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Hybrid Bio Composites from Agricultural Residues: Mechanical and Thickness Swelling Behavior

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Abstract: This research explores the effective utilization of agri-residue in polymer composites. A Hybrid polymer composite was prepared by reinforcing coir pith, rice husk and groundnut shell in an epoxy matrix system. The particle content were varied in three different ranges [7.5, 15, 22.5 and 30 wt %] and their effect on tensile and flexural strength of the composites were analyzed. The dimensional stability of the composites was also studied as per ASTM D570 standard. The fractured behavior of the composites was examined using scanning electron microscope [SEM]. The investigation evidenced the noteworthy role played by the hybrid reinforcements in improving the mechanical and dimensional stability of the composites.
Keywords: Rice husk, coir pith, groundnut shell, epoxy and mechanical properties.

Introduction

The environmental constraints and sustainable issues argues the Industrial experts and scientist to produce bio based novel materials[1].specially, the potential of renewable sources instead of petroleum based products as glass, Kevlar, carbon, boron and aramid fibers, has creating interest to produce biodegradable material[2].Most of the developed countries are very rich in agricultural fiber production and a large part of agricultural waste is being used as a fuel for various sources. India alone produces more than 400 million tones of agricultural waste such as bagasse, maize cobs, peanut shells and other wastes[3, 4, 5]. Agricultural residues are excellent potential alternative waste materials to substitute plastic products, because of their availability in nature. Apart from their abundance and renewability, utilization of agricultural residues has advantaged for its economy, environment, and technology, low density, low manufacturing energy, low CO_2 emission, and a high level of biodegradability, when compared to inorganic filler reinforced thermoplastic polymer composites[6, 7]. In the recent decades, hybrid composites have been focused by using more than one type, size, and shape of reinforcement. These composites have been developed to provide desirable properties of chosen filler particle and resin system. Although there is useful research literature in agricultural residue-composite[8, 9, 10] .Aside there is little space in research work done from agricultural by product, which must be correlated in order to produce good value economic returns to farmers.

The current research concentrates on employing the waste agricultural residue as bio-fillers with epoxy matrix by compression molding process for producing uniform dispersion of fillers with resin system. Effect of incorpation of these agro by-product particulates on mechanical and thickness swelling behavior were analyzed and summarized.

Materials and Methods

Materials

Three variety of an agricultural residue were investigated in this report namely; ground nutshell, rice husk and coir pith which was supplied local body industries, south Tamilnadu, India, with average particle size of 50μm. The chemical composition of the bio particulates are listed in Table.1.The epoxy resin used as matrix was supplied by Giba energy ltd, in the form of liquid phase with melt flow index of 18g/10min and density of 1.36gm/cm^3.

Table .1 Chemical compositions of Bio particulates

Compositions	Rice husk [4]	Groundnut shell [4]	Coir pith [19]
Cellulose %	35.7	31.3	27.1
Hemi cellulose %	18.7	24.3	44.2
Lignin %	30.2	14.3	19.5
Ash %	5.9	23.5	7.1
Pectin %	9.5	6.6	2.1

Composite fabrication

Prior to processing, residues are cleaned with sodium hydroxide and sundried for 2 days to remove water molecules and excess lignin. A stainless steel mould with a size of 300×300× 3 mm^3 was used to prepare composite sheets as per ASTM standards. Epoxy resin HY 551 was mixed araldite hardener in the ratio of 10:1 for enhancing the curing performance.Aectone was used as a releasing agent. The agri-residue particulate coir pith, rice husk and groundnut shell were mixed with epoxy resin by varying reinforcement percentage [7.5, 15, 22.5 and 30%] respectively and blended by using mechanical stirrer for 15 mins at 30 rpm in the room temperature. The mechanical properties of the composites are found to reduce when the particulate content is increased beyond 30 % by weight. The maximum value of tensile and flexural strength were achieved around 30% of particulate weight content based on the previous works reported in literature [11, 12].The prepared mixture were poured in the stainless steel die, placed in the compression molding machine at the temperature of 90^{0}C and pressure of 2.6 MPa for 1 hour, After uniform curing the composite sheets have been cut for mechanical testing.

