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*CONFERENCE PAPER*

# PERFORMANCE EVALUATION OF HYBRID EPOXY COMPOSITES REINFORCED WITH DATE PALM AND SEA PURSLANE FIBERS FOR AUTOMOTIVE APPLICATIONS

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## Abstract

The present work reports the effect of hybridization on physical and mechanical properties of date palm petiole (DP)/sea purslane (SP) fiber reinforced hybrid epoxy composites. Using a standard hand lay-up method, five types of composites were fabricated ($C_1$, $C_2$, $H_1$, $H_2$, and $H_3$) taking 20 wt% of fibers as reinforcement. Various physical properties (density, void content) and mechanical properties (tensile, flexural, impact and hardness)were investigated. It was observed that $H_3$ (5wt %DP +15wt%SP) type composites reveal highest mechanical properties. It also shows less void content with comparison to other fabricated composites which enhances its hardness. With better properties, the fabricated hybrid composites can be used for fabrication of automotive exterior parts as well as dashboard and interior door panels.



## Introduction:-

In the building, automotive, and transportation industries, the demand for lightweight materials and recyclable parts is growing constantly in order to improve energy efficiency. Recently, scientists and researchers around the world have paid close attention to the development of composites utilizing natural fibers because of environmental contamination and the depletion of petroleum resources [1]. Due to their advantages over synthetic fibers in advanced applications, such as low density, high specific strength, and being renewable, sustainable, and ecologically beneficial, natural fibers have generated a lot of interest [2-4]. In contrast to synthetic fibers, natural fibers and particles are more readily available, easier to manufacture, less damaging to production equipment, sustainable, and biodegradable, hence they are employed as reinforcement in polymer matrix composites [5]. Automobile industries also recognize the need to reduce fuel consumption by reducing weight of the vehicles, reducing dependency on non-renewable resources like petroleum-based polymers, and sourcing their replacement with natural materials that have minimal to no environmental impact [6,7].

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Recently, the matrix component of hybrid composites, a relatively new class of composite materials that has two or more components, has been enhanced [5,6].The beneficial aspect of one fiber balances out the negative aspect of another in hybrid natural fiber composites [8]. It was found that at many instances the inferior mechanical properties of a single fiber can be overcome by the method of hybridization [9]. Hybridization plays a major impact in improving the mechanical performance of natural fiber-based polymer composites. Many researchers have already worked on hybridization of various fibers. For instance, when sisal and hemp natural fiber was mixed together with PLA matrix, it was observed that the flexural and tensile strength of the composite was enhanced [9]. In another work, it was found that 30wt% of pineapple/flax fibers enhance the tensile and flexural strength by great extent [10]. Hanan et al. researched the hybridization of oil palm and kenaf in epoxy matrix and found that adding more kenaf fiber significantly improved the tensile and flexural capabilities [11]. The thermal stability of hybrid composites prepared with mixing bamboo and kenaf fibers in epoxy matrix was studied [12]. They found that the thermal oxidation stability was enhanced when 70% bamboo and 30% kenaf was taken with epoxy.

Discussing about date palm (PHOENIXdactylifera) tree, its leaves and petioles are widely used to feed the animals. Its production is much higher than coir, sisal and hemp. Several attempts were already made by various researchers to reinforce date plam fibers in either thermoset or thermoplastic matrix to fabricate useful and lightweight composite.The properties of epoxy thermoset resin reinforced with short date palm leaf fibers have been studied by Sbiai et al. [13]. Amroune researched on the chemical and thermo-physical characteristics of date palm fibers [14]. They discovered that mechanical characteristics rose up to three times post chemical treatment. In our previous work, the effect of fiber treatment and loading on various properties of date palm/ epoxy composite as studied [15]. It was found that 20 wt% of acrylic treated fiber loading reveals highest mechanical properties as compared to other composites. SESUVIUMportulacastrum is a sprawling perennial herb that grows mostly in coastal areas. It is commonly known as sea purslane (SP). In our previous work, the mechanical and thermal properties of SP/epoxy composites were studied [16]. It was observed that at 20wt% of fiber loading the mechanical and thermal properties were enhanced. The objective of the research is to fabricate hybrid composite using chemically treated date palm and sea purslane fiber as reinforcement in epoxy matrix. Five types of samples were fabricated and named as ($C_1$, $C_2$, $H_1$, $H_2$, and $H_3$) taking 20 wt% of fibers as reinforcement. Various chemical, thermo-physical, mechanical and thermal properties were investigated and compared with its single fiber composites ($C_1$& $C_2$) to study the effect and benefit of hybridization. The goal of the research is to fabricate and utilise the hybrid composites for manufacturing automotive parts.

