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Evaluation of Mechanical Properties of Bamboo/Epoxy Modified with Nanoclay Composites

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***Abstract** - The present work is carried out on the effect of bamboo fibers at 30 weight percentage reinforced 70 weight percentage epoxy modified with nanoclay at a different weight percentage (0%, 2%, 4%, and 6%), and the composites are prepared by hand layup method in the compression molding machine. In this work, bamboo fiber is used as reinforcement which is treated with NaOH solution for enhancing the binding strength between fiber and matrix by removing lignin content. The main objective of this project is to compare the mechanical properties of nanomaterials with various weight percentages and without nanomaterials. The specimens are tested experimentally for mechanical properties such as tensile, flexural, impact, water absorption test, and shear strength. The results show that the mechanical properties of composites improved by increasing wt% of nanoclay. The maximum tensile, flexural strength of bamboo epoxy nanocomposites with 6 wt% nanoclay content. Shear strength is decreased by adding nanoclay with bamboo fiber nanocomposites. The highest value of impact strength and low water absorption was obtained for 2 wt% nanoclay content bamboo epoxy nanocomposites.*

Keywords — *Nanoclay, Bamboo Fiber, Compression Moulding, Epoxy.*

I. INTRODUCTION

In recent times, there is growing knowledge in research on the addition of nanofillers (inorganic part) into the polymer matrix (organic part) to improve the mechanical, thermal, and flammability properties. The inorganic nanofillers are the most important reinforcing agents to improve the performance of the polymers and composites. Montmorillonite (MMT) clay has been utilizing as one of the most impending nanofillers for the fabrication of nanocomposites due to the low cost, high aspect ratio, diameter in nanometer scale, better thermal stability, physicomechanical property, and tremendous flammability. With the integration of this, MMT clay has a high cation exchange/ swelling capacity, high surface area, high porosity, and superior surface properties [1].

At present, the researchers as well as industrialist both have taken awareness in the utilization of organically modified nanoclay in various fields due to their wonderful performance in enhancing the properties of the manufactured wares like flame retardancy, thermal expansion coefficient, superior dimensional stability, unfortunate water uptake, etc., with uncontaminated polymers [2].

The modifier such as ammonium salts has long alkyl chains for compatibilization of organoclay with hydrophobic polymer matrix. On the other hand, reactive and functionalized with monomeric units, radical (photo) polymerization and atom transfer radical polymerization initiating groups, and reactive epoxy groups to cure and reinforce epoxy resins. The functionalization of nanoclay is carried out to attain high properties of nanocomposites and advantage from the nanoclay [3].

Montmorillonite (MMT) is a subclass of clay smectite broadly used as reinforcement in polymer matrix because it has a high surface area with good reactivity while modified, so it is well-suited for polymer exfoliation and intercalation in the interlayer area. A modified form of MMT clay with a quaternary ammonium surfactant called "Cloisite." Cloisite is generally used as filler in the polymer matrix [3].

Cloisite 10A, 15A, 25A, 93A, and 30B are some of the commercially presented organo-nanoclay explored as nanofillers in polymer composites. Higher basal spacing enhances the degree of exfoliation, and the modifier related with the nanoclay provides better bonding and increases the interfacial strength of the composites resulting in better mechanical and thermal properties [4]

Cloisite 93A is a type of clay with the aim of using a methyl, dehydrogenated tallow ammonium modifier agent.

The increase of basal d-spacing Cloisite 93A was suitable for the good interaction between the polymer chain and the modified clay surface [3].

The major benefit of these nanofillers such as clay particles is that it offers such as low density, high fracture toughness, high stiffness, and high specific strength while comparing to its weight ratio. The reinforcement epoxies offer perfect properties toward manufacturing requirements at a lower cost [5].

Composites reinforced with natural fibers are hurriedly growing. For this reason, the large source, flexibility during processing, highly specific stiffness, and low cost make them striking to manufacturers. BF indicates that this natural plant fiber has the possibility to be used as reinforcement in composites and can be useful to biodegradable reinforcing materials. This research indicates that BF-reinforced eco-composites contain several advantages over traditional polymer and plastic, including improved mechanical properties and biodegradation. Compared with the other plant fiber-reinforced composites, it is reported that bamboo fiber reinforced epoxy resin composites prove better results in the Rockwell hardness test and impact test [6].

Amongst the variety of natural fibers, bamboo is superior candidates for use as natural fibers in composite materials due to its high strength and rapid growth rate. Bamboo fiber can also be in a pulped state in which the material is extremely fine and in a crushed form. Behind the fibers are obtain, dissimilar approaches can be chosen for their use in composite materials and as a stabilizer in biopolymers, such as powder/particle size, short fiber, and long fiber reinforcement [7].

