In addition to enhancing the mechanical properties of hybrid composites, the use of discarded PU and teakwood particles as a filler material can contribute to the sustainable management of this waste. By using this technique, we may be able to reduce harm from discarded PU, conserve resources, and move the circular economy forward. The usage of discarded PU incorporated with teakwood particles as a filler material in hybrid composites for maritime applications is an exciting new area of research. The possible benefits of this approach include improved mechanical quality, less environmental impact, and sustainable long-term life of the structural hull structure. Therefore, hybrid composites made from discarded PU and teakwood particles is required to fully exploit its potential in maritime contexts.

This research looks into waste PU and teakwood particles as a possible substitute for glass fiber reinforced with a polyester matrix which is in existence. This research analyzed the mechanical and morphological properties of hybrid composites for the use of structural environmental structural applications, which were fabricated from waste PU and teakwood particles with varied weight fractions.

2. MATERIALS, FABRICATION AND EXPERIMENTAL METHODS

The sandy coastline of the Kanyakumari district in southern India were searched for three varieties of multifilament fishing nets and ropes. We obtained PU ropes from Binani India Products in Chennai. An unsaturated polyester resin was used in the production of SBA2303-Isothalic and obtained from Ciba Gugye Limited in Chennai, India where all of the AR grade chemicals were acquired. This includes the polyester resin, catalyst (methyl ethyl ketone peroxide) and the accelerator (cobalt naphthenate). PU foam scraps, nylon fibers and teakwood particles were collected and processed to achieve consistent particle sizes. The length and diameter of the processed fiber was 30 mm and 0.5–0.6 mm respectively.

2.1. Composite fabrication

The obtained discarded PU was cleaned with water and allow to dried in the atmospheric condition. The dried PU was sized and separated into fiber with a diameter of 0.5–1 mm. The collected teakwood particles s was refine using the grinding machine to obtained the fine particles, so that the equal dispersion of the particles as filler material can be obtained. Molding a composite material consisting of fibers and a matrix material using a die to prepare composites with a random orientation of fibers with a pressure of 120KPa and cured temperature of 40–45°C, in order to ensure a uniform distribution of fibers and the mixture is compressed in a die. Adjusting the fiber-to-matrix weight ratio allows one to fine-tune the composite's mechanical properties and its characterization. Standard steps in die molding include: Weight-appropriate amounts of fibers and matrix material are combined and thoroughly blended. The 50% weight ratio of blended unsaturated polyester resin is used for all the fabricated specimens (i.e. B1–B6).

By curing the mixture at high temperatures and pressures, a solid hybrid composite is produced. Because pressures are more evenly distributed throughout the material, the composite's mechanical properties benefit from the fibers' random orientation. Mechanical properties including strength, stiffness, and toughness can be enhanced or modified by adjusting the fiber-to-matrix weight ratio. The random orientation of fibers in the die-molding process is unrivaled for mass manufactures of composites with tunable mechanical properties.

The fabricated hybrid fiber composite under various amounts of discarded PU and nylon fibers, a number of hybrid composites (B1, B2, B3, B4, B5, and B6) were fabricated. The strength and stiffness of the produced composites varied as a function of the ratio of the hybrid composite materials used in their construction. Table1 shows the composition of the fabricated hybrid composites materials.

The polyester resin was then combined with a mixture of nylon fibers and PU foam particles. Once everything was blended together, the filler material teakwood particles were spread uniformly. A release agent was employed to keep the composite from sticking to the mold as it cured. Molding consists of pouring the slurry into the mold and allowing it to cure at ambient temperature. The curing time of the resin was sped up by mixing in a hardener. There are six samples taken: B1 is entirely PU; B2 contains 10% nylon, 70% PU, and 20% bio teakwood filler material; B3 contains 20% nylon, 60% PU, and 20% bio teakwood filler material; B4 contains 30% nylon, 50% PU and 20% bio teakwood filler material, and B5 contains 40% nylon 40% PU and 20% bio teakwood filler material, and B6 is entirely nylon. The composite was then post-cured at 800C for two hours after removal from the mold to enhance its mechanical properties.

2.2. Mechanical characteristics

The mechanical properties of the composite were studied by conducting tensile, flexural, and impact tests. A material's mechanical properties were evaluated by watching how it reacted to an external force. Hardness, strength, impact, ductility, fracture, creep, etc., were all tested to get a better understanding of the material. However, here we show the outcomes of testing for tensile strength, flexural strength, impact strength, and the ability to withstand both fresh and salt water. We used a Universal Testing Machine (UTM) to perform tensile and flexural tests in accordance with ASTM D638 and D790. The size of the tensile specimen is 210 mm × 10 mm × 6 mm and the size of the flexural specimen is 165 mm ×10 mm × 6 mm. The flexural properties of these manufactured materials are useful for judging the material's reliability and consistency. Flexural properties of PU and bio teakwood hybrid composites can be compared to those of other materials and to those of PU and

Table 1: Hybrid composite composition.

