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Characterisation and Properties of Recycled Craft Shell Powder/Epoxy Composites

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Abstract*: *The properties of polymer composites can be tailor made by incorporating suitable filler and fiber as a reinforcement in the polymer matrix. In this work, craft shell powder had been used a natural filler in the Epoxy resin and the composites were prepared at various proportions(4%, 8%, 12%, 16% and 20%) of craft shell powder using hand layup method. The specimens were subjected to various mechanical testing such as tensile test, flexural test, impact test as per ASTM standards. The test results revealed that particulate filler reinforcement resulted in marginal increase in tensile strength but the properties decrease at higher volume fraction of the fiber. But, the values of mechanical moduli had shown better improvement due to filler addition. SEM images were taken to analyse the interfacial bonding between the matrix and filler particles.

Keywords* :*Craft shell powder filler, Epoxy composites, Mechanical Properties,SEManalysis, Polymer Composites

I. INTRODUCTION

Composite materials find wide range of applications in numerous industries such as automobile, packaging, furniture, household items, aircraft industries, shipping, defense applications, windmills etc. Lot of interest has been shown on the use of polymer based composites for several light weight application where high strength to weight ratio is required. For the past several decades synthetic fibers such as glass fiber, carbon fiber and aramid fiber were primarily used as reinforcements in polymer composites. Recently lot of research is being done on the use of natural fibers and fillers as a suitable alternative to the synthetic reinforcements due to the environmental concern and the carbon footprint of synthetic materials. Natural fibers and fillers have the advantages of easy availability, ease of processing, low cost, better strength, recyclable, and low environmental impact, Alsoseveral researchers [1] – [3] have indicated that natural fibers and fillers can be better alternative to synthetic materials in terms of mechanical properties of the polymer composites.The properties of composites can be altered by the choice of the fibers and fillers used for reinforcement.

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Composite properties largely depend on the fiber properties such as fiber volume fraction, fiber length, fiber tensile strength, fiber-matrix adhesion, fiber orientation and aspect ratio of the fiber. Particulate fillers are, in general used to enhance the mechanical moduli such as tensile modulus, flexural modulus and also to reduce the usage of matrix material without affecting the cost of the composite material. Several researchers conducted the experiments to evaluate the effect of particulate fillers [4] – [7] on the properties of polymer composites. Naturally available particulate fillers can be either from plants of can be inorganic materials such as talk, eggshell powder, asbestos, calcium carbonate etc. Groundnut shell powder was used as particulate filler in the expoxy resin by Raju et al [8]. Groundnut shell powder of different grain sizes was used as filler to form novel bio composites. He had reported that maximum value of tensile strength was observed for the filler content of 40% for a grain size of 0.5mm. Vimalanathan et al [9] had used *Shorea Robusta*, a plant based filler derived from the Sal tree as bio filler on the polyester composite. Various tests were performed to assess the properties such as mechanical strength, thermal stability and visco elastic properties. It was reported that incorporation of the filler resulted in better thermal stability and increase in storage modulus and glass transition temperature of the composite. Kumar et al [10] have reported that the incorporation of coconut shell powder in the Epoxy resin resulted in minor variation in the mechanical strength. The wear test was conducted using pin on disc apparatus and it was reported that the addition of coconut shell powder resulted in better wear resistant upto 12% filler.

The main drawback of plant based bio fillers is that they tend to absorb moisture as they are hydrophilic. Hence inorganic fillers can be used to improve the properties of polymer composites. Manohara et al [11] have reported that incorporation of sea shell powder in Jute Epoxy matrix resulted in marginal increase in the tensile properties of the composite. A maximum tensile strength of 8400N was reported at 5% sea shell filer content. Karthick et al [12] have studied the mechanical and wear properties of Sea shell/ PMMA bio composite at different filler loading. It was shown that the addition of sea shell nano powder at 12% loading resulted in better wear resistance of the composite which can be useful for dental applications. It was also shown that addition of sea shell powder more than 16% and 20% resulted in higher wear rate of the composite. Mustafa et al [13] used sea shell powder as natural filler in the ABS matrix.

Dynamic Mechanical Analysis experimental results revealed that the incorporation of low amounts of seashell powder to ABS improves the storage modulus (E′) and also shifting of glass transition temperature (Tg) to higher temperaturevalue. Also the ABS/Sea Shell composite resulted in better tensile strength than Calcium Carbonateincorporated ABS. Thermal stability was also improved due to the addition of sea shell powder. Fire resistant polymer material from recycled polyethylene and oyster shell powder was fabricated by Chong et al [14]. It was shown that the polymers can be made fire retardant at higher temperatures due to the formation of carbon di oxide at around 800°C.

It was observed from the literature that only few researchers have reported the use of craft shell powder (CSP) as filler material in epoxy matrix. Hence, craft shell powder have been selected as particulate filler material to study its effect on the mechanical properties of Epoxy composites in this work.

II. EXPERIMENTAL DETAILS

A. Materials

Craft shell powder was procured from local vendor in Chennai, and it was finely ground to about 50 – 150 micron size using ball milling process. The finely ground craft shell powder contains calcium carbonate as its primary ingredient. The Epoxy resin (LY556) was used as the polymer matrix materialand hardener (HY951) is used at 10:1 ratio in this research work.

Composite specimens were fabricated by using different volume fractions of craft shell powder (4%, 8%, 12%, 16% and 20%) in the Epoxy matrix by using the hand layup method. After curing for 24 hours, the samples were given to light compression using the hand press.