II. METHODOLOGY

Materials Selection

(Bamboo Fiber, Epoxy Resin, and Nano Clays)

⇩

Chemical Treatment

(Alkali Method, 5%NaOH)

⇩

Nanocomposite Fabrication Method (Unidirectional)

(Hand Layup Process and Compression Molding)

⇩

Testing

(Fiber Testing)

(Tensile, Flexural, Impact Strength, Shear Strength, Water Absorption Test)

⇩

Results

A. Materials selection

Epoxy resin was used as a matrix material. The grade for epoxy resin is (LY 556) and the hardener (HY951). Standard bisphenol A (LY 556) with an epoxy equivalent weight (EEW) of 180–190 g/eq was used. HY951 (triethylenetetramine) is a two-component system that possesses low viscosity. This is used for curing at room temperature [1]. It was purchased from local resource Coimbatore. The bamboo fibers used as reinforced materials for this work were purchased from Chennai. Cloisite 93A is a type of clay that uses a methyl, dehydrogenated tallow ammonium modifier agent supplied from Ultrananotech Private Limited Bangalore

B. Chemical Treatment of Natural Fiber

Chemical treatment with sodium hydroxide (NaOH) removes moisture content from fibers, thereby increasing their strength. Also, the chemical treatment enhances the flexural rigidly of the fibers. The natural fibers are cleaned in clean running water and dried. A glass breaker is taken and 5% NaOH is added, and 80% of distilled water is added, and a solution is made. The **fibers** are soaked in the NaOH solution for 1 hour. After complete alkali treatment, fiber is washed with distilled water and dried in sunlight for 2 days.

C. Fabrication of Nano Composite

Mold is used for preparing the specimen, which is made up of EN90 steel and having dimensions of 300x300x5mm. First, the wax is applied to the mold, and then a mold releasing agent is applied on the surface used to facilitate easy removal of the laminates from the mold. The 0, 2, 4, and 6wt% of montmorillonite nanoclay concentrations are added with respect to the epoxy resin before adding epoxy resin, and the industrial-grade acetone is mixed with montmorillonite nanoclay using a mechanical stirrer for 10 minutes. And the epoxy resin is mixed with nanoclay acetone mixture solution by the mechanical stirrer at 70°C for 20minutes. During heating, acetone particles are vaporized, and the mixing process is continued till a homogeneous mixture was achieved using a mechanical ultra-sonicator. During the sonication process, the epoxy matrix and nanoparticles formed a homogeneous mixture and then allowed for cooling to room temperature. The enormous amount of air bubbles that developed during the sonication process are removed by using the vacuum evacuation process

[1]. The epoxy resin (LY 556) and nanoclay solution were mixed with hardener (HY 951) in the ratio of 10:1. The total weight of the composites plate is 300gms in that the matrix material is 70wt% and fiber is 30wt%. The bamboo fiber is placed over the mold at the required orientation manually, and the required amount of epoxy resin was poured over it. The process is continued until the required thickness, and volume percentage of fibers was obtained. The reinforce mixing is dining fully before the mixture is filled into the mold and presses in a hydraulic press under the load of 100 kg/cm2 at the temperature of 80 ºC for 1 hour for curing nanocomposites. After this sample is post-cured at room temperature for 1 hour of time according to the manufacture's guidance, table 1 shows the designation of composites.

Table 1. Designation of Composites

Materials	Specification
PC	Pure bamboo + epoxy
NC1	2 wt% nanoclay content bamboo + epoxy nanocomposite
NC2	4 wt% nanoclay content bamboo + epoxy nanocomposite
NC3	6 wt% nanoclay content bamboo + epoxy nanocomposite

D. Testing methods

a) Tensile Test

The tension test was performed on all three samples as per ASTM D3039 test standards. The tension test is mostly performed on flat specimens. A uniaxial load is applied through the ends. The ASTM standard test recommends that the length of the test section should be 250 mm specimens with fibers parallel to the loading direction should be 25 mm wide. According to ASTMD 3039, the tensile test specimen dimensions are 250mm X 25mm X 3mm. The test speed was maintained at 2mm/min, at a temperature of 22 0C and humidity 50%.

b) Flexural Test

Flexural strength was determined using universal testing machine equipment. The specimen is prepared as per ASTMD790, the test speed was maintained at 5mm/min, at a temperature of 22˚C and humidity 50%.In each case, three samples were taken, and the average value is reported. According to ASTM D 790, the flexural test specimen dimensions are 125mm X 25mm X 3mm.

c) Impact Test

The impact test specimens are prepared according to the required dimension following the ASTM D256 standard. During the testing process, the specimen must be loaded in the testing machine and allows the pendulum until it fractures or breaks.

d) Water Absorption Test.

