

Tensile and Flexural Strengths of Coconut Shell Particle & Coir Fibre Reinforced Composite

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Abstract

This paper presents the tensile and flexural strengths of coconut shell particle and coir fibre reinforced wood composite. The composites material were fabricated by reinforcing coconut shell particle (size between 200-800µm) by 17- 28 wt% and coir fibre (2-5mm) by 2-3 wt% into epoxy matrix using open mould casting method. Microscopic investigations were done for estimating properties. Experimental results showed that ultimate strength, modulus of elasticity, % elongation decreases with wt% of shell particle. Ultimate strength and % elongation increases but modulus of elasticity decreases with the increase of coir wt%. Modulus of elasticity decreases with the reinforcement of shell particle and coir both. Flexural strength decreases with addition of coir fibre. The coconut shell particles and coir fibers are good reinforcing of 30 wt% materials to reduce the consumption of resin as well as utilizing waste natural material with maintaining the properties required for structural applications. The open mould casting method used has been proved to be easy way of composite material preparation.

Keywords: Bio materials, Composites, Mechanical Properties, Thermosets.

1. Introduction

Composites consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase is usually harder and stronger than the continuous phase and is called the 'reinforcement' or 'reinforcing material', whereas the continuous phase is termed as the 'matrix'. Properties of composites are strongly dependent on the properties of their constituent materials, their distribution and the interaction among them. The geometry of the reinforcement (shape, size and size distribution) influences the properties of the composite to a great extent.

Natural fillers and fibers reinforced thermoplastic composite have successfully proven their high qualities in various fields of technical application. As replacements for conventional synthetic fibers like aramid and glass fibers are increasingly used for reinforcement in the thermoplastic due to their low density, good thermal insulation and mechanical properties, reduced tool wear, unlimited availability, low price, and problem free disposal. Wood fibers/particles provide a sufficient reinforcement at much lower cost than synthetic and mineral filled thermoplastic. When the synthetic and mineral fibers are used, machine wears and damages of processing equipment is much higher than with wood filler. Fiber damage during processing is greatly reduced when wood is utilized, which allows for recycling production waste without compromising quality [1].

Luo and Netravali [2], Ahmed [3], Faud [4], Schneider [5], and bhaskar [6] studied pineapple, filament wound

cotton fibre, oil palm wood flour and jute & kenaf fiber based composite respectively.

Coconut shell is one of the most important natural fillers produced in tropical countries like Malaysia, Indonesia, Thailand, Sri Lanka and India. Many works have been devoted to use of other natural fillers in composite in recent past and coconut shell filler is a potential candidate for the development of new composites because of their high strength and modulus properties. The coconut particles also 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.

Composite of high strength coconut filler can be used in broad range of applications as, building materials, marine cordage, fishnets, furniture, and other household appliances [7-8]. The objective of this paper is to investigate the density and tensile properties of epoxy composite based coconut shell filler particles.

As the name itself indicates, the reinforcement is of particle nature (platelets are also included in this class). It may be spherical, cubic, tetragonal, a platelet, or of other regular or irregular shape, but it is approximately equiaxed. In general, particles are not very effective in improving fracture resistance but they enhance the stiffness of the composite to a limited extent. Particle fillers are widely used to improve the properties of matrix materials such as to modify the thermal and electrical conductivities, improve performance at elevated temperatures, reduce friction,

increase wear and abrasion resistance, improve machinability, increase surface hardness and reduce shrinkage. Particles are more commonly used as extenders to lower the polymer use with other simultaneous improvement in properties.

2. Materials

2.1. Epoxy Resin

Epoxy resins (ER) are one of the most important classes of thermosetting polymers which are widely used as matrices for fiber-reinforced composite materials and as structural adhesives [1, 2, 3, 4, 9]. They are amorphous, highly cross linked polymers and this structure results in these materials possessing various desirable properties such as high tensile strength and modulus, uncomplicated processing, good thermal and chemical resistance, and dimensional stability [1]. However, it leads to low toughness and poor crack resistance, which should be upgraded before they can be considered many end-use applications [1, 2].

In the present investigation epoxy resin SY-12(319) purchased from M/s RESINOVA CHEMIE Limited, Kanpur India has been used as matrix material. The epoxy used is colourless, odorless and completely nontoxic. Tensile, modulus of elasticity compressive, flexural, and impact strengths are 43 MPa, 800-820 kg/mm², 90-100 MPa, 50-60 MPa, 2.5-4 kg-cm/cm² respectively. Density is 1.15 g/cm³. It has versatile applications in technical and industrial applications. Curing takes place at room temperature and atmospheric pressure after addition of hardener. Fully cured mixture has excellent mechanical, thermal properties and atmospheric attack. The castings have good ageing characteristics.

