Study of mechanical and water absorption characteristics of natural fibre reinforced epoxy composites

Sodisetty V N B Prasad*, M R Rupesh Krishna2, Ashwin Ashok2, Abhishek Aryan2 and T H Gopi Krishna2

1Assistant Professor, Department of Mechanical Engineering, SRM Institute of Science and Technology, Kattankulathur, Chennai 603203, India
2 Student, Department of Mechanical Engineering, SRM Institute of Science and Technology, Kattankulathur, Chennai 603203, India

*Corresponding author: bhavaniprasad.478@gmail.com

Abstract. In the fast developing world, research is mainly focussed on development of renewable eco-friendly materials as an alternative to non-biodegradable and non-renewable materials which are resulting in environmental pollution. The fibres from the natural sources such as animal and plant based offers various advantages over synthetic fibres such as abundant in nature, economical, ease of handling and processing, comparable strength and minimum amount of waste dispose. In this work, three composites are fabricated using cyperus pangorei, sponge gourd, palm fibres and banana fibres as the main reinforcing materials and epoxy resin as the matrix in order to increase the effectiveness of the natural fibre. It is envisaged to fabricate and study the banana-sponge gourd fibre, banana-cyperus pangorei fibre, banana-palm leaf fibre as a reinforced material in polymer matrix composite. Hand layup process is used to fabricate the composite samples with different fibre volume fractions. The tensile, flexural, impact and water absorption testing have been performed on these natural fibre composites. Initial optimum length and weight percentage were determined. The results are obtained from the mechanical properties testing and compared among all the three combinations. Composite with Sponge gourd along with Banana as reinforcement with epoxy matrix has got the maximum tensile, flexural and impact strength. This composite has also got lower water absorption property.

1. Introduction

The applications of plastics in recent days are ranging from daily usage articles to complex mechanical components and structures. Plastics are being widely used because of their high strength to weight ratio, low maintenance, durability, low water absorption and high stiffness. Synthetic fibres such as nylon, aramid and glass are being used as reinforcement for plastics. Because of shortage and rise in price of petroleum and it’s by products, there exists a need for an alternative to synthetic fibres. So natural fibres serves this purpose, presently fibres extracted from plant and animal base are providing a good alternative to synthetic fibres.

Natural fibers have been used as reinforcement in composites in place of synthetic fibers because they are cheaper, bio-degradable and have no environmental pollution [1, 2]. Furthermore Natural fibres are a good substitute for synthetic fibres in the future. Natural fibres are widely used in applications ranging from aerospace, automobile and construction industry etc. These fibres are either extracted from plants or derived from animals. Plant based natural fibres such as jute, coir, banana, sisal,
etc., which are abundantly available in Indian subcontinent and can be exported to other countries too. These fibres are now being used for the production of yarns, ropes, and mats etc. Various gift articles like wall hangings, table mats and also handbags are being made by using these fibres. Fibres such as cotton, banana, and pineapple are also used to make cloth as well as in paper industry. The hydrophilic nature of these natural fibres results in absorption of moisture content. So these fibres have to be treated well before the fabrication or usage. Alkali treat treatment is the most commonly used treatment on natural fibres to remove the moisture content. Plant fibres consist of various natural substances along with cellulose. The most important one is lignin. The structure and morphology of plant fibres can be increased by their lignin content. Degree of polymerization is one of the main characteristic of plant fibre. Shell and wood floor are being used as fillers in polymers due to their exceptional properties such as less shrinkage during moulding and high creep resistance.

Sapuaam et al [3] have studied the application of natural fillers and fibres in composites like coconut coir, jute and palm, as the reinforcements in composites. Luo and Netravali [4] observed the tensile and flexural properties of the natural fibre based epoxy composites with different pineapple fibre volume fractions and compared with the epoxy resin. The use of natural fibres helps in reduction of weight and energy required for fabrication of composite. These natural fibres are also economical and lower the fabrication cost by around 5% in comparison with fibre glass-reinforced components. The properties of natural fibre reinforced composites are mainly influenced by amount of filler present and content of fibre. Kulkarni et al. [5] have studied the mechanical properties of banana fibre. Flavio et al. [6] observed that natural fibres such as sisal and jute fibres provide as alternative to conventional materials such as glass and carbon fibres because of their low cost and abundant in nature. George et al. [7] observed that the stability of the composite material compared to sisal fibre may be due to high fibre matrix interaction. Therefore, suitable parameters and processing techniques must be followed for better composite combinations. Natural fibers consist of cellulose, hemi cellulose and lignin. This cellulose covers by hemi cellulose and lignin. This is an amorphous structure. Due to this cellulose could not make direct links with matrix material. Cellulose forms strong links with glucose. This nature is called hydrophilic nature [8, 9]. This will results in a week interface between fiber and matrix. In order to solve this problem chemical pretreatment was suggested by many researchers. This chemical treatment reduces the hemicellulose and lignin content. It pays way for direct contact between cellulose and matrix. Rong et al. [10] studied the application of various chemical treatments (alkalization, acetylation) on sisal fiber epoxy composites and found that chemical treatment results in better improvement of adhesion between fiber and matrix. Applications of Banana fibres includes ropes, mats etc. Banana fibres are readily available in various parts of subcontinent. The processing of banana fibres is also easy; they can be easily extracted from banana stem. The physical and chemical composition of Banana fibre is shown in Table 1.

