# Feasibility Study on Mechanical Properties of Date Palm Fiber and Epoxy Bio-Composite for Automotive Applications

**Md. Mathenulla Shariff [a)], Niyaz Ahamed. M.B [b)], Arpitha G R [c)], Al Waleed Saif Musabah Al-Maqbali [d)], Mohammed Ibrahim Murad Al-Balushi [e)], Rashid khalied Al-Muqbali [f)], Sultan Khamis Marah Al-Alawi [g)]**

[a)] Corresponding author email:matheenulla.s@presidencyuniversity.in, Research Scholar, Presidency University, Bangalore, India

[b)] niyazaec.mech@gmail.com, Lecturer, Engineering Department, University of Technology and Applied Science, Shinas, Sultanate of Oman

[c)] arpithagr@presidencyuniversity.in, Assistant Professor, Presidency University, Bangalore, India

[d)] 62s1969@shct.edu.om, [e)] 62s19172@shct.edu.om, [f)] 62j2125539@shct.edu.om, [g)] 62s1940@shct.edu.om

Engineering Department, University of Technology and Applied Science, Shinas, Sultanate of Oman

**Abstract**

In Gulf countries such as Saudi Arabia and the Sultanate of Oman, date palms are a major agricultural crop. There is a considerable supply of date palm stems and leaves as agricultural residues. It may be easy and affordable to harvest a large amount of fiber from stem and leaves of date palm trees, which are common in the Al Batinah region. Moreover, they have durability and a variety of textures on the strands. In terms of the use of waste materials and environmentally friendly disposal, the use of natural fibres derived from renewable resources is beneficial to the environment. Natural fiber composite materials have become a focus of research and development due to their availability, widespread use, renewable nature, cost effectiveness as well as ecofriendliness. Thanks to their balanced mechanical properties, the use of composite materials in vehicles, aircraft, marine and civil structures is becoming more common. The fibres must be reinforced with polymers to ensure properties such as compression, impact strength, hardness and flexural flexibility of composite materials. Therefore, for the above specified mechanical properties, the strength of the composite produced from DPFs of local varieties shall be tested in this case. In order to obtain a good natural polymer composite which can be used for a variety of applications, the main objective is to find a way to use waste palm tree fibres to obtain a good natural polymer composite.

**Keywords:** Date palm fibre, Bio-composites, Flexural strength, Epoxy binder, Impact strength.

## 1.Introduction

The majority of experts are focusing on environmentally friendly and endless natural fibers as motivating resources for business growth that is also environmentally friendly. Using renewable resources is the best for preserving the "green" environment. There are many natural fibers that are regarded as waste, including date palm oil, banana, bamboo, sisal, and pineapple leaf. Natural fibers are favored even though they have a number of advantages over synthetic fibers, such as being environmentally safe, having a smooth character, using less energy, being affordable, and having specific mechanical properties [1]. However, a number of studies have demonstrated that plant fibers can be used as reinforcement in a range of thermoset and thermoplastic polymer composites for use in the mechanical and construction industries [2].

Production of date palms is 42% more than that of coir and 20–10% more than that of hemp and sisal globally. The Sultanate of Oman ranks ninth worldwide in date production. The Sultanate of Oman and neighboring gulf countries are home to the ancient crop known as the date palm tree. Half of the agricultural land in Oman is used to grow date palms. Each stem of a palm tree is encircled by a net of fibers that resembles a naturally woven mat of fibers in varying sizes. Typically, this mat is split and washed to create ropes and baskets. Date palm fiber (DPF) is a collection of multicellular fibers that are 2 to 5 meters long, with a center void, and resemble coir fiber in both shape and structure. DPF is a multicellular lignocellulose fiber that contains wax, pectin, and trace amounts of inorganic material in addition to cellulose (38–40%) and lignin [1,3]. The DPF has undergone a number of attempts to be strengthened in an effort to improve the physical, mechanical, and thermal properties of thermoplastic and thermoset polymers [4]. To wash and clean the surface of the fibers from substantial amounts of impurities and incomplete development, however, as they may cause poor adhesion between the fiber and polymer, is often necessary prior to reinforcing [5]. One study has described short DPF-reinforced modified polyester and epoxy matrices with better morphological and mechanical characteristics. The thermal stability and natural weathering of composite structures composed of DPF-reinforced polypropylene (PP) are examined in a different study. Researchers found that the inclusion of DPF improved the mechanical and thermal properties of the PP composites by increasing the interfacial adhesion [6]. It's noteworthy that these fibers are also used as effective fillers in thermosetting and thermoplastic materials, and literature has also discussed their cutting-edge industrial and engineering applications, such as in automotive and aerospace components [7].