SL. NO	SPECIMEN NAME	FILLER MATERIAL-TEAK WOOD (WT.%)	PU (WT.%)	NYLON (WT.%)
1	B1	0	100	0
2	B2	20	70	10
3	B3	20	60	20
4	B4	20	50	30
5	B5	20	40	40
6	B6	0	0	100

bio teak wood hybrid composites of varying compositions. Impact testing was conducted utilizing a Charpy Impact Testing Machine to ASTM D256 standards and the size of the specimen is 10 mm × 10 mm × 10 mm. It is the gold standard for testing the resilience of plastics and composites. Using a pendulum-like mechanism, an impact load is applied to a specimen that has been notched. The specimen is held in place by a jig that swings a pendulum into the notch, breaking the sample. A material's ability to withstand impact is quantified by studying the amount of energy it can absorb before breaking. Researchers use the weight absorption method to calculate the evaporation rate of a material. In this study, we utilized the hybrid composites labeled B1, B2, B3, B4, B5, and B6. The specimens were submerged in both fresh and salt water for 90 days, and their weight was recorded at regular intervals and the durability of the specimen in Structural environment is evaluated. Equation (1) was used to determine the possible water absorption capacity.

$$\text{Water Absorption Capacity} = (W_i - W_f)/W_i \times 100 \quad (1)$$

W_i – Initial Weight of the specimen (gms)

W_f – Final Weight of the specimen (gms)

The ASTM-compliant dimensions of the hybrid composite are shown in Figure 1. To determine the composite's suitability for application in maritime environments, its mechanical and environmental properties were reported and analyzed.

2.3. Characterization

The filler-matrix interface and filler distribution throughout the matrix were analyzed using scanning electron microscopy (SEM) in order to describe the composite. We treated the composite to conditions supposed to replicate those found in the ocean to evaluate its durability under harsh environmental conditions. To achieve the desired mechanical properties, a hybrid composite was created by combining the PU scrap, nylon fibers and teakwood particles with a Polyester resin, shaping the resulting material, and curing it. In metallurgical characterization, the microscopic structure of the composite is studied using a variety of methods such optical microscopy, electron microscopy, and X-ray diffraction. This is helpful for identifying the direction of the reinforcement, the form of the polymer matrix, and the presence or absence of defects. The flexural strength, hardness, and fracture toughness of a material are only few of the mechanical properties that may be measured using a variety of tests. Surface-enhanced microscopy (SEM) is a subset of electron microscopy that uses a focused beam of electrons to obtain high-resolution images of the material's surface. SEM analysis allows researchers to probe the composite's microstructure on scales ranging from the nanometer to the micrometer.

Atomic Force Microscopy (AFM) offers researchers a potent instrument for examining nanoscale surface characteristics and structures with exceptional resolution and accuracy. The set point rate of AFM is 10Hz and its oscillation amplitude is 8nm.

Figure 1: Sized hybrid composite – ASTM.

3. RESULTS AND DISCUSSION

3.1. Tensile testing

The tensile strength of hybrid composites throughout all three tests is shown in Table 2 and Figure 2. The tensile strength of hybrid composites, measured in Mega Pascal's (MPa), is plotted vertically, while the total number of tests is displayed horizontally. In Figure 2, we observe that the tensile strength of B3 hybrid composites is the highest, at 59.9 MPa, followed by the tensile strengths of B4 and B5 hybrid composites, at 57.7 and 56.1 MPa, respectively. According to the data, there is not a considerable difference in tensile strength between hybrid composites of the B3, B4, and B5 types. B3, B4, and B5 hybrid composites, which had the highest tensile strength of the six studied, can be used to construct the hull of a maritime canoe. However, due to the high Nylon and recycled PU (PU-60%) and teakwood particles content of the B3 hybrid composites, they achieved a higher tensile strength value than the other hybrid composite specimens.

3.2. Flexural testing

The flexural strength of PU hybrid composites is an important mechanical property for withstanding bending stresses. Table 3 represents the flexural strength of the composite material. To evaluate this property, a specimen is bent using three or four points of contact until it breaks, a procedure known as the flexural test. In order to determine the flexural strength, flexural modulus, and other flexural properties of a PU and bio teak wood hybrid composite, a flexural test must first be conducted. The stiffness of a material can be quantified by its flexural modulus, whereas its flexural strength is the maximum force it can withstand before breaking.