Mechanical testing

Tensile test on prepared composites were done as per ASTM: 638-09 standards using universal testing machine [Tinius Olsen H-100] with extension rate of 5 mm/min and average values of strength were reported[13]. Three point bending test was carried out according to procedure stated in ASTM: D790-10 with help of Tinius Olsen UTM with load capacity of 50 KN. The morphology of fractured tensile, flexural and dimensional changes specimen has been examined through Scanning electron microscope.

Dimensional stability test

The thickness swelling behavior of agro-residue was conducted according to ASTM: D 570.Before testing each samples were measured and specimens were immersed in distilled water for 1 to 10 days at 25^{0}C.samples were removed after regular period of time and appropriate thickness were measured.

Results and Discussion

The tensile strength and flexural strength of the hybrid reinforced bio particle composites obtained experimentally are given in the Table.2.

Table.2 Experimental results of agri residue composites

Specimen code	Coir pith [%]	Rice Husk [%]	Ground nut [%]	Tensile Strength [MPa]	Flexural Strength [MPa]
RCG 1	30	0	0	9	23.2
RCG 2	0	30	0	18.3	29
RCG 3	0	0	30	23	21
RCG 4	22.5	7.5	0	11	24
RCG 5	15	15	0	15	25.6
RCG 6	7.5	22.5	0	18.1	28
RCG 7	22.5	0	7.5	12	22
RCG 8	15	0	15	16.1	24
RCG 9	7.5	0	22.5	19	26
RCG 10	0	7.5	22.5	18.4	29
RCG 11	0	15	15	20	32
RCG 12	0	22.5	7.5	26.1	29.5

Tensile strength behavior of agro-residue composites

Figure 1. Shows the variations of tensile strength with incorpations of agro-waste residue particulate composites. The lowest tensile strength 9 MPa was reached with inclusion of coir pith and epoxy resin. The highest tensile values were achieved as 26.1 MPa with addition of rice husk and groundnut combinations; it shows better hybrid reinforcement than the individual reinforcement's composites. This rice husk and groundnut indicates better reinforcement for epoxy resin than the coir pith compositions, it's due to formation of chemical bonding with epoxy resin and superior mechanical performance. The random distribution of particles inside the composites helps in increasing the mechanical properties of the composites. In addition, the particle size of 50µm offers better bindability with resin which further increases the mechanical properties. Therefore in order to enhance the mechanical strength of prepared composites, average particle size of 50µm was maintained during the fabrication[14, 15].

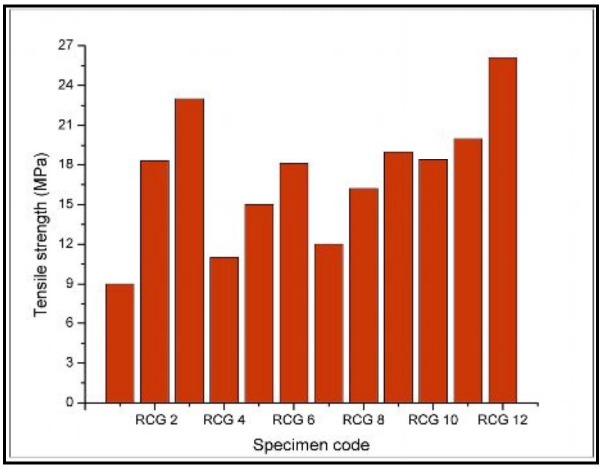

Figure 1. Effect of particle content on tensile strength of the composites

Henceforth, it can be evidenced, that the maximum tensile strength was attained with hybrid composites of rice husk and groundnut shell p articulate. The tensile strength was found to be higher for particles with highest cellulose content[16, 17]. Additionally it can be consummated that increase in cellulose content will result in increase in bindability and leads to better tensile strength. This because cellulose offers crystalline structure to the particles, higher the crystalline nature leads to higher strength.

Flexural strength behavior of agro-residue composites

Flexural strength of agricultural residue epoxy composites are shown in Figure 2. The rice husk composites produced a bending strength of 29 MPa, whereas the rice husk and groundnut hybrid composites showed a maximum flexural strength of 32.3 MPa, which is 28.1%, 10.1%, 34.9% higher than coir pith/epoxy, rice husk/epoxy and groundnut/epoxy reinforced composites. The presence of silica content in the rice husk particle increasing the stiffness of composites, it is the evident to improve the flexural strength always improved manner in this rice husk presence composites. However rough surface of rice husk compare to other reinforcement, they enhanced the bindability between particulates and resin system.