2.2. Hardener

Hardener SY31(B) is a yellowish-green liquid. Hardener SY31(B) purchased from M/s RESINOVA CHEMIE Limited, Kanpur, India has been used as curing agent. In the present investigation 8 % wt/wt has been used in all material developed. Specific viscosity of hardener is 10-20 cps. The weight percentage of hardener used in the present investigation is as per recommendation of Singh [9].

2.3. Coconut shell particle

Coconut shell particles were used as reinforcing material for investigation as shown in figure 1(a) prepared from coconut shell as shown in figure 1(b). Shell particles of size between 200-800 µm were prepared by grinding machine. Coconut shell filler are potential candidates for the development of new composites because of their high strength and modulus properties. An approximate value of coconut shell density is 1.60 g/cm³.

2.4. Coir fiber

Coconut fruit is covered inside coconut coir fiber. Fibers are very long and have good tensile properties as shown in figure 1(c). It is assumed that cover of fibre gives damping strength to the coconut fruit for protecting while falling from height. Fibers used were collected and milled to get fine form of coir fiber.

3. Composite fabrication

The measured quantity of resin, coconut shell particle and coir fibre were mixed according to required quantity of reinforcement 20 wt% to 30 wt% was kept in the furnace at a temperature of 90±5 °C for two hours as per the recommendation of Singh [10]. At each interval of 30 minutes the solution was remixed by mechanical stirrer at high speed. After two hours the whole solution was allowed to cool to a temperature of 45 °C. When a temperature of 45°C was attained 8 wt% of the hardener was mixed immediately. Due to addition of hardener high viscous solution was obtained which was again mixed mechanically by high speed mechanical stirrer. The viscous solution so obtained was poured in to different moulds for sample preparation for tensile testing.

The viscous solution obtained from resin, hardener and filler materials is poured in to different moulds for specimen preparation for tensile and flexural strength test and casted material is shown in figure 1(d). Flat plates as required for tensile test. Tensile test specimens were prepared on milling machine as per ISO 527-2(1996).



Figure 1(a). Coconut shell particles



Figure 1(b). Coconut shell



Figure 1(c). Coconut coir fiber particle



Figure 1(d). Prepared composite plates

4. Experiments

4.1. Microscopic Investigation

The scanning electron micrograph study generally performed by scanning electron microscope, which uses electron to form an image with high resolution or magnification. To obtain the topographical contrast of the morphology of the organic-inorganic samples were etched. In etching 'weakest' compound is removed, while the 'strongest' compound remains at the surface, thus creating a topographical difference. The organic phase was etched away, without affecting inorganic particles present in the material. The inorganic phase is much better visible when etching was used.

In the present investigation SEM studies has been done to see the dispersion of coconut shell particle and coir fibre. The images were obtained through microscopic investigation. To obtain the scanning electrons micrographs square samples were cut and gold coated to avoid the artifacts associated with sample charging and then placed inside a chamber in which an electron beam was falling on the material. The accelerated voltage was 20 kV. Different images are taken at various magnification ranges.

4.2. Tensile test

Tensile tests were performed to determine the modulus of elasticity, elastic limit, elongation, proportional limit, and tensile strength, yield strength and other tensile properties. In the present investigation all the tensile tests were conducted as per ISO test procedure. The tests were conducted on 100 kN servo hydraulic UTM machine under different strain rates under displacement mode of control. All measurements were performed at ambient conditions (23 ± 2 °C and 50-60% RH, relative humidity). The displacement of cross head is taken as 1 mm/min.

4.3. Flexural strength

Flexural strength is the ability of composite material to withstand bending forces applied perpendicular to its longitudinal axis. Three point bending tests were performed for characterizing flexural property of composite material. A small of rectangular cross section was placed on two supports. A displacement was applied at the centre with cross head speed of 1 mm/min and the resulting force was recorded. This test was performed on a universal testing machine (UTM).

The span was taken 40 mm to measure flexural strength. The stress-strain curves were calculated using a linear elastic approach. Because of application of load at three points it is known as three point bending test.

Sample size $60 \times 10 \times 10$ mm³ and span length= 40 mm.