Hybrid composites' number of trials is represented along the horizontal axis, while flexural strength is shown vertically. In Figure 3, we observe that the flexural strength of the B3 hybrid composites is the highest at

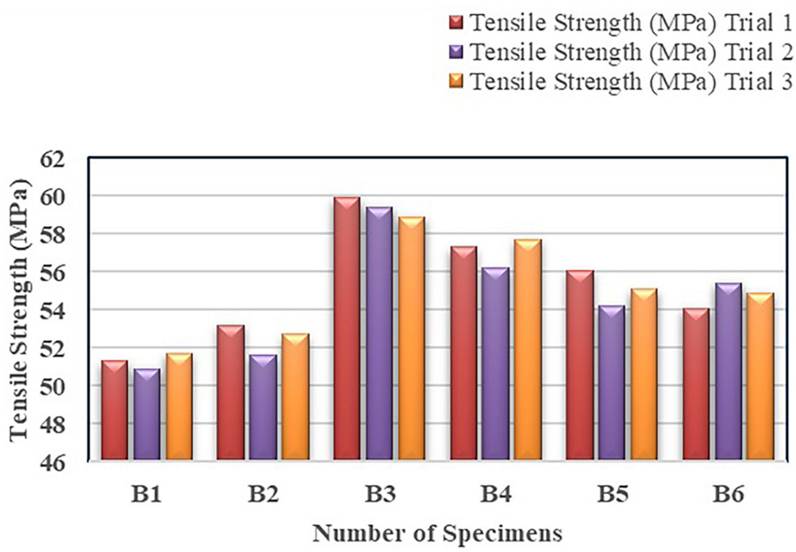

Figure 2: Tensile strength of fabricated hybrid composites.

Table 2: Tensile strength of fabricated hybrid composites.

TENSILE STRENGTH (MPa)			
HYBRID COMPOSITE SPECIMEN	TRIAL 1	TRIAL 2	TRIAL 3
B1	51.3	50.9	51.7
B2	53.2	51.6	52.7
B3	59.9	59.4	58.9
B4	57.3	56.2	57.7
B5	56.1	54.2	55.1
B6	54.1	55.4	54.9

Table 3: Flexural strength of hybrid composites.

FLEXURAL STRENGTH (MPa)			
HYBRID COMPOSITE SPECIMEN	**TRIAL 1**	**TRIAL 2**	**TRIAL 3**
B1	286.1	286.8	285.1
B2	294.2	296.1	295.7
B3	328.5	329.2	329.3
B4	326.1	326.4	325.5
B5	323	324.8	324.2
B6	320	319.2	319.3

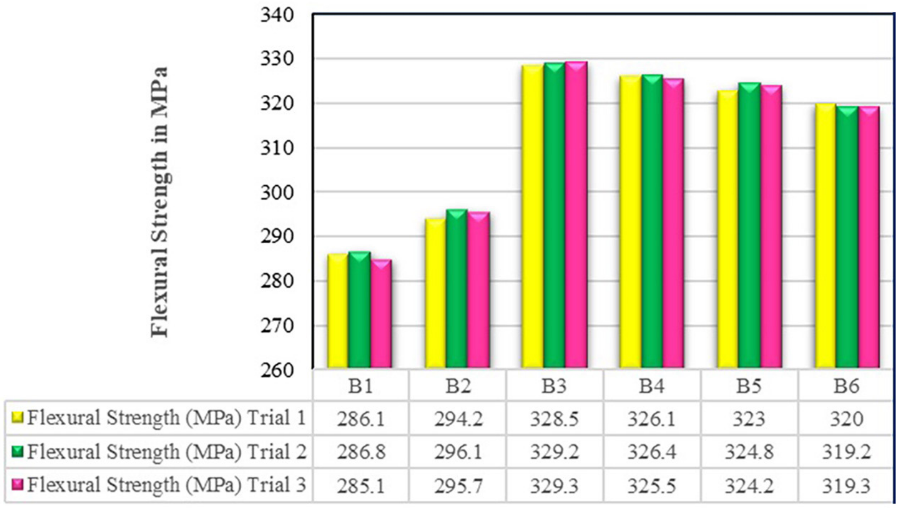

Figure 3: Flexural strength of fabricated hybrid composites.

329.3 MPa, followed by the flexural strengths of the B4 and B5 hybrid composites, which are 326.4 and 324.8 MPa, respectively. The outcomes demonstrate that there is not a sizable chasm separating hybrid composites of B3, B4, and B5 in terms of flexural strength. Hybrid composites B3, B4, and B5 exhibited the maximum flexural strength of the six tested, making them suitable for use in the Structural canoe hull structure. However, the B3 hybrid composites got a greater flexural strength value than the other hybrid composite specimens due to the presence of a sizable amount of Nylon along with discarded PU (PU-60%) and bio teak wood content. The results of this comparison will guide your choice of Structural-grade material. By illuminating the mechanisms responsible for the failure, the failure mode can be used to improve the design and processing of PU and bio teak wood hybrid composites for maritime applications. Results and analysis of flexural testing on PU and bio teak wood hybrid composites provide useful information on the mechanical properties of these materials, which may be used to enhance their performance and reliability in Structural environments.

