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An Investigation of Mechanical Properties of Honge Shell Fiber Reinforced Epoxy Composites

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***Abstract*— Natural fiber composites are considered to have potential use of reinforcing material in polymer matrix composites because of good strength, low cost, environmental friendly. In the present work mechanical and physical properties of the Honge Shell Fiber Particles (HSFP) reinforced polymer composites are investigated. The HSFP of 150-212 microns were used as reinforcement with epoxy L-12 polymer matrix. Composites were fabricated by hand layup technique as per ASTM standards with 10, 20, 30, 40 and 50% volume fraction variation in HSFP. The particles were chemically treated with 10% of NaOH to get better interfacial bonding between fiber and matrix. The samples were tested for mechanical and physical properties. The results of experiments show that the sample HE3 (30% HSFP) has maximum flexural strength of 40.72MPa and MOE of 3197MPa. Also, the sample HE3 has maximum tensile strength of 21.31 MPa, Young's modulus 1218.75 MPa and impact strength 72.70 kJ/m2. The water absorption for HE composites was 1.34-3.67% for 11 days and moisture content 0.55-0.98%. The results propose that the honge shell fiber reinforced polymer composite materials are indeed capable to serve as a potential cost effective, technically feasible substitute to the conventional wood based materials.**

***Keywords*— Natural fiber composites, Honge shell fiber particles, Epoxy, Mechanical properties.**

I. INTRODUCTION

The attraction in utilizing natural fiber, for example, distinctive wood fiber and plant fibers as reinforcement in plastics has expanded drastically throughout in last few years. Concerning the ecological viewpoints if natural fibers are utilized rather than glass fibers as fortification in some structural provisions it might be extremely intriguing. The purpose is also to present understanding of various aspects of natural fiber polymer composite material with special attention to their mechanical and physical properties of composites. Gopinath et al.[1] investigated the mechanical characterization of jute-epoxy and jute-polyester composites. The tensile strength of jute-epoxy and jute-polyester composites was found to be 12.46N/mm2 and 9.23N/mm2.

The 5% NaOH treated jute-fiber reinforced composites have higher tensile strength than 10% NaOH treated fiber reinforced epoxy composites by 18.67%. Sakthivel et al.[2] described about the NaOH treatment of natural fiber that removes impurities from fiber surface in the study on banana fiber sample treated with different concentrations to soften the fiber and made suitable for spinning.

P.Shashishakar et al.[3] investigated on banana-glass composites and observed that chemical treatment of NaOH to natural fibers increased flexural strength upto 20-30% and removes moisture content of fiber. Further, the tensile and flexural strength increased with increase in fiber volume fraction. Durowaye et al.[4] revealed that sisal particles improved the hardness property of polypropylene matrix composites. Weight fractions of reinforcement upto 25% was used for the study and found the maximum tensile strength of 6.96 MPa at 20 wt% of reinforcement. Wayansurata et al.[5] examined the mechanical properties of the rice husk fiber polymer composites. The composites were made by hand lay-up technique with variation in fiber weight fraction upto 50%. Results shows that alkalisation caused a better interfacial bonding between rice husks fiber and polyester matrix and yielded the improvement of the mechanical properties. The flexural strength was found 118.6 MPa and tensile strength 46.40 MPa at 50% fiber weight fractions. Dheenadhayal et al.[6] presented the experimental work on the sisal, sugarcane bagasse hybrid natural fiber reinforcement polymer composites for automobile applications. The sisal and sugarcane bagasse hybrid natural fiber reinforced polymer composite shows maximum tensile strength of 29.49N/mm2, 40% of sisal and bagasse hybrid composite absorbed 4.68% water. Girisha et al.[7] investigated the effect of moisture absorption of sisal, coconut spathe and ridge gourd reinforced epoxy composites at room and elevated temperature. It is found that higher fiber content samples have a greater diffusivity because of higher cellulose content. At elevated temperature there is 33% higher moisture absorption for 40% sisal-fiber reinforced composite.