It is advised to make use of the yearly date palm tree pruning because doing so well probably lead to less waste being disposed, according to the conclusions of a prior investigation. These chemicals present a problem for the vast majority of governments across the world due to their negative effects on human health and the environment [8]. Date palm plants are retted to get rid of their fibers in order to remedy these problems. DPF is a more sought-after natural fiber resource than other natural fibers because of its superior chemical composition and mechanical strength. DPF/epoxy composites have been the subject of numerous investigations in an effort to develop the required properties [9]. The summary includes information from the literature review in part. The objective of a study [10] is to determine the effective addition of DPF at various fiber loadings to enhance the characteristics of epoxy composites. The addition of DPF improves the flexural strength and modulus of epoxy composites, but 50% DPF loading shows superior improvement than the other composites because it dissipates heat more effectively, keeps fibers moist, and connects the DPF to the epoxy matrix. S. W. Ghori and G. S. Rao [11] This study studied the mechanical and morphological properties of kenaf and DPF reinforced epoxy hybrid composites and found that doing so improved the tensile properties of the DPF/Epoxy composites. Additionally, it shows that DPF-30%

composites outperform other composites in terms of mechanical properties [2]. Sisal, hemp, flax, and jute are great options for increasing polymeric matrix composites, according to S. M. Hussein's research [6]. DPFs are common in several countries and have been shown to be useful in a variety of sectors [12]. According to experimental results, the values of Young's modulus, impact strength, and hardness rose as reinforcing speed was increased. Tensile strength values were increased utilizing reinforcements of 5% and 10% DPF but decreased using 15% and 20% due of the weak link between matrix and fiber [13].

The length and composition of the DPF are observed to have an impact on mechanical properties such tensile strength, impact, and hardness, according to a study that examined numerous weight ratios of DPF [14]. The finding indicates that composites with shorter fibers are harder than composites with longer fibers. [1]. Natural fibers are frequently employed in the matrix's reinforcement because of their ability to solidly link with the epoxy matrix [1]. Compared to synthetic fibers, natural fibers are easier to produce, have better thermal and mechanical properties, and are more prevalent. Natural fibers are frequently sourced from plants and animals. Common plant-based fibers include jute, coir, pineapple and banana peels, sisal [15], kenaf, and date palm [3]. The two most popular animal-based fibers are wool and silk. Unexpectedly, animal fibers are more expensive and have a higher strength but lower stiffness than plant fibers. The potential of these fibers to produce polymer composites for vehicle parts is what drives the industrial application of DPF (DPF), according to a survey by multiple researchers. These fibers work well as fillers in thermoplastic and thermosetting plastic formulations [16]. DPFs are quite combative when it comes to enhancing the self-propelled sector's validity and capability and helping to allay the worry about waste in the environment [14]. The DPF in composite materials is an affordable, reusable, and sustainable source of material. By effectively fortifying DPF with epoxy, polypropylene, and unsaturated polyester polymers, DPFs and polymer composites with better properties are made.

A review of the pertinent literature reveals that no studies on the application of DPF from the Al-Batinah region in epoxy have been reported. The goal of the current study is to ascertain the effects of DPF loading on the mechanical characteristics of epoxy composites, including compression strength, flexural strength, hardness, and impact strength (30%, 40%, and 50% by weight). Additionally, it makes it possible to use the vast DPF reserves in the Sultanate of Oman's Al-Batinah region as a renewable and environmentally friendly substitute for other natural fibers like kenaf, bamboo [3], jute, and hemp when making polymer composites [7]. Investigating the use of this DPF in composite materials would be interesting. environmental and social.