3.3. Impact testing

Impact strength data for six hybrid composites in three tests are shown in Table 4 and Figure 4. Different hybrid composites' impact strength (in MPa) vs the number of tests (on the horizontal axis). There are six samples taken: B1 is entirely PU, B2 is nylon-and-PU and bio teak wood blend, B3 is 40% nylon, 60% PU and bio teak wood, B4 is nylon-and-PU and bio teak wood blend, B5 is nylon-and-PU and bio teak wood blend, and B6 is nylon-and-PU blend. The impact strength of several hybrid composites is shown in Figure 4; the B3 hybrid composites have the highest value, at 57.9 J, followed by the B4 hybrid composites (56.9 J) and the B6 hybrid composites (56.7 J) and the values are significantly more than the conventional materials in existence [11–13]. The statistics show that there is no statistically significant difference between the impact strengths of B3, B4, and B6 hybrid composites. Out of the six hybrid composites tested, B3, B4, and B4 had the maximum impact strength and were thus suitable for use in the hull construction of nautical canoes.

Table 4: Impact strength of hybrid composites.

IMPACT STRENGTH (J)			
HYBRID COMPOSITE SPECIMEN	TRIAL 1	TRIAL 2	TRIAL 3
B1	51.8	50.4	51.4
B2	53.5	52.7	53.4
B3	57.4	56.9	57.9
B4	56.9	56.4	55.9
B5	55.5	55.7	56.4
B6	56.7	56.2	55.8

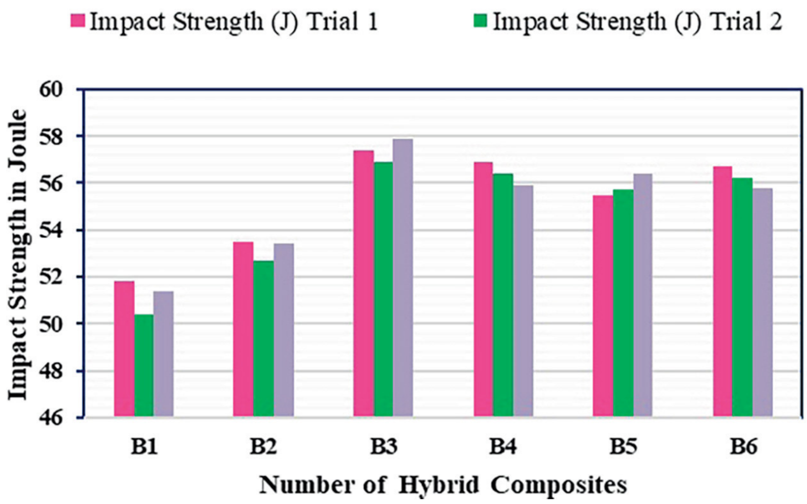

Figure 4: Impact strength of hybrid composites.

3.4. weight absorption in fresh and sea water

PU, bio teak wood and nylon (PA) hybrid composites have been investigated for potential usage as Structural constructions due to their excellent mechanical strength and endurance. The ability of Structural structures to absorb the weight of water, both fresh and salt, is essential. PU and teakwood particles hybrid composites have been researched and found to have efficient weight-absorbing characteristics in both fresh and saline water. Hybrid composites made from waste PU and bio teakwood particles and nylon fiber were tested for their weight-absorbing abilities over a 90-day submersion. The composites demonstrated a maximum weight absorption of 3.5% after 30 days in salt water. Only 1.5% of body weight was lost after 30 days of water immersion in fresh water. The low shock absorption of PU and teakwood particles hybrid composites can be traced back to a variety of different factors. The hydrophobic nature of the PU and bio teak wood matrix contributes to the composites' low water absorption. Second, the nylon fiber composition of the composite reduces its weight and increases its resistance to water.

The outcomes of fresh water absorption are shown in Table 5 and Figure 5. An immersion test in normal fresh water and salt water is conducted for 90 days on six fabricated hybrid composites. The percentage of fresh water absorbed over time is shown in Table 5 and Figure 5. The B6 content is the lowest of any of the hybrid composites. Similar values can be found in the composites B2 and B5. That leaves the hull of the Structural canoe open to being made from B6 composites. There are a number of variables that can affect the weight absorption qualities of PU and teakwood particles hybrid composites, including the content of the composite, the size and orientation of the fibers, and the processing circumstances. Because of this, it is essential to pay particular attention to the composite's composition throughout design and manufacturing in order to optimize its weight-absorbing properties for a specific Structural application. Weight growth owing to water absorption can be detrimental to the performance of a structure, hence PU and teakwood particles hybrid composites are appealing for use as Structural structures because of their low weight absorption capabilities.