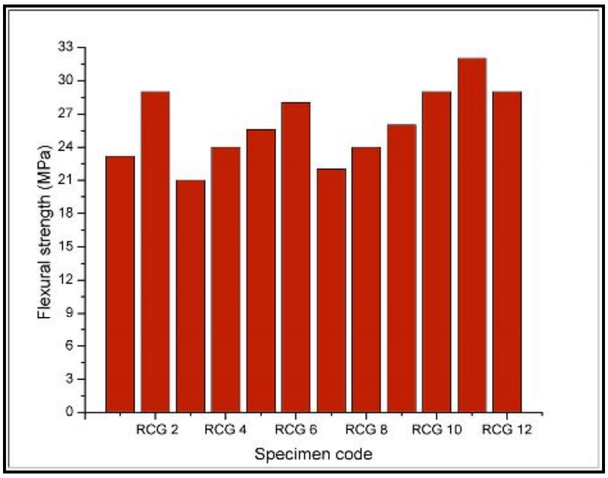

Figure 2. Effect of particle content on flexural strength of the composites

The highest flexural strength for particle reinforced composites may be attributed to strong interfacial adhesion between particle and matrix, due to greater surface area of rice husk and groundnut shell particle reinforcement[18, 19].

Thickness swelling behavior of agro-residue composites

The poor water resistance of agri particulates is primarily due to attention of OH groups and water molecules presence in the lingo-cellulosic material, that easily react with hydrogen bonding and dispersing moisture content into the outer shell of the particulates. This leads to dimensional changes in the specimen like thickness and linear expansion and finally cause micro-cracking. The initial intake of water will be high for the all compositions and there after it tends to be constant. It is clear that the water absorption of agri-residue composite increases with increase in the immersion time.

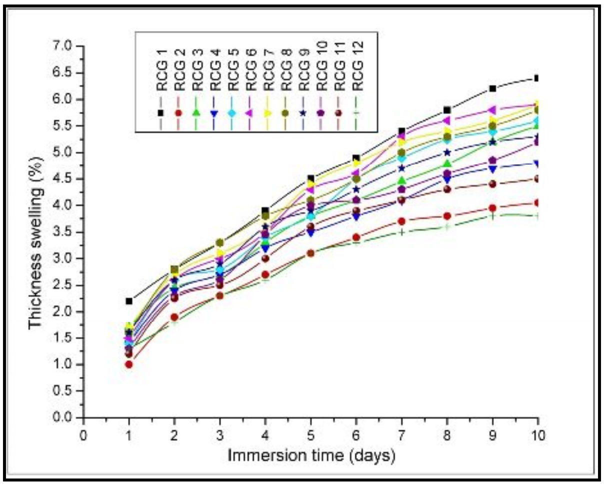

Figure 3. Short term thickness swelling behavior of composites

In the initial stage of immersion time (1-5 days), water absorption rate observed was 22 %, there after periods increased only 8%, after 10 days water incubation rate remain same and no more water absorbed. As can be seen from Figure 3.Thickness swelling rate of bio composites was found increasing with increase of immersion time and reached a saturation point with certain value as per diffusion phenomenon theory. Diffusion is the process by which a fluid migrates and spreads it through capillaries, vessels and cellular walls of particles. The composites fabricated with 30% of coir pith exhibits higher swelling than all other particulates used in this investigation. The least swelling rate due to raw rice content at 4.05%.That average change swelling rate was 3.7 % from the initial thickness. The swelling nature of particulate polymer composites transfers the stress to surrounding resin and finally leads to edge cracking, which would ending with composite structure fails to catastrophically[20]. As a consequence, hydro-philic nature of particulates was found to diminish the dimension stability of the polymer composites.

Morphology of composite fractured surfaces

The SEM images of hybrid bio particulate specimens after tensile and flexural fracture are shown in the Figure 4 & 5 respectively.