## 2. Resources and techniques

### 2.1 Raw material gathering and processing

Mechanical techniques were used to gather the date palm tree fiber (Fig. 1), and the DPF was then used as a reinforcing material. Fig. 2 displays the tree's unprocessed fiber. The proposed composite's matrix was made of the epoxy resin LY556. By pouring an epoxy and DPF mixture into molds, the fiber and fiber have been used to make the composite mechanical test specimens [5]. Sodium hydroxide and distilled water are used to clean the fibers [17,18]. To create the specimens of various sizes, a mild steel mould that is the desired size (220x200x12 mm) is created. Figures 3 and 4, respectively, depict the molds used to create the test specimen and the laminate.

### 2.2 Composites preparation

Composite materials are created using the hand lay-up technique. Different matrix weights were used to place the filler components. Three different types of epoxy composites were produced using three different filler loadings of epoxy resin. Epoxy (60 wt.%) plus DPF (40 wt.%), epoxy (70 wt.%) plus DPF (30 wt.%), and epoxy (50 wt.%) plus DPF (50 wt.%) are the names of these composites. The composite samples were prepared in a mold (220x200x12 mm3) made of mild steel. A plastic sheet was then used to line the mould's bottom. Epoxy resin and hardener were first blended in accordance with their weight ratios to generate a matrix. After that, the mixture was added, and the mold was filled. After that, a plastic covering was put on top of it. As soon as the epoxy/DPF composite's initial preparation was complete. To guarantee proper resin distribution and minimize voids, composites were crushed using a roller. Finally, the two processing methods previously mentioned are combined in the creation of the epoxy/DPF composite. The composite is cured under a load for 24 hours at room temperature (26°C–29°C) before being removed from the mould. After curing, the composites were taken out of the mould in the form of a plate. To develop samples that comply with the hardness and compression testing standards of ASTM Standards D256-87 and D790-86, respectively, the specimens were cut and machined. Pure epoxy was also used for these testing.

*Fig. 1 Date palm tree*

*Fig. 2 Raw fibre from the date palm tree*

*Fig. 3 Photographic views of the steel moulds to prepare sample laminates.*

### 2.3 Characterization of composites

---

Table 1 lists the details of the raw material used for the preparation of samples and their mixing rations. The samples are named as S1, S2 and S3. Mechanical properties (Compression, impact, flexural.) have been measured in order to examine the effects of various DPF ratios in Epoxy-DPF composites. The specimens' dimensions for the impact, flexural, compression, were carried out, according to the American Society for Testing and Materials (ASTM). The volume of the laminate, density of the matrix and density of the fiber are measure as 220x200x12 $mm^3$ (528 $cm^3$), 1.1 $g/cm^3$ (Resin + Hardener), and 0.980 $g/cm^3$,

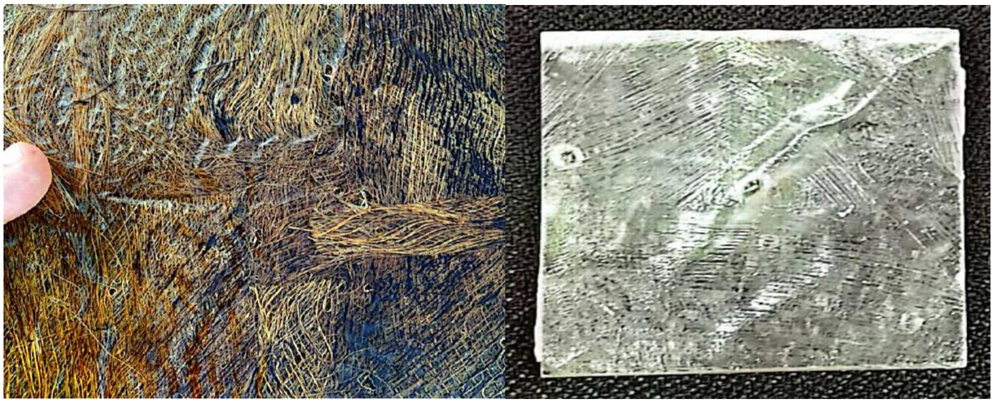

*Fig. 4 Photographic view of the laminate samples*

*Table 1 The fiber/epoxy composition in the tested samples*

| Description | Ratio of Fibre/Resin (volume) | Fibre weight (grams) | Resin weight (grams) |
|---|---|---|---|
| P-Epoxy | 0:1 | 0 | 166 |
| S1 | 0.40:0.6 | 131 | 150 |
| S2 | 0.3:0.7 | 99 | 113 |
| S3 | 0.5:0.5 | 164 | 185 |