Table 5: Water absorption of hybrid composites in fresh water.

WATER ABSORPTION-FRESH WATER (gms)				
HYBRID COMPOSITE SPECIMEN	0 DAYS	30 DAYS	60 DAYS	90 DAYS
B1	32	32.4	32.9	33.4
B2	32	32.3	32.4	32.6
B3	32	32.4	32.7	32.8
B4	32	32.1	32.2	32.4
B5	32	32.2	32.4	32.6
B6	32	32	32.1	32.3

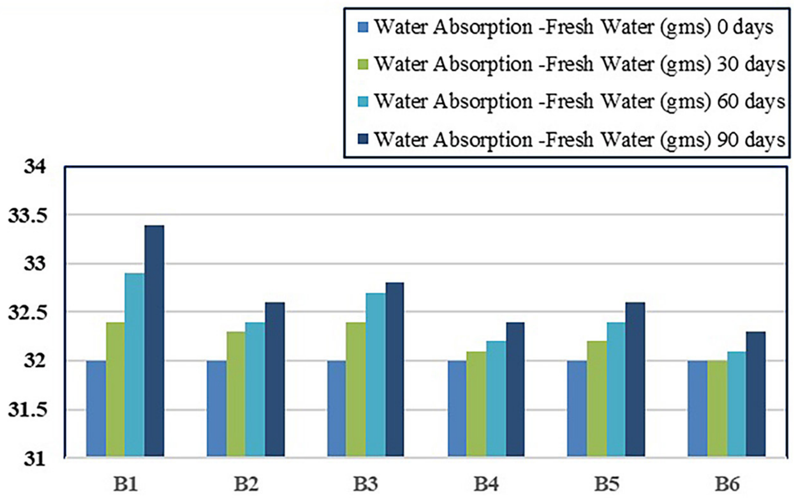

Figure 5: Water absorption of hybrid composites in fresh water.

Table 6: Water absorption of hybrid composites in sea water.

WATER ABSORPTION-SEA WATER (gms)				
HYBRID COMPOSITE SPECIMEN	0 DAYS	30 DAYS	60 DAYS	90 DAYS
B1	32	33.6	34.7	35.4
B2	32	32.4	32.9	33.2
B3	32	32.5	32.9	33.2
B4	32	32.2	32.5	32.8
B5	32	32.2	32.4	32.7
B6	32	32.1	32.2	32.4

Findings of a water absorption test performed after 90 days at sea are shown in Table 6 and Figure 6. After 90 days, composite B6 absorbs the least amount of sea water (32.4gms), followed by composites S7 (32.6gms), B5, 32.7gms, B4, 32.8gms, B3, 33.2gms, B2, and 35.4gms. The foregoing findings suggest that compared to the other hybrid composites, B6 has a poorer absorption capability for sea water.

Table 7 and Figure 7 indicate the proportion and time of water absorption in seawater, respectively. B2 and B5 hybrid composites make up 2.14 percent of the total, with 1.23 percent coming from B3 hybrid composites. Since hybrid composites B2 and B5 both include PU and bio teak wood fibers, their values are the same. Because of this, the hull of the Structural canoe can be made out of B3 composites. The best absorption

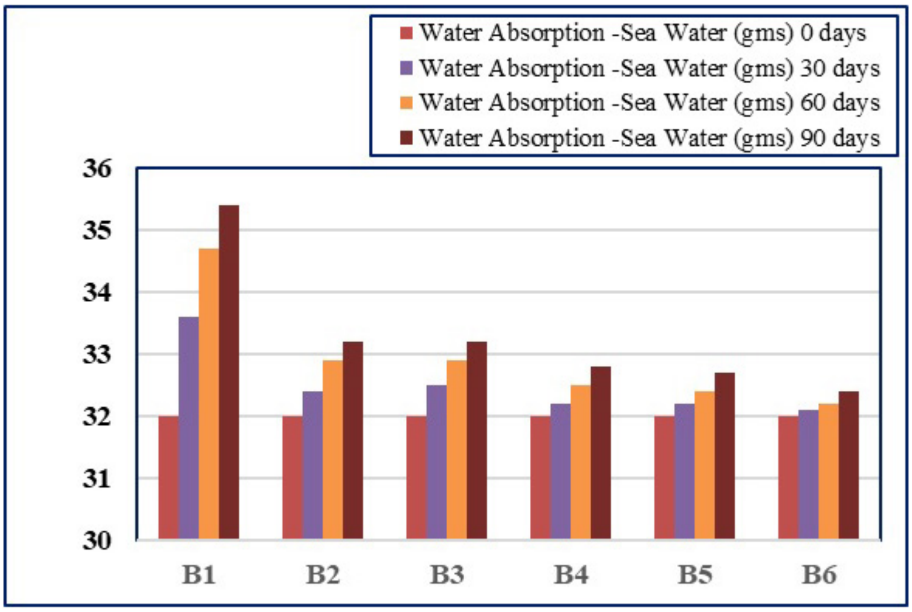

Figure 6: Water absorption of hybrid composites in sea water.