## Materials and Method:-

### Materials:-

In this work, epoxy (LY556) and hardener (HY951) were used and purchased from Herenba Instruments, Chennai, India. DP and SP fibers were extracted manually at the workplace. Chemicals such as sodium hydroxide and acrylic acid were bought from Mohapatra chemicals, Bhubaneswar, India and used without further purifications.

**Extraction and modification of fibers:-**

The date palm petiole and sea purslane stems were collected locally. The extraction procedure was same for both the fibers. The DP petiole and SP stem was washed thoroughly to remove the dirt present. Then both were soaked in water for around 10 days which is known as retting process to free the fibers for easy removal. A metal brush was used to remove the fibers after ten days, making sure the fibers were not damaged. After being removed, the fibers were dried for two days in the sun and then for twenty-four hours at 70 °C in an oven to eliminate any remaining moisture. The extracted fibers DP and SP are shown in Fig. 1.


**Fig. 1 Extracted (a) date palm fiber (b) sea purslane fiber.**

Chemical modification is used to enhance fiber–polymer bonding by reducing the incompatibility between hydrophilic natural fibers and hydrophobic polymers. Treatments remove surface impurities such as lignin, hemicellulose, waxes, and oils, increasing surface roughness and improving interfacial adhesion. In this process, fibers were treated with 5% NaOH at 80 °C for 1 hour, washed to neutral pH, and oven-dried for 24 hours. They were then treated in a water–benzene solution at 85 °C for 15 minutes, followed by immersion in 0.3 M acrylic acid for 1 hour, rinsed with distilled water, and dried.

**Fabrication of DP/SP/Epoxy hybrid composites:-**

Fabrication of DP/SP/Epoxy hybrid composites was done by a wooden mould of dimension 180mm×150mm×5mm using simple hand layup technique. Before fabrication, both acrylic acid treated SP and DP fibers were first cut into small pieces approximately 3 mm in size. Then, they were mixed with LY-556 epoxy matrix and HY-951 hardener with a proportion of 10:1 to form 3 sets of hybrid composites (i.e. H1, H2, and H3) with varying weight percentage of DP and SP fibers as given in Table 1. Another 2 sets of DP/epoxy and SP/epoxy composites (i.e. C1 and C2) at 20 wt% of fiber loadings for comparison were fabricated. A load of 20kg was applied over the mold and allowed for curing up to 24 hrs at room temperature. The composites specimens (Fig. 2) were cut into different sizes as required by various tests to be conducted

**Table 1. Composition of fabricated composites**

| Type of composite | Composition | DP (wt%) | SP (wt%) | Matrix (wt%) |
|---|---|---|---|---|
| **C1** | 20wt% DP | 20 | 0 | 80 |
| **C2** | 20wt% SP | 0 | 20 | 80 |
| **H1** | 15wt %DP+5wt%SP | 15 | 5 | 80 |
| **H2** | 10wt%DP+10wt%SP | 10 | 10 | 80 |
| **H3** | 5wt %DP +15wt%SP | 5 | 15 | 80 |

**Fig. 2 Fabricated composites**

**Study of physical properties:-**

**Density and void content:-**

The density of the manufactured composite was evaluated using the Archimedes principle or the water immersion method (ASTM D 792-91), and the void content was assessed using the ASTM D-2734-70 standard. A digital scale with a resolution of $\pm 10^{-1}$ was used to compute sample weights, and the water displacement method was used to calculate volume. The theoretical density and void content of the composite samples were determined by using Eq. 1 and 2 respectively.

$$\rho_{\text{theoritical}} = \frac{1}{\frac{w_f}{\rho_f}+\frac{w_m}{\rho_m}} \tag{1}$$

$$\text{Void content (\%)} = \frac{\rho_{\text{theoritical}} - \rho_{\text{exp erimental}}}{\rho_{\text{theoritical}}} \times 100 \tag{2}$$

Where w and ƒ are weight fraction and density respectively. The suffixes f and w stand for fiber and matrix resp.

Out of 10 test specimens done for each set of composite, the average reading was recorded.

**Mechanical properties of DP/SP/Epoxy hybrid composites:-**

**Tensile Test:** Tensile properties were evaluated using a universal testing machine at a crosshead speed of 2 mm/min, following ASTM D 638-14 standards. Dog-bone specimens (165 × 19 × 5 $mm^3$) were used, and the average of 10 samples was reported.