## 3.0 Results

### 3.1 Examining the findings of compression tests

The high-strength DPF epoxy composite and pure epoxy specimens were able to withstand compression stresses of up to 2500 kN at a loading rate of 2.5 kN/sec when tested in accordance with the ASTM-D695 standard. The cube specimens have dimensions of 50 x 50 x 12 $mm^3$. The samples were then cured for a week before being examined. Fig. 5 depicts the samples' appearance both before and after the test. Prior to testing, the samples were kept for 24 hours at room temperature (23 °C to 2 °C). Three samples for each combination were examined, and the outcomes are shown in Figs. 6 and 7. The figures show the variation in compression strength and density for several fiber/epoxy composite specimens at different weight proportions. S1 (40:60), one of the samples utilized in this analysis, had the strongest compression strength. P-epoxy has the lowest compressive strength at 764.0 MPa. It proves that density increases compressive strength. Table 2 provides a sample of the testing parameters and their values.

*Fig. 5 The photographic view of the sample before and after test.*

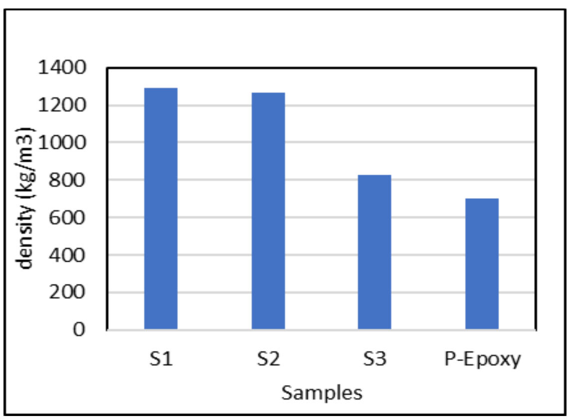


*Fig. 6 Average density of the tested samples*

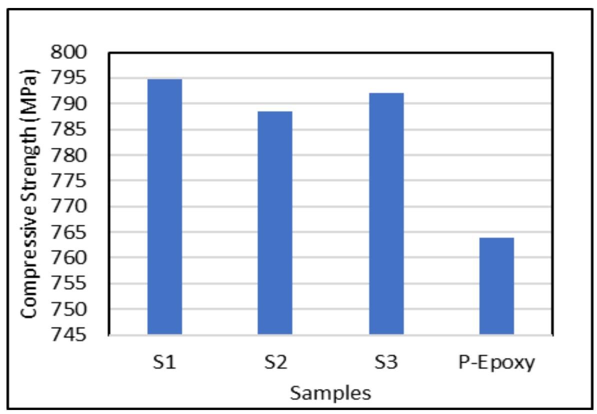


*Fig. 7 Average compressive strength of the samples*

***Table 2*** *Compressive Strength calculation for the samples.*

| Sample | Weight in gms | Density in Kg/m$^3$ | Failure load in kN | Compressive strength in MPa | Strain |
|---|---|---|---|---|---|
| **S1** | 38.8 | 1293.33 | 1987 | 794.8 | 0.805 |
| **S2** | 38.0 | 1266.66 | 1971 | 788.4 | 0.903 |

| | | | | | |
|---|---|---|---|---|---|
| **S3** | 24.8 | 826.66 | 1980 | 792.0 | 0.630 |
| **P-epoxy** | 17.8 | 700 | 1910 | 764.0 | 0.620 |

### 3.2 Impact test

An impact test measures how well a material can stand up to loads that are put on it quickly and out of the blue. Toughness is a measure of how much energy a material can take in while it is being deformed [18]. Because they can only withstand a certain degree of plastic deformation, brittle materials have low toughness. This test is done to find out how strong the composite is or how tough the sample is. In the impact test, the size of the sample (70x8x8 $mm^3$) met the requirements of ASTM D256. The failure of the samples after the test and the impact variation of impact strength are shown in Figs. 8 and 9, respectively. The graph's analysis makes it abundantly clear that Sample S1, with a ratio of 40:60, has the highest impact strength, or 21.4 N/m.