Table 7: Percentage of water absorption in sea water.

WATER ABSORPTION – SEA WATER (%)				
HYBRID COMPOSITE SPECIMEN	0 DAYS	30 DAYS	60 DAYS	90 DAYS
B1	0	0.62	1.54	2.44
B2	0	0.62	1.23	2.14
B3	0	0.31	0.62	1.23
B4	0	1.54	2.74	3.61
B5	0	0.62	1.23	2.14
B6	0	4.76	7.78	9.60

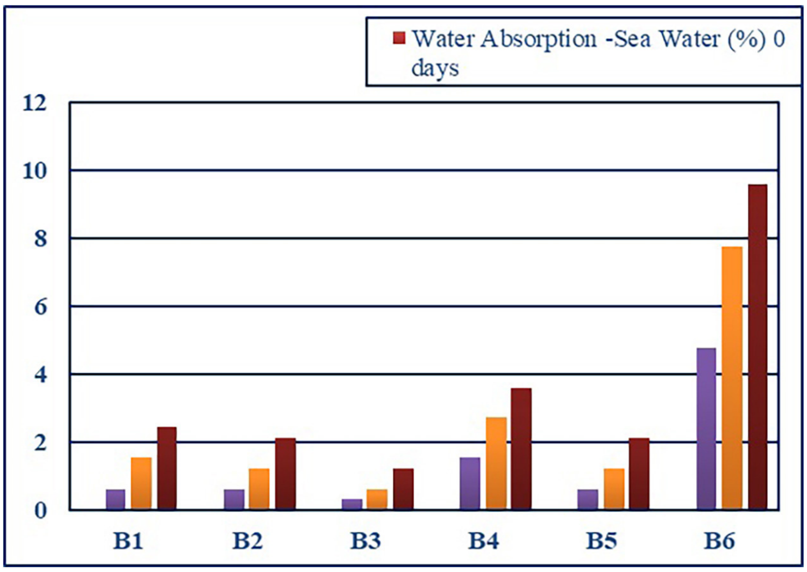

Figure 7: Percentage of water absorption in sea water.

resistance was observed in PU and bio teak wood. The increased number of fibers and the direction in which they are woven make this possible. Because of the degradation and deterioration that can result from continuous contact with water, water absorption is a common concern for PU and bio teak wood hybrid composites with Structural applications. The physical and mechanical effects of water absorption in PU and bio teakwood particles hybrid composites vary with the composite's characteristics and the extent to which they are exposed to water. Water absorption in PU and bio teakwood particles hybrid composites has a detrimental effect on mechanical properties such as flexural strength, tensile strength, and impact strength. As the composite ages, the interfacial connection between the reinforcement and the matrix diminishes, allowing the fibers to bond between the matrix and reinforcement. The degree of degradation can be affected by factors such as the type of reinforcement used, the PU and bio teakwood particles matrix composition, the water temperature, and the length of time the material is exposed.

In addition to mechanical degradation, water absorption in PU and bio teakwood particles hybrid composites can cause noticeable dimensional changes, bending, and swelling. This is especially concerning in maritime contexts, when dimensional stability is crucial to the integrity of the vessel or component in question. Factors including reinforcing type and quantity, PU and bio teakwood particles matrix composition, and composite thickness all play a role in the extent to which dimensions alter.

Because they absorb so much water, PU and teakwood particles hybrid composites are also vulnerable to hydrolysis and oxidation of the matrix and the reinforcement. Because of this, the composite may deteriorate, alter its color, and show defects like cracks and cavities. There are a number of methods for decreasing PU and bio teakwood particles hybrid composites' propensity to absorb water. The PU and bio teakwood particles matrix composition can be optimized, and the appropriate reinforcement types and amounts can be selected, and water-resistant additives can be incorporated. Coatings or surface treatments can reduce or prevent the composite from absorbing water. Regular maintenance and inspection can help prevent water absorption issues with PU and teakwood particles hybrid composites used in Structural applications.