Formulae used for calculation: Flexural stress

$$= 3PL/2bd^2$$

Where P= load at given point (N), L= support, b=width (mm), d=depth (mm)

5. Results and Discussions

5.1. Microscopic investigation

In this investigation SEM was carried out on coconut based composite containing different weight percentage of shell particle and coir fiber to evaluate matrix interface and dispersion of the particle and coir fiber in the epoxy resin matrix. SEM was done on 10000 times magnification factor and 1000 times magnification factor. The state of dispersion of coconut shell particles and coir fibre into the resin matrix plays a significant role on the mechanical properties of the composite.

Figure 2 & 3 shows the SEM photographs of different shell particle composite material investigated in the present work. The absence of any voids around the particle indicates a satisfactory adhesion between particle and epoxy matrix. The concentrations of shell powder are also seen in figures. From the above figures it is also evidence that there is no chemical reaction between shell powder and epoxy resin.

Hence, from the above micrographs it is can be concluded that due to somewhat uniform dispersion of coconut shell particle in the epoxy resin, a remarkably affect on the mechanical properties. Role of dispersion of particle and bonding/adhesion can be seen easily from SEM. A suitable coupling agent could improve adhesion and bonding among particles and coir fibre.

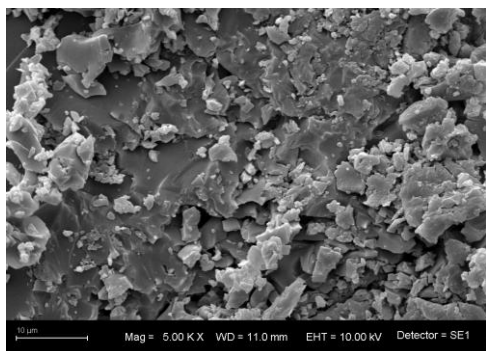


Figure 2(a). 18 wt% coconut shell particle & 2 wt% coir fibre reinforced composite.

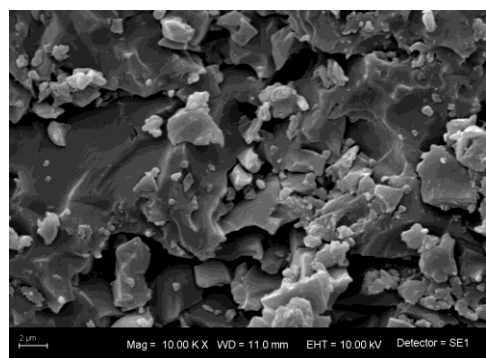


Figure 2(b). 17 wt% coconut shell particle & 3 wt% coir fibre reinforced composite.

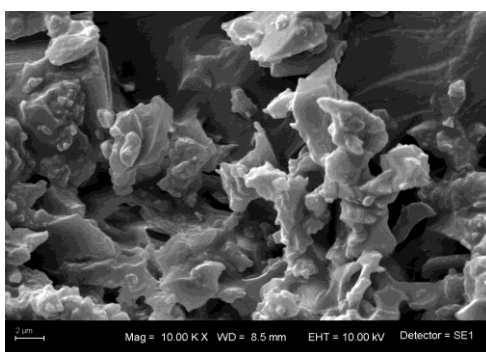


Figure 3(a). 28 wt% coconut shell particle & 2 wt% coir fibre reinforced composite

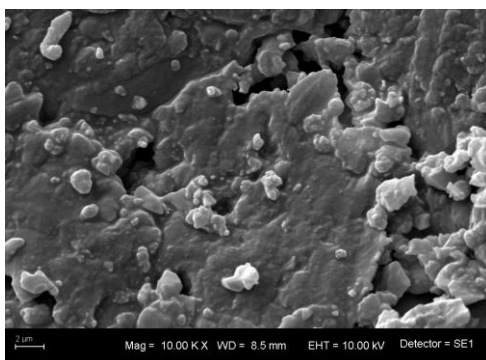


Figure 3(b). 27 wt% coconut shell particle & 3 wt% coir fibre reinforced composite

5.2. Tensile properties

The Mechanical properties of the natural fibre reinforced composites depend on several factors such as the stress-strain behaviors of fibre/particle and matrix phases, the phase volume fraction, the fiber concentration, the size of particles, the distribution and orientation of the fibre or fillers relative to one another.

Figure 4 shows the typical stress vs. strain curves for coconut shell particle and coir fibre reinforced composite. It can be seen that ultimate tensile strength decreases with coconut shell particle and increases with coir fiber when coir and shell particle used as reinforcement.