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Srinivas et al.[8] reported that it is possible to enhance the properties of composites through fiber surface modification by NaOH chemical treatment. The mechanical properties of chemically treated areca fiber composites show better results compared to natural untreated fibers. Impact energy increased from 3 Joules (untreated) to 5 Joules (treated) and hardness number increased from 23HRB to 28HRB. Anilkumar et al.[9] presented the mechanical properties such as tensile, flexural, and compression strength of eucalyptus fiber reinforced composites. The results showed that higher tensile strength of 70.08 MPa, flexural strength 60 MPa and compression strength 182.05 MPa was observed for fiber loading of 25 wt.%. The micrographs showed that there is poor fiber-matrix adhesion and more fiber pull out in 10wt.% fiber content. Tewari et al.[10] developed bagasse glass fiber composite material with 15%, 20%, 25% and 30% of bagasse fiber and 5% glass fiber. The addition of fiber increased the modulus of elasticity of epoxy. Bagasse glass reinforced fiber improves the impact strength of epoxy material due to more elasticity of fiber in comparison to matrix material. In the present study, honge shell fibers which are waste material while extracting honge seeds for the preparation of biodiesel, was used as reinforcement in polymer matrix.

Honge trees are botanically known as Pongamia tree. India has the largest cultivation of honge trees. Other countries that grow honge trees are Malaysia, Bangladesh, Thailand, etc. These trees are very fast growing medium size plant with an average height of 30-40 feet and are an adaptable tree for tropical and subtropical regions. The elliptical shape pod consists of thick walled shells and single seed inside. Shells are 3-6 cm long and 2-3 cm wide and these are harvested from December to April in India. Honge seed weigh about 2- 3 g and shell weighs about 2 g. The yield potential per hectare is 900 to 9000 Kg. The objective of the present work is to prepare novel composite material from honge shell fiber particles with epoxy resin and to determine the mechanical and physical properties such as flexural strength, tensile strength, impact strength, hardness, moisture content and water absorption.

II. Materials And Methods

A. Materials

1) *Honge shell fiber particles:* Dry Honge shells were first washed with water to remove all impurities.

Washed shells were chemically treated with 10% of NaOH solution for 2 hours and then washed with distilled water [11, 12]. Subsequently, the shells were solar dried and ground. The fiber particles were sieved to get particles of 150 to 212 micron sizes. Figure 1 shows honge shells and honge shell fiber particles. Table1 shows chemical composition of Honge shell fibers tested in Essar laboratories, Hubli.

Figure 1: Honge shells and Honge shell fiber particles

2) *Epoxy resin:* Epoxy resins are a class of thermoset materials used extensively in structural and typical composite applications because of its unique combination of properties that are unattainable with other thermoset resins. Epoxy resins also chemically compatible with most substrates tend to wet surfaces easily, making them particularly well suited for polymer composite materials. Lapox L-12 having density 1.1-1.25g/cm^3 with K-6 hardener was used for the present work. The mixing ratio of resin and hardener is 100:10 [13, 24].

TABLE I:
CHEMICAL COMPOSITION OF HONGE SHELL FIBERS

Parameters	Content (%)
Cellulose	57.00
Hemicelluloses	6.70
Lignin	32.40
Moisture	7.21
Crude fiber	18.24
Total ash	6.50
Fat	1.62

B. Fabrication of Composite Materials

The composite boards are prepared by hand layup technique with the mould dimension 230×160 mm and 7mm thick. The composite boards are designated as Honge shell particles reinforced epoxy (HE) composites.

The fiber volume fractions varied from 10%, 30%, 30%, 40%, and 50%, and are designated as HE1, HE2, HE3, HE4, and HE5 respectively.

Appropriate amount of fiber particles and epoxy is taken in a beaker and stirred thoroughly at 60°C for 15 minute to get a homogeneous mixture.