3.5. Metallurgical characterization-scanning electron microscope

Using a scanning electron microscope with increasing magnification (50,000x, 1, 3, 4, and 5 m), the surface microstructure of the engineered hybrid composites B3 was identified. Figure 8 shows the morphology of B3 hybrid composites at multiple scales. PU and bio teak wood hybrid composites for Structural applications benefit greatly from metallurgical characterization and scanning electron microscopy (SEM) investigation in order to evaluate their microstructure and mechanical properties.

SEM images revealed the orientation and distribution of PU and bio teak wood, Nylon fiber, and teak wood; the stability of the contact between the reinforcement and the matrix; and the absence of cavities, defects, or damage. PU and bio teak wood hybrid composites used in the maritime industry are easily characterized and studied using SEM after being cut into small pieces or sections. The microstructure can be observed by etching the samples with the proper chemical solution after they have been polished to a smooth surface. Analysis of the SEM provides quantitative data on the microstructure, including the size and distribution of the reinforcement and the porosity of the hybrid composite material. The microstructure and mechanical properties of PU and bio teak wood hybrid composites were improved by metallurgical characterization and SEM, thanks to the good interfacial bonding nature between the fiber and the filler materials. This has the potential to aid in the development of new materials with improved performance and durability for maritime applications.

3.6. Atomic force microscopy

PU and bio teak wood hybrid composites used in Structural applications were investigated with the potent approach of AFM to determine their 3D surface shape and topography. Figure 9 shows the AFM structure of the fabricated hybrid composite material. AFM renders nanoscale properties of hybrid PU and bio teak wood composites as clear as day by generating high-resolution images of the sample's surface. Reinforcement materials for PU and bio teak wood hybrid composites can be AFM analysis of teak wood reinforced with nylon fiber and filler materials shows improved 3D morphology and distribution. To add to this, the 3D image revealed that the mechanical properties of the PU and bio teak wood hybrid composites are improved by the surface roughness and other surface attributes of the composite. The 3D AFM images showed that the nylon fibers were uniformly disseminated inside the PU and bio teak wood matrix, demonstrating a good interfacial adhesion between the two.

The impact of different surface treatments on PU fibers and bio teak wood and overall composite characteristics was also investigated using AFM. Flexural strength and stiffness can be improved by treating the composite with a saline coupling agent and then using general absorption procedures to boost the adhesion between