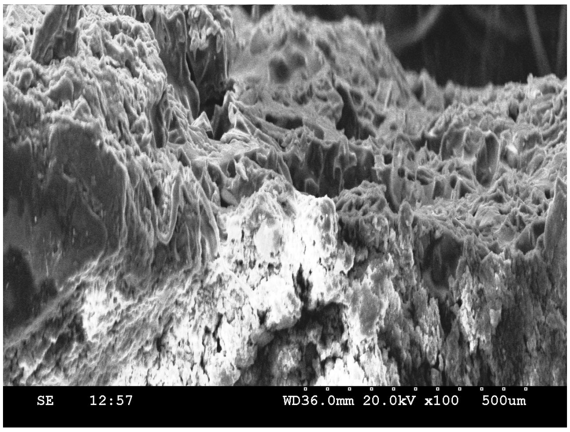

Figure 4. SEM of rice husk and ground nut reinforced epoxy composites after tensile fracture

The agglomeration of rice husk and ground nut particles shown in the SEM image of tensile fractured specimen confirms the effective participation of bio particles against the pull load applied during tensile test. Segregation was found to decrease manner with additional amount presence of agricultural residues, especially due to cellouse content of rice husk this might be due to the improvement in compatibility between waste residue particulate and epoxy resin.

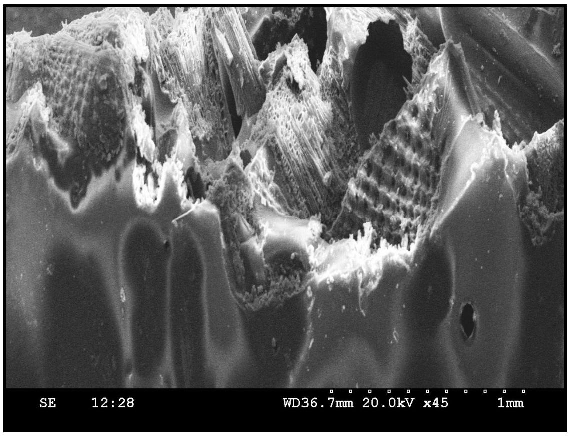

Figure 5. SEM of rice husk and ground nut reinforced epoxy Composites after flexural fracture

The river pattern found in the flexural fractured specimen confirms the confrontation offered by the bio particles to prevent the rupture development in the matrix surface. The rice husk and ground nut reinforced hybrid particulates epoxy composites which resulted in low thickness swelling is depicted in the Figure 6.

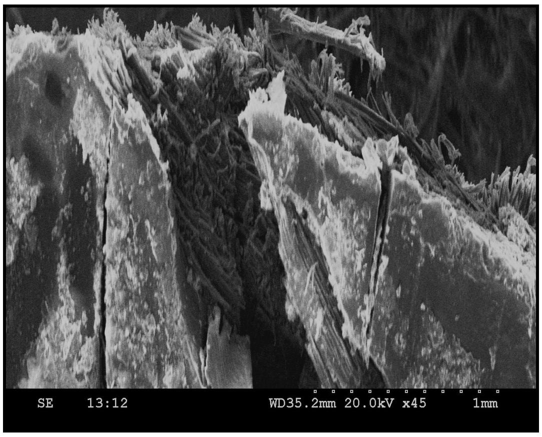

Figure 6. SEM of rice husk and ground nut reinforced epoxy after immersion condition

It was inferred that the presence of coir pith into the epoxy matrix enhances the stiffness of the composites, but also exhibited poor inter-laminar bonding between particulate and matrix. The SEM images of thickness swelled specimen revealed the restriction offered by the bio particles against crack which was resulted from expansion of composites due to excess water absorption[20].

Conclusion

The effect of particle hybridization on the mechanical and swelling behaviour of the epoxy composites were investigated in this study. The tensile and flexural properties of the composites were greatly influenced by hybridization of particles in the epoxy matrix. The hybridization of rice husk with coir pith and ground nut particles improved the mechanical properties to a greater extent. The swelling behaviours was also found be greatly influenced by particle hybridization. The swelling was found to be minimal for composites fabricated 22.5 % rice husk and 7.5% ground nut. Further research on optimization would help in finding the most promising composition of particulate content for best mechanical properties.

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