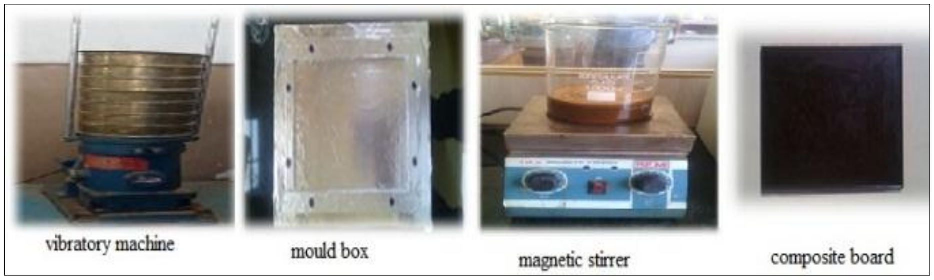

Figure 2: Process for fabrication of composite boards

After adding the hardener k-6, mixture was poured into a mould quickly. The setup was kept for 24hours for proper curing at room temperature. Figure 2 shows the process of fabrication.

III. EXPERIMENTAL DETAILS

A. Flexural test

Flexural test is carried out as per ASTM standard D790. Three point bending test with 0.25 mm/min strain rate was employed to find flexural properties. Four test specimens having dimensions 135x15x7mm were used for testing. The flexural strength was calculated using the following equation.

Flexural strength, MOR $=\frac{3PL}{2bh^2}$ MPa

Where, P -Applied force (N),
L -Support span (mm),
b - Width of specimen (mm)

In the three point bending test, flexural modulus was found by secant method where initial strain point is zero [14]. It is calculated using the equation,

Modulus of Elasticity, MOE $= \frac{mL^3}{4bh^3}$ MPa

m – Initial slope of the force-deflection curve

B. Tensile test

Tensile test was carried out as per ASTM standard D638 using the computerised tensile testing machine. The test determines the tensile properties of Honge shell fiber particles reinforced polymer composites. The cross head speed was maintained at 3mm/min at room temperature 38°C and humidity 30RH. In each case four samples were tested and average value was considered. Tensile strength and Young's modulus are calculated using the formula.

C. Impact test

The Izod impact test was performed according to ASTM D256 standard. The test method determines the Izod impact strength of Honge shell fiber particles reinforced epoxy composites. Five specimens for each sample having dimension of 63.5x12.7 mm and 7mm thick were used for the testing. The specimen has a V notch at centre at a depth of 2.5mm with 45° angle. Impact strength was calculated by:

Impact strength = $\frac{J}{A}$ KJ/m^2

Where, J- Energy absorbed (Joules), A- Area of cross section of specimen below the notch (m^2)

D. Hardness test

The hardness test was carries out as per ASTM standard D785. Specimen size 30×30mm and 7mm thick were used for testing. A steel ball indenter 3.175 mm diameter is used to find Rockwell hardness number. The hardness was measured on Rockwell hardness B-scale with major load 100kg and minor load 60kg [21, 22]. The average of four readings was taken as Rockwell hardness number of the composite specimen.

E. Moisture content test

The testing was carried out as per ASTM D6980 standard and test method covers the determination of moisture by means of loss in weight technology. The specimens were kept on the sample pan in a heating chamber that was heated and equilibrated to the temperature 103±2°C, until the mass is constant to ± 0.2 % between two successive weighing made at an interval of not less than one hour.

