Experimental Investigation and Fabrication of Palmyra Palm Natural Fiber with Tamarind seed powder Reinforced Composite

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Abstract. The usages of composite materials in industries are become as a growing trend due to their inherent material properties such as good strength, low thermal expansion and high strength-to-weight ratio. Among the many classifications of composite materials, natural fiber composites are generally preferred due to their unique characteristics such as bio-degradable property towards the environment. In this study, based on the above selection criteria, from Borassus Tree trunk, Palmyra palm fiber and tamarind powder is selected for the study to use the same for practical application. During this course of examination, tamarind seed powder along with the exact proportionate of Palmyra palm fiber (treated and untreated) has been taken as the reinforcement, similarly epoxy resin has been chosen as the matrix material. To thoroughly validate the physical strength of the individual combination, five set of specimens were fabricated (treated and untreated) as well as their physical strengths such as tensile, flexural, impact and moisture absorption tests were evaluated. Out of all the tests, treated fibers wer shown the better upsurge in tensile, flexural, impact and moisture tests as against the untreated fibers.

Keywords: Natural fiber, Borassus tree trunk, palmyra palm, tamarind powder, physical strength.

1. Introduction

In recent decade, there is a phenomenal growth in the area of exploring the natural fiber utilization in various fields and engineering sectors. Many of the researchers are vigorously trying out usage of various set of natural fibers and resins to manufacture the basic elements to the complicate and intricate parts in the view to replace the conventional metallic materials and synthetic fiber composites [1-3]. Main aim of this work is to effectively use the bio degradable characteristics of the natural fiber and their low cost property cum easy availability. Moreover many of the developing countries are continuously keep exporting their agricultural products to many of the global giants in order to increase their considerable foreign exchange value. During this course of action, precise and more explicit kind of technology needed to completely purify or to get the finished agricultural products. In
the pretext, agricultural firms often come across abundant amount of agricultural bio-degradable wastes, still researchers could not find the viable solution to dump the waste in eco friendly way [4-6]. In order to overcome such as issue as well as to effectively use those waste as the useful product, the concept of natural fiber reinforced composites are originated. In the line of the above, the plant fibers like banana, jute, sisal, pineapple, talipot, hemp, Palmyra are holding very important role in composite fabrication, since it is considered as the very good physical strength holding capability as compared with the other set of natural fibers [7-9]. However to get the final product, the matrix material plays the major role, it is completely gives the outer structure to the fiber as well as allows the better stress transformation across the axis of the composites. Besides that, various set of research still proceeded in this area, in order to find out the compatibility of the resin material with the different natural resins. As well as to increase the strength of the natural fiber reinforced composite material, the fibers are chopped with different length and their physical examination was done with different matrix material [10-12].

Some of the researchers have taken some further initiation in this particular area, in which adopted the natural fiber as one laminate and sandwiched with another natural fiber to get the better characteristics upon the hybrid testament towards use of the natural fibers. Further into that, synthetic fiber laminate is again sandwiched with the natural fiber to get the better mechanical aspects to meet out the current requirement of the engineering industries. Out of all, palm fibers are considered as the unique characteristics one, and it is widely used as the reinforcement in producing the natural fiber reinforced composite material. Because palm trees are highly yield edible oil crop in this world, and it is almost cultivated in nearly 45 countries in all over the world. It is mainly cultivated in Malaysia, Indonesia, Latin America and India, which sources as the main feed to the palm oil production industries. Additionally, it produces nearly, about to 55 tons of dry mater in the form of fibrous waste [13-15]. The empty fruit bunch is the main source of fibrous left and during the production of raw source for oil industries. Naturally it consists of 73% of fibers, along the way of extraction of palm oil, refinery industries are in the position to dispose nearly 1.1 tons of waste during the production of 1 ton of oil extraction. Though partially some quantity of the fibrous material is been used as the boiler fuel since it possess high cellulosic material, still scientists could not find the proper way to dispose the waste material other than dumping the same in the open yard, during this course of open dumping, it creates a lot of environmental issues [16]. To properly use this dumped material as the useful product the concept of palm fiber reinforced composite material has been evoked. Another very important bio degradable material which is extracted from the tamarindus indica seed powder. The tamarind tree is a very important tree as far as Indian customized traditional system and it is abundantly cultivated in India, statistical data says, its production in India is nearly crossed 3 lakh tons per year [17]. Further, the tamarind seed is containing nearly 30% testa and having 70% kernel, as well as the tamarind kernel powder is rich source of xyloglucan gum. By inculcating the environmental concern of both the, fibers abundance and low cost, the concept of fabrication of low cost natural fiber reinforced composite fabrication is initiated in this work. The various proportion of palm fiber and tamarind seed paste have been chosen as the reinforcement and particulate, epoxy resin is been used as the matrix material in this study. To validate the physical properties of the fabricated composite, tests like tensile, flexural, impact and moisture absorption tests are conducted and their results were compared with each other [18]