Applications of palm fibre includes roof for huts, mats and material to provide a covering. Cyperus pangorei fibre finds applications in broom materials, table mats and house hold decorates. Sponge gourd fibre is used as material for cleaning the body by rubbing against it. It can also be used to clean the dishes and utensils.

### Table 1. The physical and chemical composition of Banana fibre. [11]

| Moisture Content (wt %) | Ash Content (wt %) | Carbon Content (wt %) | Water Absorption (wt %) | Tensile Strength (MPa) | Lignin (wt %) | Cellulose (wt %) | Hemi cellulose (wt %) |
|------------------------|-------------------|----------------------|------------------------|----------------------|--------------|-----------------|---------------------|
| 85.6                   | 8.3               | 50.9                 | 40                     | 142.9                | 9            | 43.46           | 38.54               |
2. Methodology

The aim is to replace the use of the synthetic fibres by natural fibres to minimize the effect of the pollution caused due to the synthetic fibres. For this study, natural fibres such as banana, cyperus pangorei, palm and sponge gourd are used with their different combinations. The banana fibre is taken as the base fibre and rest all are used to form the composite with it. The binder used is epoxy resin (CIBA LY5561) mixed with hardener HY9511. The fabrication process is done using the hand-layup method, where the fibres in the form of sheets are put on each other with epoxy and hardener mixture in between forming the sandwich structure. Continuous pressure is applied onto the sheets to remove the extra binding material. The aim during the fabrication is to keep the amount of the fibre high and amount of epoxy is to be kept as low as possible. The same procedure is used to form the composites of the following combinations, such as banana + palm, banana + sponge gourd and banana + cyperus pangorei. After the fabrication is done, the composite is left to cure for two to three days by applying some continuous pressure on it. The composite sheet then obtained is removed and cut into different specimen according to ASTM Standard for testing.

First of all the sponge gourd fibre is treated with the NaOH solution to remove the moisture content. The fibre is then dried under the sun to remove the leftover moisture content. The fibres are then ready for the fabrication by hand-layup method. In this method, the corresponding fibres are arranged in a sandwiched pattern with epoxy resin and hardener in between the fibre sheets. The binder and the hardener are mixed in the ratio of 10:1. The fibre sheets are arranged in such a way that they are cross linked to each other. Each fibre sheet is kept up other after applying some epoxy resin on the previous fibre sheet. Three layers of such combinations are formed. The excessive epoxy resin is drained out using a roller. The final composite sheet is applied with some pressure and is left to cure for two to three days.

![Figure 1. Alkali treatment of Fibres and Hand Layup Method.](image)

The alkali treatment of fibres is done using 10% NaOH Solution which is shown in figure 1. The hand layup process for fabricating the composites is also shown in the above figure. The table 3 shows the width and thickness of the specimen used by comparing with three samples from each of the three combinations and taking average of the width and the thickness of three combinations of the fibres. The average width and thickness are considered for rule of mixtures for epoxy and fibres.

3. Mechanical and water Absorption testing

3.1 Tensile test

Hand cutter is used for machining the specimen to required dimensions. ASTM B790 standard is followed for tensile testing. Gauge length and the dimensions are followed according to the ASTMB 790 standard. The tensile test for all the three specimens are carried out by using Universal Testing
Machine (UTM). The test sample is placed in the UTM and tension is applied until the fracture of the specimen. Stress vs. Strain curve is plotted.

3.2 Flexural Test
ASTM B790 standard is used for flexural testing. The specimen dimensions are machined according to the standard. 3-point flexural testing was carried out on all the three specimens. This testing provides the bending strength of all three composite specimens. 3 samples are tested for each composite plate and average value of all three samples is considered for calculation of bending strength.

