A Study on Tensile Properties of Bamboo Textile Reinforced Composites

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Abstract. A composite material is a material, which combines complementary nature and features of two or more constituents to result in a new material with unique and outstanding characteristics when compared with its original constituents. Conventional fibres such as glass and carbon can be replaced by environment-friendly bamboo fibres having good mechanical properties. Also being fastest-growing plants in the world (growing at a rate of 3 cm per hour), bamboo is abundantly available. Better fibre-matrix interaction will result in good interfacial adhesion between fibre and matrix and thereby reduces voids in the composite. This paper describes the tensile properties of bamboo textile reinforced composites. In this study, two different types of bamboo textiles i.e. knitted and weaved are used. Hand layup technique was incorporated in the production of composites and after that, air-cooling is adopted. All the tensile testing specimens are prepared according to ASTM D3039. Variation of the tensile properties of composite with different layers of bamboo textile and age are studied. The number of layers varies from 1 to 10. Tensile properties of these two bidirectional bamboo textile reinforced composites are tested for 7 days and 28 days. Keeping, the fibre volume fraction constant, increasing the number of layers enhances the ultimate tensile strength. Further increase in the number of layers shows no considerable variation in its ultimate tensile strength. Modulus of elasticity and percentage elongation of bamboo textile reinforced composites are also investigated.

1. Introduction
Composite materials or composites are engineering materials made up of two or more constituent materials that remain distinct and separate on a macroscopic level while forming a single component. For the past few decades a significant increase in the demand for the materials that are stiffer and stronger, but lighter, have been observed especially in the field of energy, aerospace and civil infrastructure [2]. As a result, manufacturers started producing composite materials that exactly fit the required properties for a particular purpose by selecting an appropriate combination of reinforcement and matrix material. Composite material systems offer great advantages of flexible design and results in a performance that are unreachable by individual constituents. For the past several years, natural fibres have been commonly used as reinforcement material across the world [3]. More recently, it is introduced in combination with plastics. Several types of natural fibres have been employed for use in plastics which include hemp, flax, straw, jute, wood fibre, barley, wheat, rye, oats, cane (sugar and bamboo), ramie, grass reeds, coir, sisal, rice husks, pineapple leaf fibre, pennywort, banana fibre, papyrus etc. [4]. For the last few years, there has been a heightened interest in natural fibre as a replacement for conventional FRP materials such as carbon and glass fibres. The advantages of using sustainable natural fibre or textile are weight saving, lower raw material cost, thermal recycling etc. Among the various natural fibres, bamboo fibre reinforced polymer composites, coir fibre reinforced polymer composites...
and silk fibre-reinforced composites are of great interest, as these composites have high impact strength besides having moderate flexural and tensile properties. However, currently, several advanced fibre treatments have been developed which improve their tensile properties considerably [1]. There are many works carried out in composites using natural and conventional fibre reinforced polymer composites. Not much works have been carried out using textile reinforced polymer composites.

2. Experimental procedure

Experimental procedure includes the preparation of composite materials and testing the tensile properties of the composite specimen using Universal Testing Machine. Two types of bamboo textiles are collected which differ in their manufacturing process i.e. knitted and weaved bamboo textile. Knitting is the process in which yarn or thread is made into cloth and other crafts. It consists of loops or stitches of the material consecutively run together. Weaving is the process in which two types of threads or yarn are interlaced together to form a cloth or fabric. The two types of threads or yarns used are warp or weft thread, which is running in a different direction, in which warp threads are running in lengthwise and weft thread in crosswise or horizontal direction. Both knitted and weaved fibres are bidirectional. In the present work, a total of twelve specimens are prepared for each layer, out of which six specimens are prepared using weaved type fabric and the remaining six using knitted type fabric. Out of six specimens in each type, three specimens are used for finding 7-day ultimate tensile strength and remaining three for testing 28-day ultimate tensile strength. Number of layers in each type varies from 1 to 10. Altogether, 120 specimens are considered in the present study.

Composite consists of two parts, which are reinforcement and matrix. Bamboo textile is used as reinforcement and corn-starch based polyvinyl epoxy is used as matrix. For epoxy, EPOFINE-230 and for hardener, FINEHARD-950 are used. The property of epoxy and hardener is shown in table 1. Acetone is introduced in the epoxy to reduce the viscosity of the matrix system. Being a natural fibre it absorbs more amount of matrix as compared to other fibres, therefore to reduce the viscosity of the matrix, 5% of the volume of matrix acetone has been used. It mainly allows the matrix to ease the flow over the fabric. It should be kept in mind that the acetone amount must not be applied more than 10% of the matrix volume as it affects the strength of composite badly. The property of acetone is shown in table 2. The experiment consists of casting the composite and finding its tensile properties by conducting tension test using Universal Testing Machine.

| Characteristics       | Finehard 951 | Epofine 230 | Test method | Unit   |
|-----------------------|--------------|-------------|-------------|--------|
| Viscosity at 25°C     | 1200 – 1900  | <20         | ASTM – D 445| mPa s  |
| Epoxy Content         | 4.00 – 4.50  | -           | ISO – 3001  | Eq/kg  |
| Density at 25°C       | 1.12 – 1.16  | 0.97 – 0.99 | ASTM – D 4052| g/cc   |
| Flash Point           | 190 – 200    | 110 – 120   | ASTM – D 93 | °C     |
| Storage life          | 3            | 1           |             | years  |

The advantages that make hardener and epoxy ideal for industrial use are (i) simple mixing ratio (Resin: Hardener = 100: 10 by weight), (ii) tolerant mixing ratio (2%), (iii) low viscosity resin/hardener mix, (iv) proper flow into the mould, (v) very good water resistance, (vi) excellent chemical resistance and (vii) electrical insulation.