**Flexural Test:** Flexural strength was measured using the same machine at 2 mm/min with specimens of size 150 × 9 × 5 $mm^3$following ASTM D2344-84. The displacement and bending behavior were calculated using standard beam equations. Ten samples were tested, and average values were considered.

**Impact Test:** Charpy impact testing was performed on V-notched specimens (55 × 10 × 5 $mm^3$) using a pendulum impact tester in accordance with ASTM E23. The hammer velocity and weight were 3.45 m/s and 0.904 kg, respectively. Results were averaged over 10 specimens.

**Micro-Hardness Test:** Vickers micro-hardness was determined using a diamond indenter as per ASTM D384 standard. Indentation diagonals were measured to calculate hardness values. Tests were conducted on 10 samples, and mean values were used for analysis.

Overall, multiple specimens were tested for each property to ensure accuracy and reliability of results.

## Results and Discussion:-

### Density and void content:-

Different physical properties such as densities and void content were evaluated for SP/DP/Epoxy hybrid composites (i.e. H1, H2, an H3) at different fiber proportions and compared with DP/Epoxy and SP/Epoxy composites at 20wt% fiber loading (i.e. C1 and C2) and presented in Table 2.From the tabulated results, the measured densities of DP/SP/Epoxy hybrid composites increase with increase in SP fiber loading and it is highest (i.e. 1.263 gm/cc) for H3 composite with 15 wt% SP fiber content. Further, for the composites without hybridization, composite with 20 wt% of SP fiber content (i.e. C2) shows higher density (i.e. 1.275 gm/cc) in comparison to density of composite with 20 wt% of DP fiber loading (i.e. C1). As far as percentage of void content is concerned, the H3 type hybrid composite shows less void content (i.e. 1.018%) in comparison to other types. Similarly, the percentage of void content is less (i.e. 1.062%) in C2 type of composite in comparison to C1 type. From the above results, it was found that the density is more and percentage of void content is less because of more amount of SP fiber concentration in both sets of composites (i.e. with and without hybridization). The hybrid composites made by reinforcing tamarind and borassus fruit fibers in epoxy polymer had a void fraction of 4.26 to 6.60% [17] and a void fraction of 3.56% for areca/moringa hybrid composites [5].

**Table 2. Comparison of densities and void contents of various composites**

| Types of composites | Theoretical density (gm/cc) | Experimental density (gm/cc) | Void content (%) |
|---|---|---|---|
| **C1** | 1.129 | 1.117 | 1.086 |
| **C2** | 1.289 | 1.275 | 1.062 |
| **H1** | 1.237 | 1.223 | 1.131 |
| **H2** | 1.256 | 1.242 | 1.114 |
| **H3** | 1.276 | 1.263 | 1.018 |

### Study of mechanical properties:-

Fig. 3 presents the tensile strength and Young’s modulus of all fabricated composites in bar chart form. It is observed that mechanical properties improve with increasing SP fiber content, owing to the higher strength of SP fibers compared to DP fibers. The H3 hybrid composite (5 wt% DP + 15 wt% SP) exhibits the maximum tensile strength of 53.56 MPa, which is higher than non-hybrid composites C1 and C2 (20 wt% DP and 20 wt% SP). This improvement is attributed to better stress transfer between fiber and matrix due to enhanced interfacial bonding [18]. However, fiber entanglement and agglomeration may reduce stress transfer efficiency [19]. The tensile strength of H3 shows an increase of 27.31% and 8.03% compared to 20 wt% DP/Epoxy and SP/Epoxy composites, respectively. Similarly, Young’s modulus increases with hybridization, reaching a maximum value of 2.816 GPa for H3, which is higher than non-hybrid composites (Fig. 3b). The modulus improvement for H3 is 30.37% and 18.32% compared to 20 wt% DP/Epoxy (C1) and SP/Epoxy (C2) composites, respectively.

