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Evaluation of Tensile and Flexural Properties of Coconut Coir and Coconut Shell Powder Reinforced Epoxy Composites

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***Abstract* — The prime objective of this research is to investigate the potentiality of coconut coir and coconut shell powder as reinforcements in preparation of polymer composites as an ecological alternative to glass, carbon and other man-made fibers. In the present work the mechanical properties namely tensile and flexural properties are evaluated by preparing composites using coconut coir fiber and coconut shell powder by mixing with polymer. In tensile test the composite made from HCL treated coconut coir and untreated coconut shell powder exhibits more strength as compared untreated composite. In flexural test the composite made from HCL treated coconut shell powder and untreated coconut coir exhibits more strength as compared to untreated composite. Hence the result obtained from the tests concludes that the HCL treatment enhances the mechanical properties as compared to untreated composites.**

Keywords— Natural Fiber/Filler, Treatment, Polymer Composites, Mechanical Properties.

1. INTRODUCTION

Natural fibers may play an important role in developing biodegradable composites to resolve the current ecological and environmental problems. Composites made of natural fibers offer the opportunity for extensive applications in fields such as consumer goods, low cost housing and civil structures, and for many other common applications where the prohibitive cost of reinforcements at present restricts the use of conventional lightweight reinforced plastics [5]. The natural fiber composites have a potential to replace in many applications like automobile and aircraft industry. The artificial fibers posses twice the weight of natural fibers and more cost, cause damage to human beings and energy for extraction is more compared to natural fibers [11].

Common fiber reinforced composites are composed of fibers and a matrix. Fibers are the reinforcement and the main source of strength while matrix glues all the fibers together in shape and transfers stresses between the reinforcing fibers. The fibers carry the loads along their longitudinal directions. Sometimes, filler might be added to smooth the manufacturing process, impact special properties to the composites, and / or reduce the product cost [12]. Natural-fiber reinforced composites offer a good mechanical performance and eco friendliness. The application of natural-fiber-based composites is increasing rapidly. This is especially related to certain problems concerning the use of synthetic fiber reinforced composites. As far as synthetic polymer composites are concerned, waste disposal and recycling are major issues worldwide [10].

Natural fibers like jute, hemp, sisal, banana, coconut (coir) and bamboo in their natural form as well as several waste cellulosic products such as shell flour, wood flour and pulp have been used to reinforce different thermosetting and thermoplastic composites [14]. Each fiber has a complex, layered structure consisting of a thin primary wall which is the first layer deposited during cell growth encircling a secondary wall. The secondary wall is made up of three layers and the thick middle layer determines the mechanical properties of the fiber [22]. Some of the advantages wood fibers bring to cement fiber composites are availability, high tensile strength, relatively high modulus of elasticity and the well-developed technology to easily extract the fibers from wood for use in the composites [3].

The general advantages of coconut fibers include moth-proof; resistant to fungi and rot, provide excellent insulation against temperature and sound, flame-retardant, unaffected by moisture and dampness, tough and durable, resilient, spring back to shape even after constant use. Coconut fiber is the toughest fibre (21.5 MPa) amongst natural fibers [13]. Balarami Reddy T studied the effect of fiber length and fiber volume fraction on mechanical behavior of green coconut fiber reinforced HDPE based composites. This work shows that the Mechanical properties viz., Tensile strength of the green coconut fiber reinforced HDPE composite material is greatly influenced by fiber length as well as fiber volume fraction [15].

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Natural filler like a coconut shell powder is made from the most versatile part of the coconut shell and it is organic in nature also. The incorporation of coconut shell powder as a matrix material into thermoset resin is reduced the production cost of the molded product [16]. The overall cost can be reduced either by finding a less expensive processing method or by blending the polymer with low cost filler materials. In order to improve the mechanical, physical and other properties, or to tailor a composite for specific use or to facilitate processing and reducing the cost, natural fibers has been used as reinforcing or filler materials [6].

In this study the investigation was carried out on the evaluation of tensile and flexural strength of coconut coir and coconut shell powder with a view to explore the suitability in processing and producing composites and also to explore the potential of coconut coir and coconut shell powder as possible reinforcements for epoxy and as a substitute for synthetic fibers in preparation of polymer composites.

Chemical treatments are considered in modifying the fiber surface properties because it can enhance the bond strength between fiber and matrix, due to differential hydroxyl group and also can reduce water absorption of the natural fiber [26]. Generally, the adhesion at the interface can be described by the following main interactions: physical adhesion related to surface energies of the fiber and the matrix, chemical bonding and thirdly mechanical interlocking created on rough fiber surfaces. Good interfacial adhesion initially requires a good wetting between the fiber and the matrix [17]. Treatment of natural filler is beneficial in order to improve the water resistance of fillers, enhance the wettability of natural filler surface by polymers and promote interfacial adhesion [18].