2. Materials and methods

2.1 Palm fiber extraction
Initially the fibers were extracted from palm leaf stalk, following which the skin of the stalk of the leaf were removed through the manual process as shown in the Fig.1.
After finishing the removal of stalk, the stalks were retted in water environment for nearly 20 days, simultaneously the contents were hammered gently to completely separate out the fibers from the stalk [19]. The extracted fiber materials were again washed, cleaned thoroughly with solvents, the corresponding process of fiber preparation was shown in the Fig.2.

Figure 1. Typical Natural fibres

Figure 2. Water retting process

2.2. *Pre-treatment of palm fibers*

Three different types of treatment methods were proposed in this study, based on their corresponding drying time, soaking time as such tabulated in the table 1.

| Specimen                                      | Matrix       | Soaking time (min) | Oven drying temperature (°C) |
|-----------------------------------------------|--------------|--------------------|------------------------------|
| Epoxy + Tamarind seed powder (ESC)            | Epoxy        | -                  | -                            |
| Untreated fiber + Tamarind seed powder (UTSC) | Epoxy        | -                  | -                            |
| Alkali treated fiber + Tamarind seed powder   | Epoxy        | 30                 | 70°C                         |
| (ATSC) (5% NaOH)                              |              |                    |                              |
| Benzoyl chloride treated fiber + Tamarind     | Epoxy        | 15                 | 70°C                         |
| seed powder (BTSC)                            |              |                    |                              |
| Permanganate + Tamarind seed powder (PTSC)    | Epoxy        | 3                  | 70°C                         |
|                                               |              | (0.02% KMnO4/acetone) |                              |

During the processing of fibers, the fibers were soaked in the respective chemical and cleaned with ethanol and thoroughly washed with running water to completely keep away the solvents presence in the fibers, to confirm that, the fibers were kept in an oven by maintaining the temperature of 70°C.
2.3. Tamarind Seed
From the locally available tamarind trees, the raw seeds were collected initially. Following which, the testa or seed coat was removed from the kernel, to remove the seed coat, the seeds were kept in a hot air oven for the period of 45 min, during the time, the temperature of the roasting was maintained around 130°C. After the roasting was done, the seeds were hammered lightly to completely remove the over coat. With help of the flour mill, the tamarind seed was thoroughly made as the flour. Additionally the tamarind powder was mixed with the distilled water and the combination was boiled for the period of 3 hours by maintaining the temperature of 90°C, constant stirring was maintained throughout the boiling process in order to avoid the layer formation on the surface. At last, the final concentration of polysaccharide part which is present in the solution was extracted by drying up the entire dissolved powder [20-21].

2.4. Fabrication process
An electrically heated hot press compression molding technique was used to fabricate the composite instead of using common hand layup method, as it takes a long time to cure. Polymer matrix like Epoxy of grade LY556 is mixed with a proper hardener of grade HY906 at the proportion of 10:1. Compressive force was applied to distribute the resin throughout the fiber surface and to ensure even distribution, the plate is allowed to cure for 30 minutes by maintaining a curing temperature of 100°C. During the fabrication of the specimen, the combination of variation of fiber and epoxy (treated and untreated) resin was maintained as shown in the table 1 [22-23].

3. Characterization of the composites
3.1. Tensile test analysis
The tensile test was carried out as per the ASTM D 3039 standard by maintaining the cross head speed of 2 mm/min. Further to this, the Instron universal testing machine was used, besides that five specimens were tested from each formulation [24]. The size of the specimen was maintained as 300 X 30 X 3 mm. The sample test specimens were shown in the figure 3.