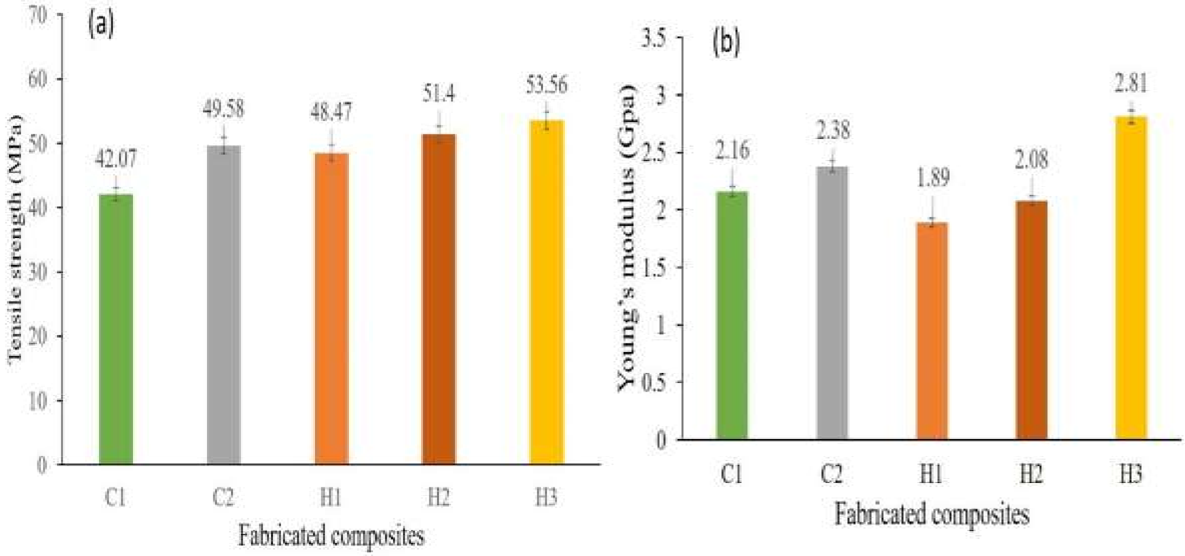


**Fig. 3 (a) Tensile strength and (b) Young's modulus of fabricated composites**

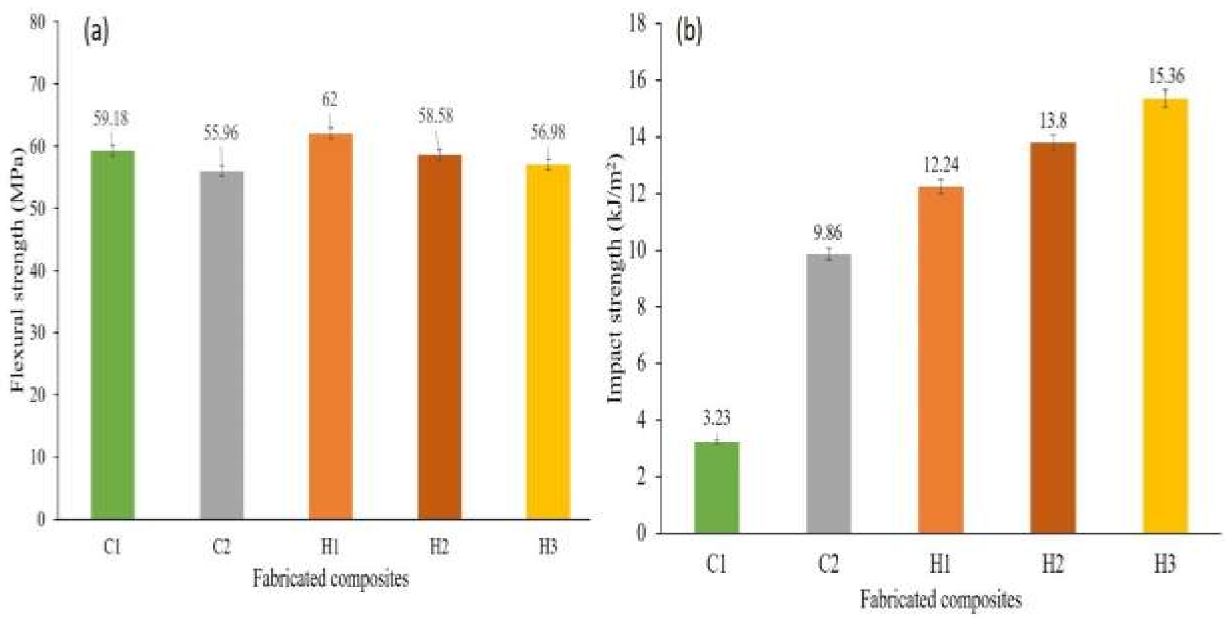


**Fig. 4 (a) Flexural strength and (b) Impact strength of fabricated composites.**

The flexural and impact properties of the composites exhibit contrasting trends. The flexural strength (Fig. 4a) shows a reverse behavior compared to tensile strength, where the hybrid composite H1 (maximum DP content) achieves the highest value of 62 MPa. Similarly, the non-hybrid composite C1 (20 wt% DP) shows higher flexural strength than C2 (20 wt% SP). However, the difference between C1 and H1 is minimal, with only a 4.76% increase. This improvement with higher DP content may be attributed to restricted fiber expansion within the matrix, leading to better fiber–matrix equilibrium and enhanced flexural strength [20]. In contrast, the impact strength (Fig. 4b) follows a trend similar to tensile strength, increasing with higher SP fiber content. The maximum impact strength of 15.36 kJ/m² is observed for the hybrid composite containing 15% SP and 5% DP. Likewise, non-hybrid C2 (20 wt% SP) exhibits better impact strength than C1 (20 wt% DP), indicating that SP fibers contribute significantly to impact resistance. Overall, hybridization results in a substantial improvement in impact strength of about 55.78%.

As observed from the chart (Fig. 5), the hardness values ($H_v$) of both the sets of composites also display same trend as that of impact strengths and tensile strengths. Reason is quite obvious as the strength of SP fibers is better than DP fibers, it is expected that the composites with higher wt% of SP fibers will reveal better hardness. Moreover, the hardness of H3 hybrid composite with 15 wt% of SP fibers shows highest value (i.e. 27.5 $H_v$) in comparison to other hybrid composites. This value is also higher than that of composites without hybridization. However, it is observed that the increase in hardness is not significant as far as hybridization is concerned. Similar trend has been observed in the findings of Chaudhary et al. [21] in case of jute/hemp/flax reinforced hybrid composites. The reason may be due to the reinforcements' restriction, which prevents the indenter from intending the composite.