2. MATERIALS AND EXPERIMENTATION

2.1 Coconut coir

Coconut (Cocos nucifera), a member of the palm family, grows broadly in tropical and sub-tropical regions and is employed for a range of applications including decoration, culinary, and non-culinary uses [24]. Coconut Coir is a ligno-cellulosic natural fiber. It is a seed-hair fiber obtained from the outer shell, or husk, of the coconut, the fruit of Cocos-nucifera. The coir fiber is relatively waterproof and is the only natural fiber resistant to damage by salt water [25].

Sri Lanka and India are considered to be the major coir fiber producers in the world. Coir fiber may be used as the reinforcement material in the composite production. Coir fibres may be decomposed in 20–30 years in the nature, it may be regarded as an environmentally friendly material. To develop its industrial employ, thorough understanding of the coir fiber is necessary [19].

The coir was extracted from coconut fruit by manual separation of the nut from the husk, and then these fibers are cut in to short fibers of about (6-8mm) for the preparation of composites. The density of coir is found to be 1.2 g/cm^3.

Fig. 1 Coir fiber

Fig. 2 Chopped coir

2.2 Coconut shell powder

Coconut shell is non-food part of coconut, which is hard lignocellulosic agro-waste. Coconut shell is 15–20% of coconut. The coconut husk, or mesocarp, is composed of fibers called coir. The inner stone or endocarp is the hardest part of the nut called shell [9]. The coconut particles have remarkable interest in the automotive industry owing to its hard-wearing quality and high hardness (not fragile like glass fiber), good acoustic resistance, moth-proof, not toxic, resistant to microbial and fungi degradation, and not easily combustible [23]. Natural lignocellulosics such as coconut shell powder (cocosnucifera) has outstanding potentials as reinforcement in plastic. Coconut Shell is important filler for the development of new composites as a result of its inherent properties such as high strength and high modulus [21].

The collected coconut shells are cleaned thoroughly so as to remove the fibers and husk which is present on its surface. Cleaned shells were then dried in Sun light for duration of about one week so as to remove the oily content. Afterwards dried shells were broken into small pieces. It is then converted in to fine powder by using manual pounding technique. The so formed powder with random grain size is divided into 104 to 211 μm size with the use of respective sized sieves. The density of coconut shell is found to be 1.60g/cm^3.

Fig. 3 Coconut shell powder

2.3 Epoxy resin

Epoxy resins are a class of thermoset materials used extensively in structural and specialty composite applications because they offer a unique combination of properties that are unattainable with other thermoset resins. Epoxy resins are also chemically compatible with most substrates and tend to wet surfaces easily, making them especially well suited to composites applications [1]. Applications for epoxy resins are extensive: adhesives, bonding, construction materials (flooring, paving, and aggregates), composites, laminates, coatings, molding, and textile finishing. They have recently found uses in the air- and spacecraft industries [20]. Lapox L–12 and K–6 hardener manufactured by Atul Ltd. is purchased from Yuje Marketing, Bangalore, India, is used in the present work. The density of epoxy is found to be 1.25g/cm3. The hardener is used to act as curing agent. The weight percentage of hardener used in the present work is in the ratio of 10:1.

3. CHEMICAL TREATMENT OF COIR AND COCONUT SHELL POWDER

Chemical treatment of coir and coconut shell powder will usually remove the moisture content thereby increasing its strength and also enhances the mechanical properties. This treatment clears all the impurities and also stabilizes the molecular orientation. In view of this, the coir and coconut shell powder used in the preparation of the composite is pretreated with acidic solution. Based on the literature, the coir and coconut shell powder is treated with acidic solution of Hydrochloric acid (HCL 0.1N). The treatment is done for time duration of 3 hours. After chemical treatment the coir and coconut shell powder was washed thoroughly with deionized water to remove the residues of the chemical content in it. Then the washed coir and coconut shell powder is dried at room temperature.

4. SPECIMEN PREPARATION

Moulds were prepared for the fabrication of specimens as per the requirements of the tests to be conducted. The inner surface of the moulds was initially coated with a releasing agent to prevent the sticking of composites to the mould wall. From calculations the weight fractions of coir, coconut shell, and epoxy are obtained, and weighed. Coconut shell powder, coir in chopped form were mixed with epoxy and hardener in a container and stirred well for 5 – 7 minutes. The prepared mixture is then poured in to the moulds. The samples so prepared after pouring are kept for drying for duration of 48 hours at room temperature. After drying the samples were carefully taken out from the moulds. Finally the specimens were cut in accordance with ASTM standards and Specimens are prepared as per requirements.

5. MECHANICAL TESTS

After specimen preparation the specimens are subjected to mechanical tests such as tensile and flexural tests according to ASTM standards by using Universal Testing Machine. The tensile test specimen is prepared according to ASTM D3039 standard and the flexural test specimen is prepared according to the ASTM D790 standard. To obtain a better result for each condition, three specimens were tested to evaluate the mechanical properties.