*Fig. 8 Photographic view of the samples after failure*

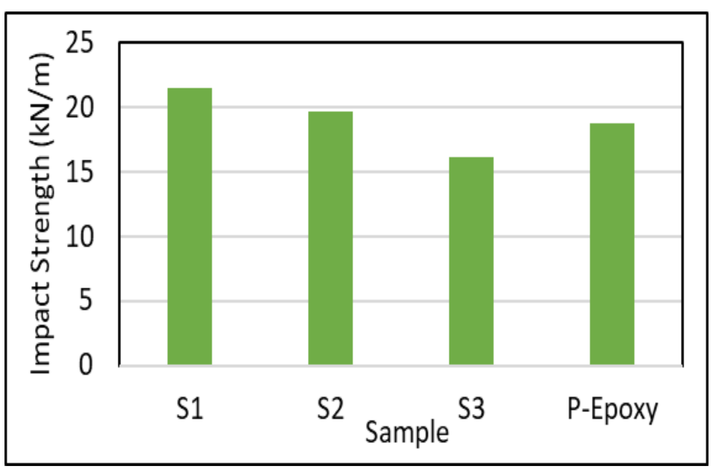


*Fig. 9 The impact strength of the tested samples*

### 3.3 Flexural strength

Three-point bend test in line with (ASTM) Method D790 was conducted to evaluate the flexural properties. The samples measured 190 mm long, 100 mm wide, and were 12 mm thick. Samples were tested for three-point bending at a cross-head speed of 1.25 kN/sec and a distance between the outer rollers of 45 mm. To get the average, three samples from each case were examined. Testing continues on a specimen until it cracks. Figures 10 and 11 show, respectively, the samples' flexural failure pattern and flexural strength. The flexural strength of the composite was calculated using the relationship shown below. The flexural strength of composites is shown in the graphic below as M/I = F/Y. The graph clearly shows that the flexural strength increases along with the fiber concentration. The flexural strength of several samples examined in this experiment is shown in the figure above. The data clearly shows that sample 1 has the highest flexural strength value, which is around 260.41 MPa. In contrast, the lowest flexural strength value is found in other samples.

*Fig. 10 Flexural failure of the tested samples*

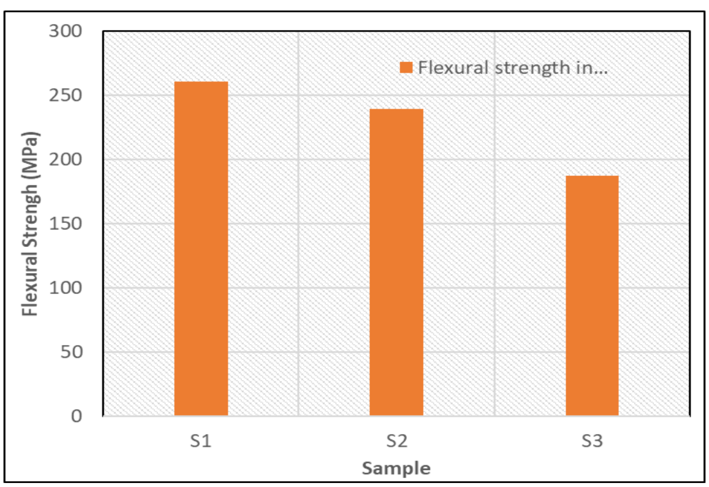

*Fig. 11 The flexural strength of the specimens*

## 4.0 Conclusions.

In this study, DPF was used as a filler at different weight ratios, changing the mechanical (compressive, hardness, flexural, and impact strength) and microstructural properties of pure epoxy resin. The outcomes showed that the compressive characteristics, impact strength, and flexural strength were all enhanced by the addition of DPF. However, with 40/60 DPF/epoxy composites, notable improvements were attained because the DPF filler was superbly distributed, mixed, and dispersed without error and without aggregating or creating micro voids. The following results are reached after analyzing the material characteristics of natural fiber reinforced epoxy composites with three distinct weight fractions.