For the water absorption test, the samples with dimensions 76.2 mm long by 25.4 mm wide by the thickness of the material were used. The specimens were placed in a container of distilled water at around 258C. After 24 h, the specimen was removed from the water one at a time, all surface water wiped off with a dry cloth, and water uptake was measured by electronic microbalance and then replaced in the water. The weighing was repeated at the end of 192, 528, 864, 1,200, 1,536, and 1,800 h. Water absorption test was performed according to ASTM D 570-98.

E. Results And Discussions

a) Tensile Test

The tensile test specimens of the required dimension were cut from the fabricated composites plate. The tensile test specimen was prepared according to the dimensions with the cross head speed of 2mm/min found in ASTM D3039. The specimen samples are tested in a computerized universal testing machine (UTM). All the test results were taken from the average test samples. The test results are plotted as shown in table 2. The specimen for tensile strength of nanocomposite is shown in fig 4. The effect of nanoclay on the tensile properties of bamboo epoxy composites is shown in fig 5. Improvement in the tensile properties was observed after the addition of montmorillonite nanoclay into bamboo epoxy composites, increases significantly and continuously with the addition of nanoclay, however peak value of tensile strength 190 Mpa, respectively, was obtained for 6 wt% nanoclay content bamboo epoxy composites. Further increase in nanoclay content decreases tensile strength of bamboo fiber reinforced epoxy composites due to agglomeration of nanoparticles. 6 wt% nanoclay increased tensile strength of BFRE composites by 60% as compared to pure BFRE composites.

Table 2 Tensile Properties of Nanocomposites

S.No	Materials	Tensile Strength(Mpa)	Tensile Modulus(Gpa)
1	PC	134	8.5
2	NC2	174	10.5
3	NC4	150	9
4	NC6	190	12

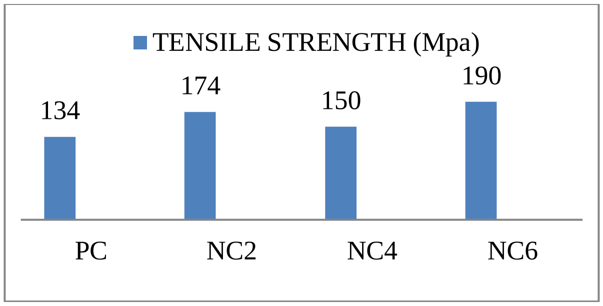

Fig 1 Tensile Strength for Bamboo Epoxy Composites

b) Flexural Test

A flexural test was done on the universal testing machine according to ASTM D 790 with a cross head speed of 10mm/min. The dimension of the specimens is 125x13x3mm. Three samples were taken for each composition, and results are averaged. The flexural strength of the composites is given in table 3. The effect of nanoclay on the tensile properties of bamboo epoxy composites is shown in fig 7. The Improvement in the flexural properties was observed after the addition of montmorillonite nanoclay into bamboo epoxy composites. Increases significantly and continuously with the addition of nanoclay. However, the peak value of flexural strength 225 Mpa, respectively, was obtained for 6 wt% nanoclay content bamboo epoxy composites. 6 wt% nanoclay increased flexural strength of BFRE composites by 60% as compared to pure BFRE composites.

Table 3 Flexural Properties of Nanocomposites

S.No	Materials	Flexural strength (Mpa)	Flexural modulus (Gpa)
1	PC	150	18
2	NC2	198	21
3	NC4	176	19.5
4	NC6	225	23