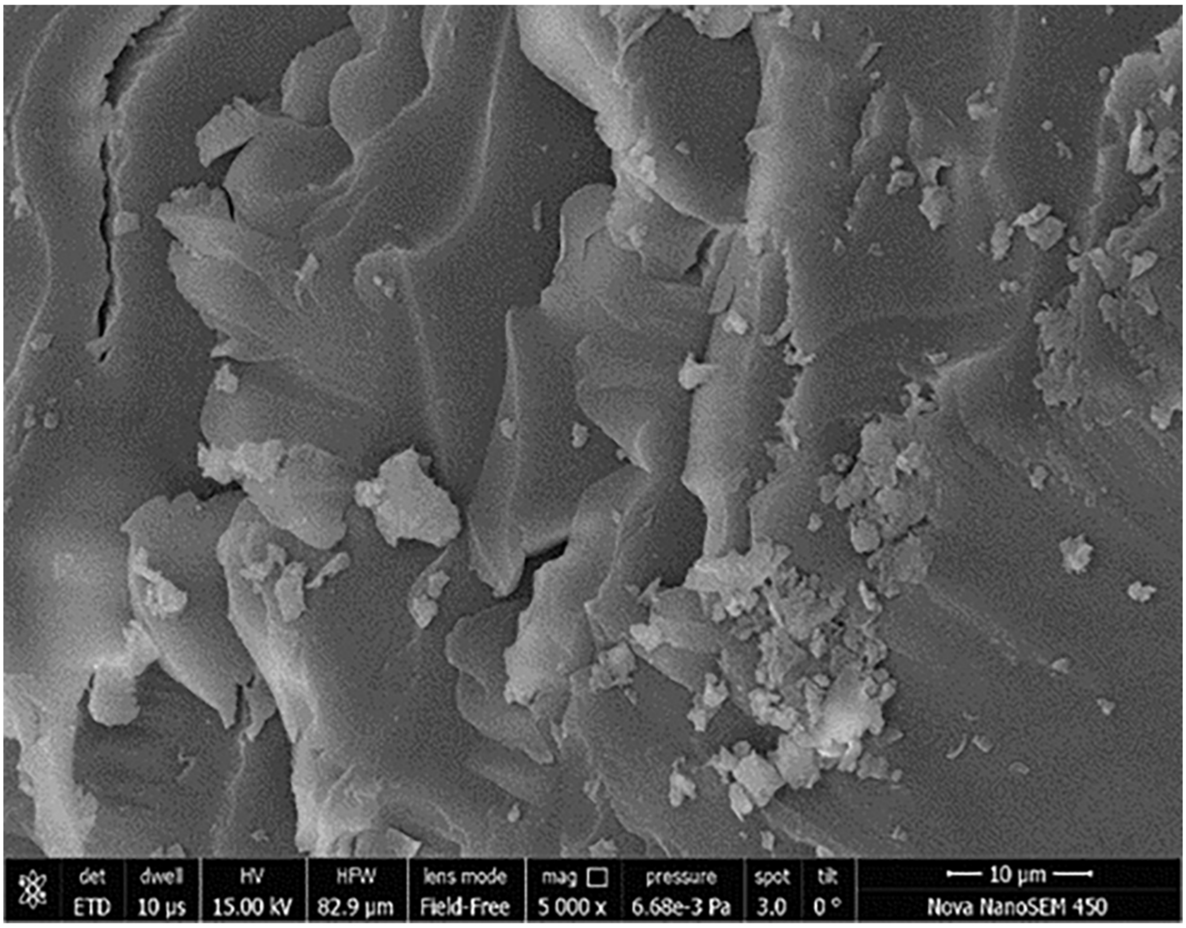

Figure 8: SEM image of the B3 hybrid composite specimen.

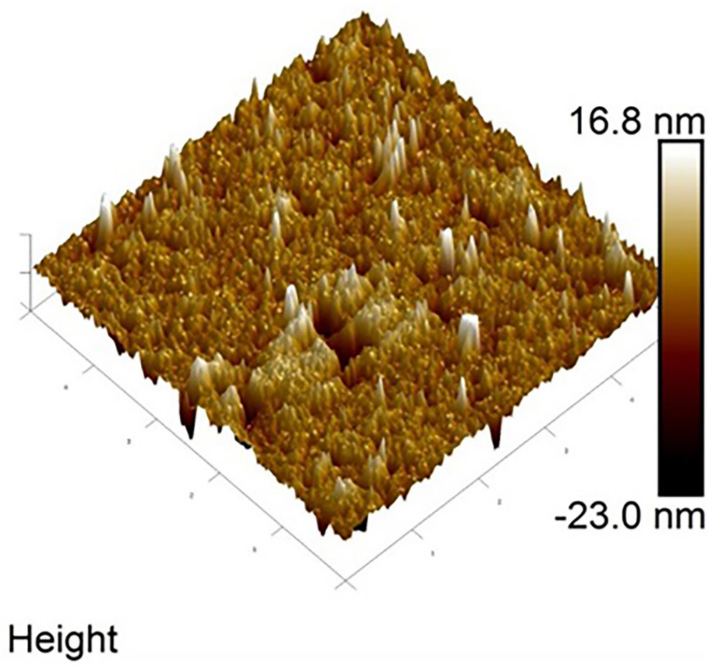

Figure 9: AFM structure of the fabricated B3 hybrid composite.

the nylon and PU fibers and bio teak wood as filler material. To better understand the surface morphology, topography, and adhesion of PU and bio teak wood hybrid composites for maritime applications, AFM analysis can be used. The information gleaned from this approach could be utilized to better the composite.

4. CONCLUSIONS

The use of recycled PU and nylon as reinforcement and bio teak wood as filler material in the hybrid composites has been the subject of a number of investigations. These materials are appealing because their unique properties can be used into high-performance composites. Used PU and bio teak wood/nylon hybrid composites' flexural characteristics were investigated. The study found that when PU/nylon fibres were combined with teak wood as a filler material, the flexural strength of the resulting B3 hybrid composites increased significantly. Improved options for B3 hybrid composites can be found through research on the effect nylon fibres have on the tensile qualities of waste PU and bio teak wood hybrid composites. The results showed that using bio teakwood particles as filler significantly improved the composites' tensile strength. When compared to B3, B4, B5, and B6, the hybrid composites' ability to absorb water was much lower. It demonstrates that the voids and spaces are quite minute. The morphology of the hybrid composites was shown to change after the inclusion of nylon fibres. The hybrid composites were shown to have improved mechanical properties thanks to the nylon fibres, which were found to be uniformly dispersed throughout the PU and bio teak wood matrix, thanks to scanning electron microscopy (SEM) analysis. These studies demonstrate the potential of recycled PU/nylon and bio teak wood hybrid composites as a replacement for conventional materials in several engineering applications. The use of recycled PU and bio teak wood in the matrix of composites has the potential to reduce landfill waste and increase environmental friendliness, while the addition of nylon fibres can significantly improve the materials' mechanical properties. Fabricated PU, nylon fibre, and teak wood as filler can be used in maritime canoe construction because of their high mechanical stability, lack of gaps and cavities, and strong interfacial bonding between the matrix and reinforcement.

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