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The analysis was completed when the indicated weight loss falls below the specified test condition. Percentage of moisture content was calculated using the formula,

$$\% \text{ Moisture content} = \frac{m_i - m_f}{m_f} \times 100$$

Where, m_i- initial mass (gm) m_f - final mass (gm)

F. Water absorption test

The water absorption tests are performed as per the ASTM D570 standard, the specimen dimension was 75x50mm and 7mm thick. Most of the natural fibers absorb excessive moisture compared to synthetic fibers and results in decreased strength properties. The specimens were submerged horizontally under 25 mm fresh clean water maintained at a temperature of 27±2°C. The specimens were separated by 15 mm from each other and from the bottom and side of the container. After 2 hours, the specimens were taken out and suspended to drain for 10 minutes, so as to remove the excess surface water and then weighed. The specimen was then submerged again and the above weighing procedure was repeated after 24 hours. The specimens were immersed in water for a period of 11 days. The moisture absorption in the composite was measured by the weight gain of the material at regular intervals. The percent moisture absorption was expressed as the ratio of increase in mass of the specimen to the initial mass.

$$\% \text{ Moisture absorption} = \frac{m_f - m_i}{m_i} \times 100$$

IV. Results And Discussions

Figure 3 shows the effect of fiber loading on MOR and MOE of Honge shell fiber particles reinforced epoxy composites. From figure it was observed that flexural strength and modulus of elasticity increased up to 30 % volume fraction of fiber loading and decreased for further loading. The maximum MOR and MOE are 40.72 MPa and 3197 MPa respectively. The increase in flexural strength is due to high flexural stiffness of composite and improved adhesion between the matrix and fibers. The strength decreased with the increase in the fiber content beyond 30% due to insufficient wetting of fibers with resin. Similar results have been reported by several authors that the flexural strength decreased after 30 to 40% of fiber loading [15, 20]. Based on EN standard 312-2 and 312-3, 11.5 N/mm^2 and 1600 N/mm^2 are the minimum requirements for MOR and MOE of panels for general purpose and interior fitments, respectively. All the HE composites satisfy the MOR and MOE requirements as specified in EN standard.

The variation of the tensile strength and Young's modulus of the HE composite specimens at different fiber loading are shown in Figure 4(a) and (b) respectively. From the results of the experiments, it has been observed that HE composite specimens show increase in tensile strength and Young's modulus with an increase in fiber content upto 30%. However, on further loading of fibers, both tensile strength and Young's modulus are decreased. This could be due to the reason that during tensile loading partially separated micro spaces are created that obstructs stress propagation between the fiber and the matrix. For higher fiber loading the degree of obstruction increases that cause decrease in the properties of the composites. Further, inadequate wettability of the fibers due to higher fiber loading resulted in poor fiber-matrix adhesion and thus decreased tensile strength and Young's modulus. Similar observations were reported by Panneerdhass et al.[18], Cholachagudda et al.[19] and Garadimani et al.[20]. The maximum values of tensile strength and Young's modulus are 21.31 MPa and 1218.7 MPa at 30% of fiber reinforcement.

Figure 5 shows the impact test results of the HE composite specimens. The composite samples exhibit increase in impact strength upto 30 % of the fiber loading. This behaviour could be due to better fiber-matrix adhesion in composites. Impact strength decreased for increase in weight percentage of fiber content beyond 30%. This may be attributed to the weak interfacial interaction between the filler and matrix materials for higher fiber loading. Similar behaviour of composites was also observed by other researchers [16, 17]. The maximum impact strength of 72.7 kJ/m^2 was obtained for HE3 composite and minimum impact strength of 57.97 kJ/m^2 was obtained for HE1 composite at 10% fiber content.

Figure 6 shows variation of hardness of HE composites with fiber loading. From experimental results it was observed that composites with 30% fiber loading shows good hardness property compared to other composites. Maximum hardness value of 68HRB was found for HE3 composite at 30% fiber volume fraction. On further loading of fiber, hardness value decreased due to poor interfacial bonding between fiber and matrix [23].

From the moisture content test shown in Figure 7, it was observed that moisture content increases with increase in filler content ranging from 0.55 to 0.98%. Moisture content was increasing with increase in fiber volume fractions from 10 to 50%. Moisture content of honge shell fiber composite is minimum compared to other natural fiber composite materials such as groundnut shell particles reinforced polymer composites [17].

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The effect of fiber loading on water absorption of HSFP composites with increasing in number of days is shown in Figure 8. From the graph, it can be observed that the rate of water absorption increases with the increase in fiber loading. Generally, the rate of absorption is influenced by materials density and void content.