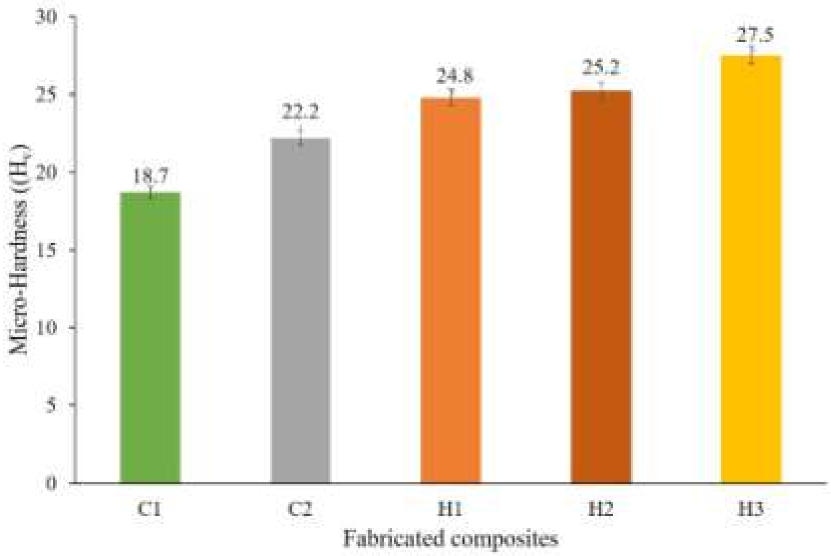


**Fig. 5 Micro-hardness of fabricated composites.**

## Conclusion:-

The present study demonstrates that hybridization of date palm (DP) and sea purslane (SP) fibers significantly improves the physical and mechanical properties of epoxy composites. The increase in SP fiber content led to higher density and lower void content, with the H3 composite (5 wt% DP + 15 wt% SP) showing the least void content (1.018%) and better structural integrity. Mechanical properties such as tensile strength, Young's modulus, impact strength, and hardness were found to improve with increasing SP content, while flexural strength was higher for composites with greater DP content. The H3 composite exhibited the best overall performance, achieving a tensile strength of 53.56 MPa, Young's modulus of 2.816 GPa, impact strength of 15.36 kJ/m², and hardness of 27.5 Hv. These improvements are attributed to enhanced interfacial bonding, effective stress transfer, and reduced void content due to chemical treatment and hybridization. From an application perspective, the developed hybrid composites are suitable for automotive components, particularly non-structural and semi-structural parts such as interior door panels, dashboards, trims, and lightweight exterior panels. Their low density, improved mechanical performance, and eco-friendly nature make them promising alternatives to conventional synthetic composites, contributing to weight reduction and improved fuel efficiency. For future scope, further work can focus on optimizing fiber ratios and chemical treatments, studying thermal and durability properties, and evaluating environmental effects such as moisture absorption and aging. Additionally, the use of bio-based resins and advanced fabrication techniques can further enhance sustainability and performance. These advancements can expand the applicability of such hybrid composites in broader engineering and automotive applications.

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