![Sample Tensile Test Specimen](image)

(a) Tensile test specimen without tamarind seed  
(b) Tensile test specimen with tamarind seed

**Figure 3.** Sample tensile Test Specimen

3.2. Flexural test analysis
The flexural test was carried out as per ASTM D790 standards, simultaneously to carry out further investigation on that, the cross head speed of 2 mm/min was maintained. Similarly from each combination five specimens were subjected for testing, the size of the specimen was 127 X 12.7 X 3 mm, similarly the total testing methodology was shown in the figure 4 [25].
3.3. Impact test analysis
The izod test was performed on the fabricated specimens as per the ASTM D256 standards. The size of the specimen was 64 X 13 X 3 mm [26].

3.4. Water absorption test
To carry out the water absorption test as per the ASTM D590, the specimen was shaped as 76.2 X 25.4 X 3 mm and their edges were completely sealed off with epoxy resin to ensure that, the water intrusion was happened on the edges, the specimen was initially dried in hot air oven for about 1 hour to completely dry out the moisture presence in the specimen, then the initial weight was done with an accuracy of 0.00001 mg. In addition to that, the weighed specimen was again immersed in the water for the period of 30, 60, 90, 120, 180 min respectively as shown in the figure 5, further the taken out specimen was wiped out from moisture and weighed precisely [27-29].

4. Result and discussion
4.1. Tensile properties
The tensile strength analysis of treated and untreated palm fiber reinforced tamarind seed powder composite were shown in the figure 6.
The ESC (Epoxy tamarind seed composite) specimen had shown the tensile stress value as 10 MPa, this value was quite less as compared with the other set of remaining set of specimens. Similarly the untreated palm fiber reinforced tamarind seed particulate powder composite showed the tensile stress value as 19.59 MPa. Likewise, untreated fiber reinforced composite (UTSC) showed the higher value as compared with the, without palm fiber reinforced epoxy composite. It shows that the palm fiber reinforcement plays the major and significant factor in increasing the strength of the specimen. Besides the alkali treated tamarind seed powder reinforced composite (ATSC) has shown the tensile strength value as 30 MPa, the obtained value was nearly 33% higher than the untreated composite. Whereas the benzoxy chloride treated tamarind seed powder fiber (BTSC) reinforced composite had shown the value as 26.54 MPa. It was interesting to note that, the benzoxy treated fiber showed less value as compared with the alkali treated fiber composite. However the permanganate treated fiber with tamarind seed powder (PTSC) composite had shown the tensile stress value as 31.15 MPa, it shows the slight higher value than the ATSC. It was observed from all the tests that, the treated palm fiber reinforced tamarind seed powder composite shown the higher value than the untreated fiber reinforced composite.

![Figure 7. Tensile modulus analysis of palm fiber reinforced (treated & untreated) tamarind seed composite](image)

As seen in the tensile stress analysis the tensile modulus value of the all specimens were shown the similar trend of tensile strength analysis. In the figure 7, it was seen that, the ESC had shown the modulus value as 599.54 MPa, it was very low value as compared with the other set of palm fiber reinforced composites. The UTSC had shown the value of 1201.12 MPa, the reinforcement had shown the higher value as compared with the unreinforced composite. Besides, the ATSC showed the modulus value as 1599.14 MPa, the treated fiber had made better bonding with the epoxy matrix and retain the strength across the composite material. The increase of the modulus value proved that, the interfacial strength between the fiber and matrix was good and in turn it yields higher strength in both tensile stress and modulus of the specimens. The BTSC had showed the modulus value as 1550.15 MPa, its value was lesser than the value of ATSC. Again the PTSC had showed the modulus value as 1798.51 MPa, the obtained value of PTSC was higher as compared with the remaining all set of composite specimens. The obtained higher strength evidences that, there was better interfacial adhesion between the fiber and tamarind seed powder and matrix component.

4.2. Flexural Properties
The figure 8 shows the flexural strength behavior of the palm fiber reinforced (treated and un treated) tamarind seed powder composite specimens.
Figure 8. Flexural stress analysis of palm fiber reinforced (treated & untreated) tamarind seed composite

The ESC specimens had showed the value of 19.72 MPa on flexural stress, since it was not incorporated with the fiber it showed the value of negative trend as compared with the remaining set of specimens. Whereas the UTSC specimens showed the flexural stress value as 49.97 MPa, the fiber reinforcement along with the tamarind seed powder incorporation had shown the tremendous increase in the flexural stress value. As such, ATSC specimens had shown the flexural stress value as 53.45 MPa, this value was nearly 2.67% higher than the UTSC value. The higher value towards the flexural strength shows that, the treated fiber have had better interfacial adhesion between the fiber surface and matrix. To have the proof for the same, the BTSC specimens had shown the flexural stress value as 79.87 MPa, this value was nearly 33% higher than the ATSC specimens. Whereas PTSC specimens showed the flexural value as 63.45 MPa, this was lesser than the obtained value of BTSC. The treated fibers with tamarind seed powder had shown the better interfacial adhesion between the fiber surface and matrix and thus the way yields higher flexural strength in all combinations.