6. RESULTS AND DISCUSSIONS

6.1 Tensile Strength of Composites

The Fig.4 shows the comparison of tensile strength of UN – treated and treated composites of three different combinations. From fig. it is observed that the composites containing HCL-treated fiber and un-treated filler shows more load as compared to untreated composites. This may be due to HCL-treatment of fiber and filler.

The chemical treatment improves fiber, filler-matrix adhesion largely by introducing polar or excited groups or even a new polymer layer that can form strong covalent bonds between the fiber and the matrix, and sometimes by roughening the surface of fibers to increase mechanical interlocks between the fiber and the matrix [2].

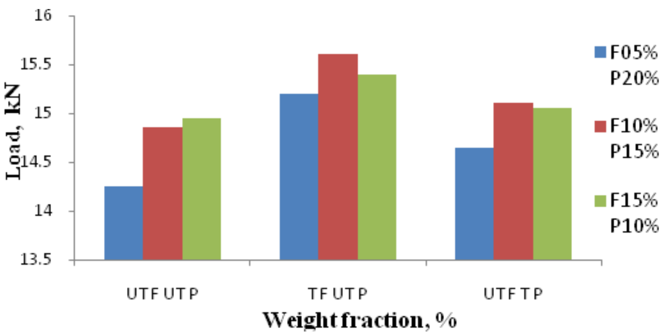

Fig. 4 Comparison of tensile strength of Un– treated and HCL treated composites

All the three proportions of HCL - treated fiber composites shows maximum load than all other combination composites, and in the next position are HCL-treated filler composites. In both HCL-treated filler and HCL-treated fiber composites the composites with F-10% P-15% shows maximum load. However, the further addition of the coir fiber beyond 10%decreased the tensile strength of the samples.

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This may be due to decrease in the amount of the bonding between the coir fibers as a result of decreasing polymer content. The improvement in the tensile strength of the samples is a function of increasing the coir fiber content up to 10% was mainly attributed to the increased stress transfer from polymer matrix to the coir fiber [7].

6.2 Flexural Strength of Composites

The Fig.5 shows the comparison of flexural strength of UN – treated and treated composites of three different combinations. From above figure it is observed that there is no much difference in flexural strength by varying the percentage of fiber and filler in both un-treated composites and in HCL- treated fiber and untreated filler composites. But the HCL-treated filler and un-treated fiber composites are better than both untreated fiber and filler composites, as those have higher loads. This indicates that the chemical treatment has positive effect on flexural strength of composites as the chemical treatment improves fiber, filler-matrix adhesion.

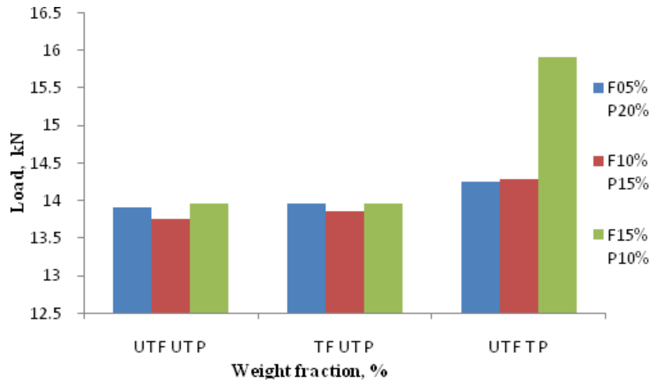

Fig. 5 Comparison of flexural strength of Un–treated and HCL treated composites

Out of all composites the F15% P10% HCL treated filler composite shows maximum load. This increase in flexural strength indicates complete matrix fusion which facilitated fiber impregnation, formation of strong fiber/matrix interfacial bonding and superior matrix to fiber stress transfer efficiency [8]. The composites containing P20% and P15% shows fewer loads. It may be due to high filler content present in the composites. The strains decrease with the increase in the filler contents due to the fact that the materials have become harder with the increase in filler contents [4].

7. CONCLUSIONS

The tensile and flexural properties of coconut coir and coconut shell powder reinforced epoxy composites have been studied and discussed here, and from this investigation the following conclusions can be drawn.

- The tensile and flexural properties are affected by the chemical treatment of fiber and filler. The chemically treated composites show more tensile and flexural strength than un-treated composites.
- In tensile testing the chemically treated fiber contained all the three combinations of composites exhibits more load bearing capacity and the maximum is for the composite F-10% P-15% which shows 15.6 kN. Whereas in the un-treated composites the maximum load is of 14.95 kN.
- In flexural testing the chemically treated filler contained all the three combination composites show maximum load bearing capacity and maximum is for composite F-15% P-10% which shows 15.9 kN. Whereas in the un-treated composites the maximum load is of 13.95 kN.

Abbreviations

F	Fiber (Coconut Coir)
P	Filler Particle (Coconut Shell Powder)
UT F	Untreated Fiber
UT P	Untreated Filler Particle
T F	HCL Treated Fiber
T P	HCL Treated Filler Particle
HCL	Hydro Chloric Acid
HDPE	High-Density Polyethylene

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