Sapuan [11, 12, 13] investigated that tensile properties (27-35 MPa) increases for coconut shell particle (50-200 µm) reinforced into epoxy upto 0-15 wt% and decrease beyond 15 wt% of reinforcement of shell particle.

The reinforcement used in this experiment was 20%wt shell particle & coir fibre that is more than 15 wt% used in Sapuan's experiment [11, 12, 13]. So, same fashions of decrement in the tensile properties were also observed for this range of reinforcement as given in table 1. Tensile strength of 35 MPa was retained even after 30 wt% reinforcement of shell particle and coir fibre. But it is quite appreciable when compared with tensile strength of 24.8-19.8 MPa and modulus of elasticity (633-318 MPa) of coir reinforced for 5-15 wt% polyester composite.

Stress strain diagram was plotted for shell particle and coir fibre in figure 4. A low stress level was observed in particle and coir fibre composite with 28 wt% particle & 2 wt% coir fibre and 27 wt% particle & 3 wt% coir fibre. Stress was maximum for 17 wt% of particle and 3 wt% of coir. Reduction in ultimate tensile strength due to shell article was compensated with coir fibre. Reduction in tensile strength with addition of particle would due to poor adhesion of particles of this bigger average size 0.200-0.800 mm. Reinforcement of fibre would be improving the adhesion or bonding strength among resin, shell particle and fibre. Finally 2-3 wt% fibre contributed to improve tensile strength as shown in figure 5.

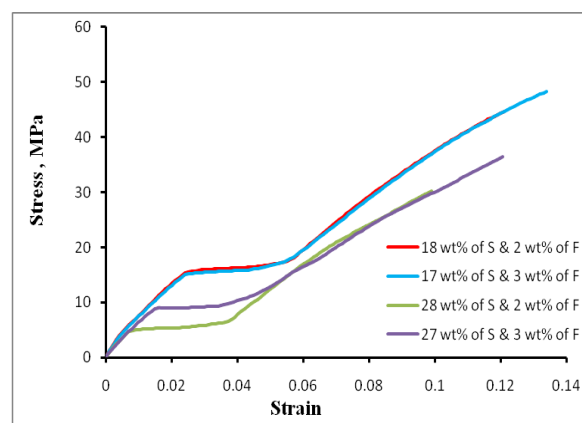


Figure 4. Stress-Strain diagram coconut shell particle and coir fiber reinforced composite

S.No.	20 wt% Reinforcement		20 wt% reinforcement		30 wt% reinforcement		30 wt% reinforcement	
	18 wt% S	2 wt% F	17 wt% S	3 wt% F	28 wt% S	2 wt% F	27 wt% S	3 wt% F
Ultimate tensile strength (MPa)	44.59		48.27		30.20		38.99	
Modulus of elasticity (MPa)	920.81		848.53		720.06		684.93	
Percentage elongation	12.09		13.39		9.90		13.06	

Table 1. Tensile Properties of coconut shell particle (S) and coir fibre (F) reinforced composite

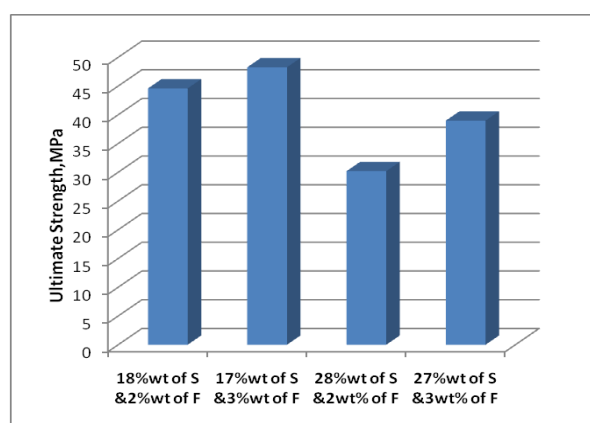


Figure 5. Variation of ultimate strength of coconut shell particle and coir fibre reinforced composite

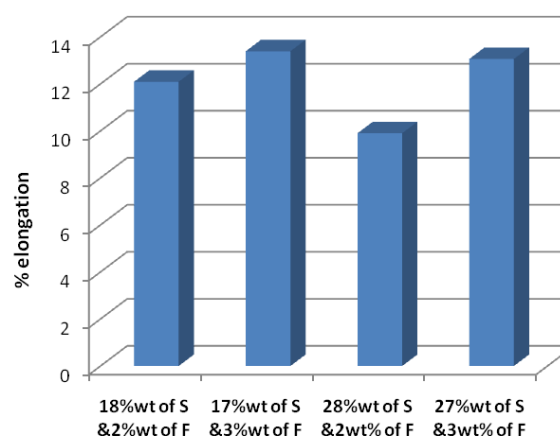


Figure 7. Variation of % elongation of coconut shell particle and coir fibre reinforced composite