3.3 Impact Test (Charpy Impact Test)
Impact test determines the amount of energy absorbed by a material under sudden application of load during fracture. Charpy impact test was carried out on all the three specimens. The values of Impact energy ranged from 2 Joules to 6 Joules based on the specimen. ASTM E23 standard was followed for carrying out the impact test. The experimental setup for all the three tests is shown in figure 2.

![Figure 2. Mechanical Testing – Tensile, Flexural and Impact Testing.](image)

| Composite          | Specimen Number | Width of the specimen (mm) | Thickness of the specimen (mm) |
|--------------------|----------------|---------------------------|-------------------------------|
|                    |                | W1  | W2  | W3  | Wavg | T1  | T2  | T3  | Tavg |
| Banana+ Cyperus Pangorei | 1              | 12.60 | 12.74 | 12.71 | 12.68 | 5.69 | 5.97 | 6.12 | 6.01 |
|                    | 2              | 12.89 | 12.73 | 12.71 | 12.77 | 6.06 | 6.01 | 5.91 | 5.99 |
|                    | 3              | 12.53 | 12.62 | 12.68 | 12.61 | 6.15 | 6.14 | 6.10 | 6.13 |
| Banana + Sponge Gourd | 1              | 12.84 | 12.83 | 12.60 | 12.75 | 7.77 | 7.8  | 7.79 | 7.79 |
|                    | 2              | 11.97 | 12.60 | 12.54 | 12.37 | 7.10 | 7.58 | 7.91 | 7.53 |
|                    | 3              | 12.87 | 12.76 | 12.73 | 12.78 | 7.90 | 7.97 | 8.25 | 8.04 |
| Banana+ Palm       | 1              | 12.60 | 12.63 | 12.56 | 12.59 | 6.71 | 6.29 | 7.01 | 6.67 |
|                    | 2              | 12.60 | 12.76 | 12.58 | 12.64 | 7.3  | 7.7  | 7.1  | 7.36 |
|                    | 3              | 12.08 | 12.69 | 12.56 | 12.64 | 7.25 | 6.54 | 7.30 | 7.03 |
Table 3. Evaluation of Strength from Mechanical testing

| Composite                        | Tensile Strength (MPa) | Flexural Strength (MPa) | Impact Strength (Joules) |
|----------------------------------|------------------------|-------------------------|--------------------------|
| Banana + Cyperus Pangorei        | 12.134                 | 26                      | 3.3                      |
| Banana + Sponge Gourd            | 40.125                 | 68                      | 6.66                     |
| Banana + Palm                    | 5.135                  | 20                      | 2.33                     |

The Dimension of the fabricated specimens are shown in table 2. The test specimens for mechanical testing are shown in figure 3. The strength values from experimental testing are shown in table 3.

Figure 3. Test Specimens after Tensile, Flexural and Impact Testing

3.4 Water Absorption Test
The specimen is kept in the water for more than 24hrs and the following results are obtained and shown in table 4.

Table 4. Water absorption Test values

| Composite                        | Weight of Specimen before testing (gm) | Weight of the specimen after testing (gm) | Difference In Weight (gm) | Percentage Of Water Absorption (%) |
|----------------------------------|----------------------------------------|------------------------------------------|---------------------------|-----------------------------------|
| Banana + Cyperus Pangorei        | 12.5                                   | 14                                       | 1.5                       | 12                                |
| Banana + Sponge Gourd            | 17.5                                   | 18                                       | 0.5                       | 2.85                              |
| Banana + Palm                    | 9.5                                    | 11                                       | 1.2                       | 9                                 |

4. Conclusion
In this experimental study, the banana fibres are used as a reinforcing material in combination with sponge gourd fibre, palm fibre and cyperus pangorei fibre in epoxy matrix, the composites have been fabricated and mechanical testing such as tensile, flexural, impact and water absorption has been carried out on these composites. From the experimental results, the following conclusions have been drawn: All the three composites have gained an increase in their tensile strength by two fold. The maximum value of tensile strength is for banana-sponge gourd composite that is 40.125 MPa that is
increasing the tensile strength of banana by 13 times. Even the flexural rigidity of the banana fibre has been increased by 3 times that is 68MPa but in the case of banana-sponge gourd composite there is an increase by 9 times. The compressive strength has also got increased by 3 times the highest being 300MPa. Composite with Sponge gourd + Banana as reinforcement with epoxy matrix has got the maximum tensile flexural and impact strength. This combination can be compared with the synthetic fibres for various applications.

5. References

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