| Property       | Value          | Standard      |
|----------------|----------------|---------------|
| Colour         | Colourless     | HSDB 1992     |
| Physical state | Liquid         | HSDB 1992     |
| Melting point  | -95.35°C       | HSDB 1992     |
| Boiling point  | 56.2°C @ 1 atm | HSDB 1992     |
| Density        | 0.78 g/ml      | HSDB 1992     |
Molecular weight 58.08

2.1. Fabrication of composite

The fabrication of composite is done by hand layup technique. The fibre volume fraction is fixed as 35%. It is found that many of the literatures are showing high value for the tensile strength, modulus of elasticity and percentage elongation at 35% fibre volume fraction. After the application of each layer of fibre, the roller has been applied to remove all the bubbles present inside the composite. Initially composite is kept in ambient temperature for 24 hours and further, it is cured in an oven for 6 hours @ 80°C and 2 hours @ 120°C. The specimens are prepared according to ASTM D7565M. Initially, composite sheets of size 30 cm × 10 cm are prepared. From each sheet three tensile specimens of size 27 cm×2.5 cm are cut according to ASTM D3039/D3039M. Figure 1 shows a sample coupon used for testing the tensile strength. The average thickness of each composite was found using Vernier callipers. Tensile load is applied to each specimen using a universal testing machine. Ultimate tensile strength, percentage elongation, modulus of elasticity, breaking load and stress-strain behaviour are found. Figure 2 shows one of the specimens after breaking.

![Figure 1. Tensile test specimen.](image1)

![Figure 2. Specimen after breaking.](image2)

3. Results and discussions

Ultimate tensile strength of Knitted Bamboo Textile Reinforced Polymer (KBTRP) composite and Weaved Bamboo Textile Reinforced Polymer (WBTRP) composite with one layer to ten layers are found at 7 days and 28 days and is shown in figure 3. For all layers from one to ten, WBTRP composites have higher ultimate tensile strength than KBTRP composite. Ultimate tensile strength of WBTRP increased to 200% on varying the number of layers from one to five. Further, increasing the number of layers from six to ten showed no considerable variation in its ultimate tensile strength. In the case of KBTRP, ultimate tensile strength increased by 190% on varying number of layers from one to five. Further, increasing the number of layers from six to ten showed no considerable variation. For WBTRP
It is noted that 28-day ultimate tensile strength is more than 7-day ultimate tensile strength by 3 to 4% and 2 to 3% respectively.

![Figure 3](image1.png)

**Figure 3.** Maximum tensile stress for different layers of weaved and knitted bamboo textile reinforced composites.

Increase in the thickness on increasing the number of layers is shown in figure 4. The thickness of composite for number of layers from one to four is found to be almost same for KBTRP composite and WBTRP composite. As the number of layers increases from four to ten it is observed that KBTRP composite has more thickness when compared to WBTRP composite. It is found that the thickness of composite goes on increasing and maximum thickness is observed for 10 layer knitted bamboo textile reinforced polymer composite. Ultimate tensile load carrying capacity of KBTRP composite and WBTRP composite is also found for number of layers from one to ten and is shown in figure 5. It is observed that the ultimate tensile load keeps on increasing as the number of layer increases.

![Figure 4](image2.png)

**Figure 4.** Thickness for different layers of weaved and knitted bamboo textile reinforced composites.
Figure 5. Loads for different layers of weaved and knitted bamboo textile reinforced composites.

From the results, it is found that the ultimate tensile strength of WBTRP composites is more than KBTRP composites. So, the stress-strain characteristics of WBTRP composites are shown for number of layers from one to ten at 28 days in figure 6. Modulus of elasticity and percentage elongation is found for each layer of WBTRP composite and is shown in Table 3. It is found that percentage elongation is maximum with 7 layers of WBTRP composite and it is 3.35%. From table 3 and figure 6 it can be concluded that WBTRP composite with 7 layers has more ductility. From figure 6 it is observed that the slope of the curve does not vary much as the number of layers change, i.e. modulus of elasticity has not much variation. Modulus of elasticity of WBTRP composite is found to be varying from 1.17 GPa to 1.92 GPa, and the maximum is obtained for WBTRP composite with five layers. It can also be observed that ultimate tensile strength is maximum for WBTRP composite with 5 layers which is having a higher modulus of elasticity. All the tensile specimens are found to break at an angle 90° with the specimen axis, hence it is a brittle failure.

Table 3. Modulus of elasticity and % elongation for different layers of weaved bamboo textile reinforced composites.

| Number of layers | Modulus of elasticity GPa | % elongation |
|------------------|---------------------------|--------------|
| 1                | 1.17                      | 1.10         |
| 2                | 1.37                      | 1.49         |
| 3                | 1.42                      | 2.18         |
| 4                | 1.75                      | 2.62         |
| 5                | 1.92                      | 2.87         |
| 6                | 1.81                      | 3.02         |
| 7                | 1.67                      | 3.35         |
| 8                | 1.62                      | 3.05         |
| 9                | 1.52                      | 2.65         |
| 10               | 1.48                      | 2.51         |
4. Conclusions
From the study, it can be concluded that the ultimate tensile strength for WBTRP composites is greater than KBTRP composites for all layers of the composite specimen. Ductility, as well as percentage elongation, is maximum for WBTRP composite with seven layers. Ultimate tensile strength and modulus of elasticity are maximum for WBTRP with five layers. Modulus of elasticity of WBTRP composite for different layers ranges from 1.17 GPa to 1.92 GPa. WBTRP composite with more than three layers has failure strain in the range 2.25 to 3 percentage.

5. References
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