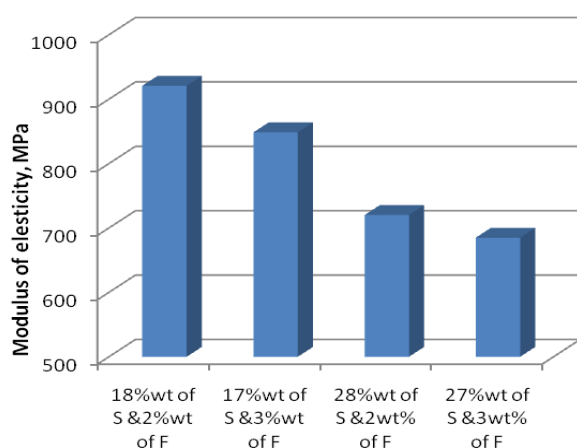


Figure 6. Variation of modulus of elasticity of coconut shell particle and coir fibre reinforced composite

Figure 6 & 7 shows that the variation of modulus of elasticity and percentage elongation with wt% of coconut shell particle and wt% coir fibre. Modulus of elasticity decreased with the increase in wt% of coir fibre and shell particle both. Fibre reinforcement reduces the modulus of elasticity more severely for only 1 wt% increase in wt% of coir from 2 wt % to 3 wt%. The lowest value modulus of elasticity was 650 MPa for 27 wt% of particle 3 wt% of coir. It was observed from figure 7 that percentage elongation showed same pattern of modulus of elasticity reflection.

5.3. Flexural strength

Flexural property of wood composite is very necessary for structural application to avoid failure. This property for tested composite is presented in table 2 and figure 8.

The role of coir and particle reinforcement in the resin matrix can be observed and shown in figure 8. The flexural strength was reduced for increasing the reinforcement of coir from 2 wt% to 3 wt%. But flexural strength was not affected

much more when wt% of particle was increased from 17 wt% to 27 wt%. 2 wt% of coir fibre is appropriate in view of

flexural strength.

S.No.	20 wt% Reinforcement		20 wt% reinforcement		30 wt% reinforcement		30 wt% reinforcement	
	18 wt% S	2 wt% F	17 wt% S	3 wt% F	28 wt% S	2 wt% F	27 wt% S	3 wt% F
Flexural Strength (MPa)	58.140		51.048		58.494		44.910	

Table 2. Flexural strength for composites of coconut shell particle and coir fibre reinforced composite.

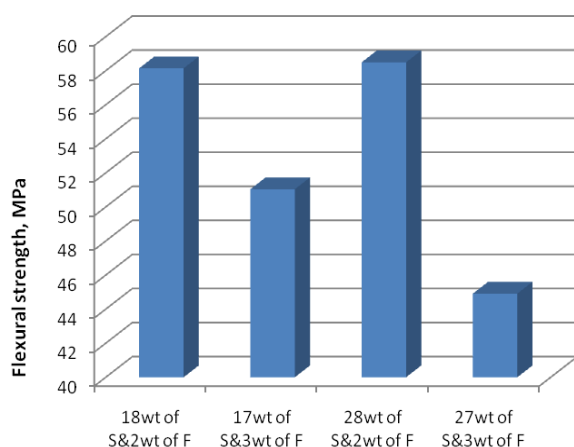


Figure 8. Flexural strength of shell particle and coir fibre reinforced composite.

6. Conclusions

The tensile and flexural properties of epoxy composite reinforced with coconut shell particle and coir fibre have studied and discussed here. A satisfactory dispersion of coconut shell particle and coir was observed. Disorder could be easily maintained by coupling agent. Ultimate tensile strength and percentage elongation increases with the increase of coir wt% and modulus of elasticity decreases with the reinforcement of shell particle and coir both. Flexural strength decreases with addition of coir fibre. The coconut shell particles and coir fibers are good reinforcing (30 wt%) material to reduce requirement of matrix material. The tensile and flexural properties this coir and shell particle based composite are found to be equivalent to other materials or composite used for structural applications. But there is a certain hope to improve tensile and flexural properties with the use of proper coupling agent.

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