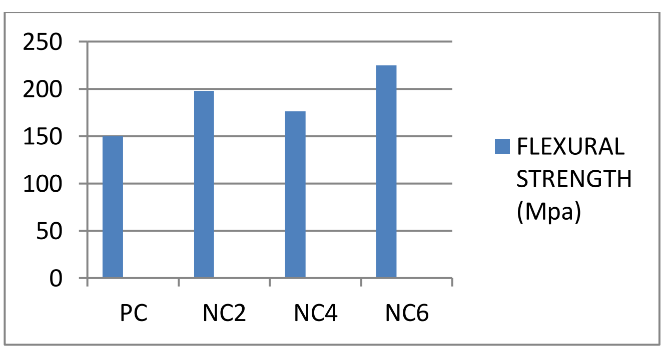

Fig 2 Flexural Strength for Bamboo Epoxy Composites

c) Impact Test

The impact test was carried out using an impact test machine with the specimen of ASTM D 256. The dimensions of the specimens are 65x13x3mm. Three samples were taken for each composition, and results are averaged. The measured values are given in table 4. The impact strength of bamboo epoxy nanocomposite is shown in fig 8 for different nanoclay content. The highest value of impact strength is 3.55 J was observed for 2wt% of nanoclay content bamboo epoxy nanocomposite and decreased to 2.75 J for 6wt% nanoclay composites. The impact strength of pure bamboo epoxy composites was 3.47 J. The impact strength of the pure bamboo epoxy composite is higher than 4 wt% and 6 wt% nanoclay content bamboo epoxy nanocomposites. Increases the nanoclay content decreases the impact strength of the nanocomposites.

Table 4 Impact Test Values

S.No	Materials	Impact strength (joules)
1	PC	3.47
2	NC2	3.55
3	NC4	3.05
4	NC6	2.75

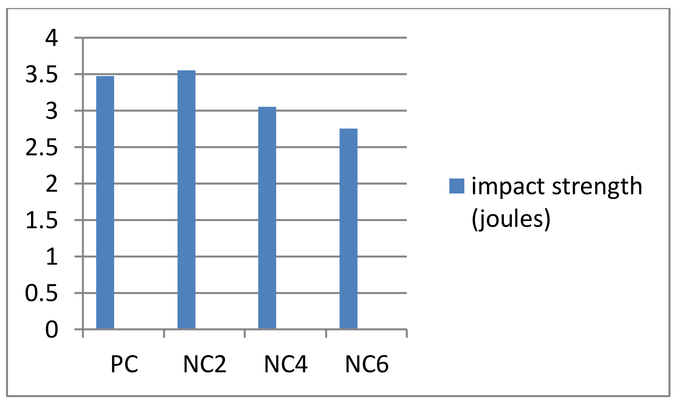

Fig 3 Impact Strength for Bamboo Epoxy Composites

d) Water Absorption Test

Water absorption is used to determine the amount of water absorbed under specified conditions. The typical percentage of water absorbed for bamboo epoxy composites containing 0 wt%, 2 wt%, 4 wt%, and 6 wt% nanoclay is shown in table 5. By looking at the graph, 4 wt% of bamboo epoxy nanoclay content absorbs more water % compared to other wt % nanocomposite. Low water absorption was obtained by 2 wt% of nanoclay filled bamboo epoxy nanocomposite as compared to pure composites.

Table 5 Water Absorption Test Values

S. No	Materials	Immersion time (hrs)	Weight of sample before immersion (gms)	Weight of sample after immersion (gms)	Percentage of weight gain (%)
1	PC	24	6	7.5	25
2	NC2	24	7	7.5	7.14
3	NC4	24	5.5	7	27.27
4	NC6	24	7.5	8.5	13.33

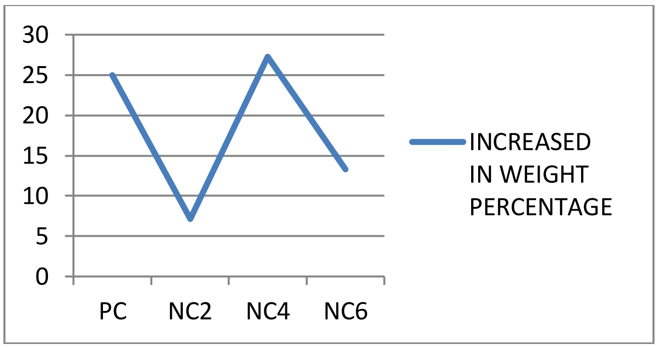

Fig 4 Water Absorption Test Values

III. CONCLUSION

The experiments were carried out the effect of bamboo epoxy with nanoclay content ranging from 0 to 6 wt % were fabricated and characterized. Dispersion of nanoclay results in increased tensile, flexural, impact, water-resistance, and shear strength properties of BFRE composites.

- Tensile strength and modulus of bamboo epoxy nanocomposites with 6 wt% nanoclay increased by 60% and 25%, respectively.
- Flexural strength and flexural modulus of bamboo epoxy nanocomposites with 6 wt% of nanoclay increased by 58% and 22%, respectively.
- The addition of nanoclay considerably increased the impact strength of BFRE nanocomposites. The highest value of impact strength was obtained for 2 wt% nanoclay content. Further increases in the nanoclay content decrease the strength of the composites.
- Low water absorption was obtained for 2 wt% of nanoclay content as compared to pure BFRE composites.
- The maximum shear strength was obtained at 0 wt% of nanoclay content. The shear strength is decreased by adding nanoclay content.

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