Figure 9. Flexural modulus analysis of palm fiber reinforced (treated & untreated) tamarind seed composite

The flexural modulus value of the ESC specimen had shown modulus value as 0.375 GPa, whereas the UTSC flexural modulus value was 0.815 GPa. This value was nearly 50.3% higher than the unreinforced composite. It clearly shows that the reinforcement increases the flexural modulus value as significant way. Similarly the ATSC modulus value was 1.575 GPa, it was twice the time higher than the UTSC. It seems that, the treated fibers reinforced composite material shows the better modulus value as against the untreated composites. The BTSC specimens had showed the very higher value as compared with the other set of composites, the obtained value was nearly 1.799 GPa. But contrarily the PTSC modulus value was just 1.125 GPa, lower than the BTSC specimens.

4.3. Impact Test

The figure 10 shows the impact strength analysis of palm fiber reinforced (treated and untreated) with tamarind seed powder particulate composite.
Figure 10. Impact strength analysis of palm fiber reinforced (treated & untreated) tamarind seed composite

From the figure 10, it was observed that, the ESC specimens had shown the value of 0.325 J, this value was quite less than the other reinforcement. Because tamarind seed powder acts as the particulate with epoxy and yields lesser value than of other reinforcement. The UTSC specimens had shown the value of 0.485 J, it clearly evidences that the reinforcement increases the strength value to the triple the fold of the ESC. Besides, the ATSC specimens had shown the impact strength value as 0.625 J, it was almost 28% higher than the UTSC. It seems that, the treated fibers are showing better impact resistance against the untreated reinforcement composites. This is the good evident for the better interfacial strength between the fiber and matrix compound. The BTSC specimens had shown the quite higher value among all the specimens, the obtained value was nearly 0.695 J. As well as the PTSC specimens had shown the value of 0.525 J, this was lesser than the BTSC.

4.4. Moisture absorption analysis
The figure 11 shows the moisture absorption analysis of Palmyra reinforced (treated and untreated) tamarind seed powder reinforced composite specimens.

Figure 11. Moisture absorption behavior of Palmyra reinforced tamarind seed powder composites

From the figure 11, it was observed that, the UTSC specimens had shown the moisture absorption intake was nearly 2.2%, 3.1%, 3.8%, 4.1%, 5.01% for 30, 60, 90, 120, 180 minutes respectively. It seems that, the untreated reinforcement composite specimen had shown significant level of moisture absorption rate as compared with other set of treated composite specimen. However the ATSC
specimen had shown little amount of moisture absorption, it purely depends upon the level of immersing time of the specimen in the water. As much of immersion time increases, it keeps hike the moisture absorption level for all the specimens. This was again evidenced in the BTSC specimens; the level of moisture absorption of the BTSC specimen was quite less as compared with the ATSC. Nevertheless the treatment on the fibers adversely increases the better interfacial adhesion between the fiber surface and matrix and thus the way it reduces the moisture absorption level of the specimen.

5. Conclusion
The combinations of the palmyra fiber reinforced (treated and untreated) tamarind seed powder reinforced epoxy composite specimens had subjected with the various tests like tensile, flexural, impact and moisture absorption. The obtained results were drafted below.

- During the tensile, flexural and impact test analysis, it was observed that, the specimen with fiber treatment had shown the significant level of strength increase as compared against the untreated (33% to 67% - hike) specimens. This was the result of better interfacial adhesion between the fiber surface and matrix.
- Another important finding was that, during the treatment of fiber, the hydrophilic nature of the composite significantly reduces and thus the way it increases the lesser moisture absorption characteristics of the specimen.
- The tamarind seed powder acts as the particulate composite and simultaneously increases the strength of the composite in favorable way.

6. Reference
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