• Epoxy and fiber composites bonded with natural fibers might be produced using the hand lay-up technique.

• To provide the desired characteristics, the epoxy/fiber treatment with 4.5% NaOH and a weight fraction of 40/60 proved adequate.

• The composite with a weight fraction of 40/60 treated with 4.5% NaOH has the greatest strength throughout all tests.

• The trials conducted for this study's experiments showed that epoxy with fiber might be a great filler for creating fine composites while minimizing waste deposition.

• A greater density, 260.41 MPa flexural strength, 21.42 kN/m2 impact strength, 764.0 MPa compressive strength, were all displayed by the fiber/resin (volume%) ratio 40/60.

## Acknowledgement

The authors acknowledge the funding provided by the Ministry of Higher Education, Research, and Innovation, Oman, through research grant BFP/URG/EBR/21/257 for the experimental facility.

## References

1. R. B. Alsuwait, M. Souiyah, I. Momohjimoh, S. A. Ganiyu, and A. O. Bakare, Polymers (Basel). **15**, (2023).
2. G. Petrone and V. Meruane, Compos. Part A Appl. Sci. Manuf. **94**, 226 (2017).
3. A. B. M. Supian, M. Jawaid, B. Rashid, H. Fouad, N. Saba, H. N. Dhakal, and R. Khiari, J. Mater. Res. Technol. **15**, 1330 (2021).
4. M. R. A. Refaai, R. M. Reddy, M. I. Reddy, B. S. H. Khan, V. Nagaraju, and S. P. Kumar, Adv. Polym. Technol. **2022**, (2022).
5. M. Ali, Int. J. Polym. Sci. **2023**, (2023).
6. S. Mousa, A. S. Alomari, S. Vantadori, W. H. Alhazmi, A. A. Abd-Elhady, and H. E. D. M. Sallam, Sustain. **14**, 1 (2022).

7. P. Sahu and M. K. Gupta, Proc. Inst. Mech. Eng. Part L J. Mater. Des. Appl. **234**, 198 (2020).

8. Z. T. Abİd and H. J. Abdulsamad, J. Curr. Res. Eng. Sci. Technol. **8**, 17 (2022).

9. J. Dehury, J. R. Mohanty, S. Nayak, P. Samal, S. K. Khuntia, C. Malla, S. D. Mohanty, and J. Mohapatra, J. Nat. Fibers **19**, 9457 (2022).

10. M. H. Gheith, M. A. Aziz, W. Ghori, N. Saba, M. Asim, M. Jawaid, and O. Y. Alothman, J. Mater. Res. Technol. **8**, 853 (2019).

11. S. W. Ghori and G. S. Rao, J. Renew. Mater. **9**, 1283 (2021).

12. S. M. Hussein, Iraqi J. Sci. 1960 (2020).

13. T. Sadik, S. Muthuraman, M. Sivaraj, and S. Rajkumar, Mater. Today Proc. **37**, 3372 (2020).

14. M. Ali, A. H. Al-Assaf, and M. Salah, Adv. Polym. Technol. **2022**, (2022).

15. J. Nagarjun, J. Kanchana, and G. Rajesh Kumar, J. Nat. Fibers **19**, 475 (2022).

16. F. M. Al-Oqla and S. M. Sapuan, J. Clean. Prod. **66**, 347 (2014).

17. N. Saba, O. Y. Alothman, Z. Almutairi, M. Jawaid, and W. Ghori, J. Mater. Res. Technol. **8**, 3959 (2019).

18. B. A. Alshammari, N. Saba, M. D. Alotaibi, M. F. Alotibi, M. Jawaid, and O. Y. Alothman, Materials (Basel). **12**, (2019).