The water absorption rate increases with immersion time reaching a certain value at saturation point. Water absorption value ranges from 1.34% to 3.67% for 10 to 50% weight fraction of composite specimens. The water absorption of composite material is minimum compared to other natural fiber reinforced composite materials.

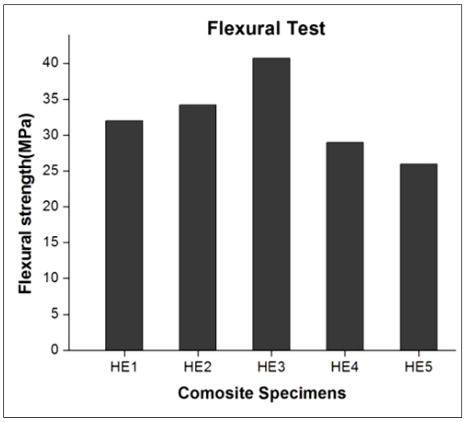

Figure 3(a) **: MOR of HE composites**

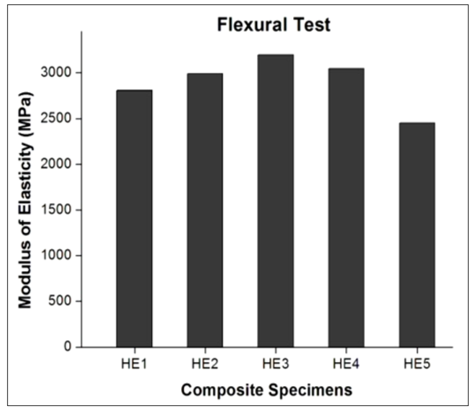

Figure 3(b) **: MOE of HE composites**

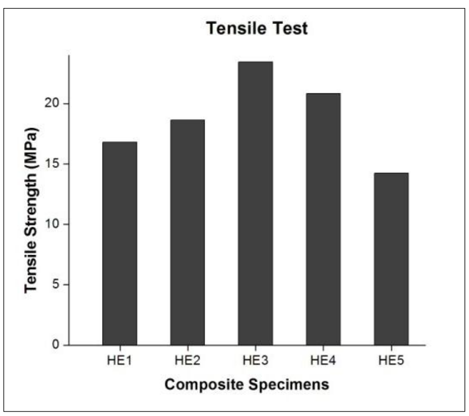

Figure 4(a)**: Tensile strength of HE composites**

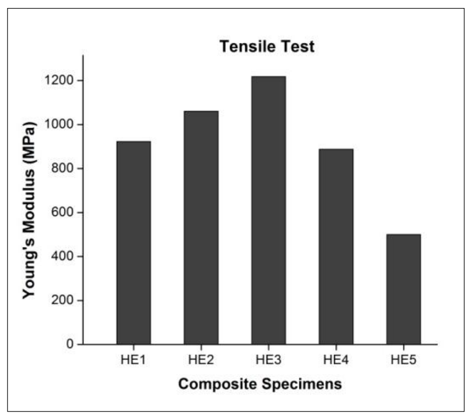

Figure 4(b)**: Young's modulus of HE composites**

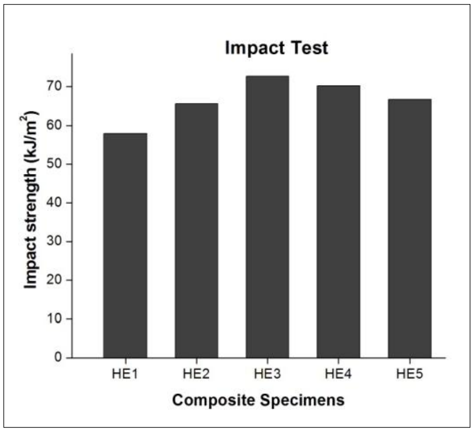

Figure 5: Impact strength of HE composites

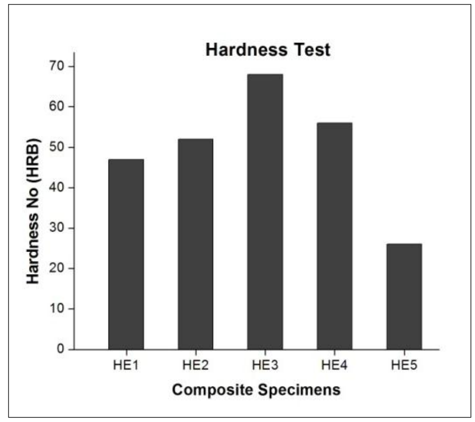

Figure 6: Hardness of HE composites

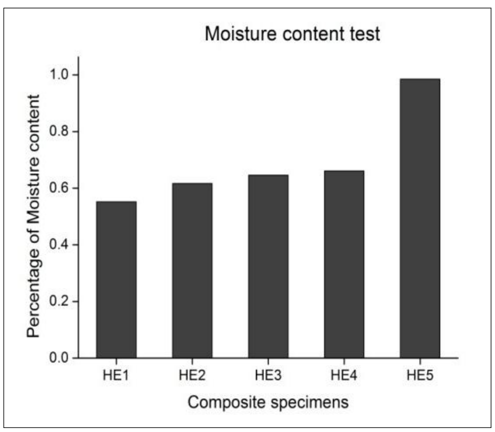

Figure 7: Moisture content of HE composites

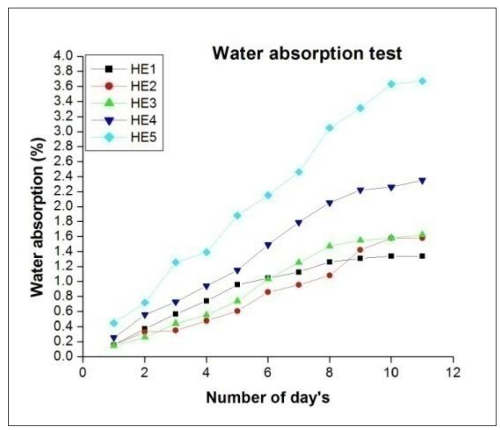

Figure 8: Water absorption of HE composites

TABLE II:
EXPERIMENTAL VALUES OF THE COMPOSITE SPECIMENS

Composite specimens	Flexural strength (MPa)	Modulus of elasticity (MPa)	Impact strength (kJ/m^2)	Tensile strength (MPa)	Young's modulus (MPa)	Hardness (HRB)
HE1	32.20	2809	57.97	16.81	923	47
HE2	34.22	2989	65.57	16.66	1061	52
HE3	40.72	3197	72.70	21.31	1218	68
HE4	28.99	3044	70.17	20.82	888	56
HE5	25.96	2455	66.66	14.25	500	26

V. CONCLUSIONS

The main purpose of the experimental investigation was to prepare the composite by utilizing waste natural fiber and to examine the feasibility of using with polymer for the preparation of composites.

The result shows that a useful composite with moderate strength could be successfully developed using Honge shell particles as reinforcement in epoxy matrix. These composites are found to have good mechanical and physical properties.

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In addition HE composites satisfy the minimum requirement of MOR and MOE as specified by EN standard for of panels of general purpose use. It was observed that HE composites have better strength properties for 30% fiber loading. The maximum flexural strength of 40.72MPa, tensile strength 21.31MPa, impact strength 72.7kJ/m^2, hardness of 68HRB was obtained for 30% fiber volume fractions. Also, this composite has only 0.55-0.98% moisture content and up to 3.67% of water absorption for 11 days. Therefore, HE composites could be considered as an alternative to wood material in the manufacture of particleboard used in indoor environment due to moderate mechanical properties and very low water absorption. This would be a promising material for structural, packaging, and other general applications.

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