B. Testing Standards

ASTM standards were used to study the mechanical behavior of the craft shell powder incorporated Epoxy composite specimens.Dog bone shaped tensile specimens as per ASTM D638 was used to evaluate tensile properties. Bending strength and bending modulus was evaluated using ASTM D790 testing standard. Impact strength was evaluated using ASTM D256, Izod impact test..Five samples were used in each test to tabulate the results.

The interface bonding between the matrix and particulate filler material was analyzed using Scanning Electron Micrograph (SEM) images. The broken surface of the tensile test, flexural test specimens were used to take SEM images. Hitachi – S 3400N scanning electron microscope was used to take the SEM images. The accelerating voltage was 20kv. The samples were cut and carbon coated before SEM analysis.

III. RESULTS AND DISCUSSION

A. Mechanical Properties

The tensile and flexural strength and modulus of the craft shell incorporated Epoxy composites were evaluated based on the stress-strain plots obtained from the universal testing machine. The average value is plotted and is presented in Fig. 1. The plot showed that the addition of craft shell powder had insignificant impact on the tensile strength and flexural strength upto 16% volume fraction of the CSP. A maximum increase of 7.4% in the tensile strength of the CSP incorporated Epoxy was obtained at 16% v/v of the filler. Flexural strength had also exhibited similar trend with the addition of CSP in Epoxy matrix. An increase of 8.4% in the flexural strength of the composite was observed due to the addition of CSP in Epoxy matrix. Impact test results also revealed an increase of 4.7% increase in the impact strength value at 12% volume fraction of CSP.

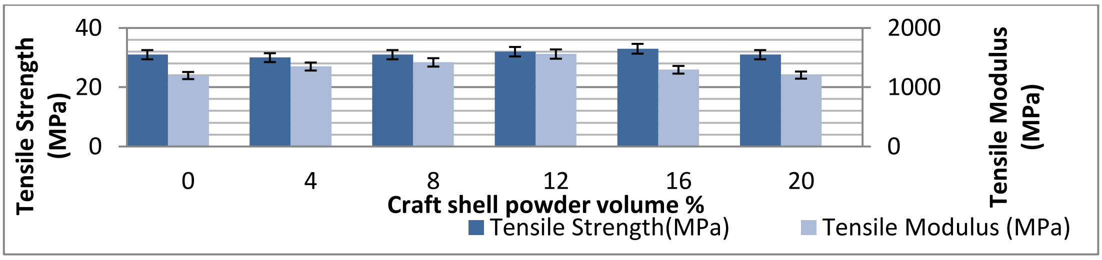

Fig.1. Tensile properties of the Neat Epoxy and CSP/Epoxy composite

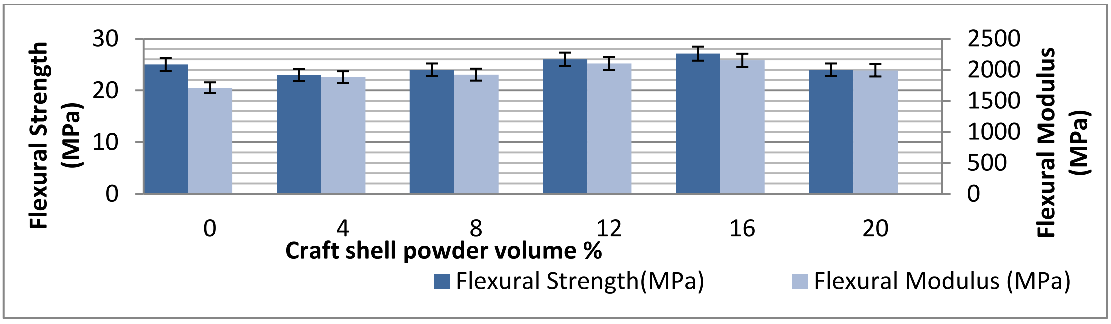

Fig. 2. Flexural properties of the Neat Epoxy and CSP/Epoxy composite

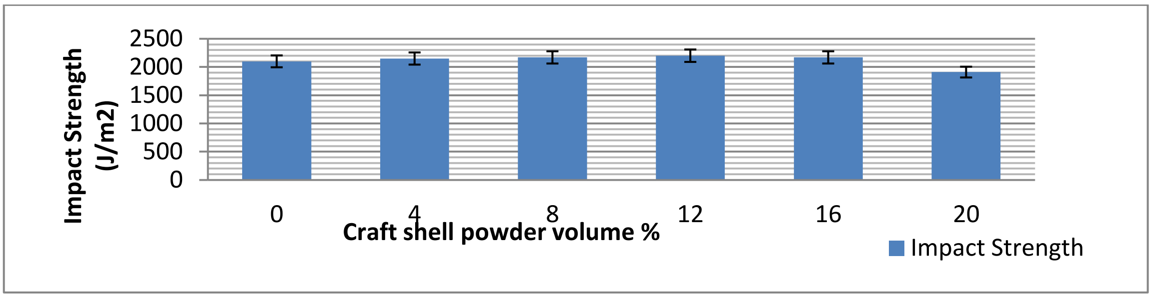

Fig. 3. Impact properties of the Neat Epoxy and CSP/Epoxy composite

Table - I: Effect of craft shell powder on the mechanical properties of Epoxy composite

Filler volume percent	Tensile Strength(MPa)	Tensile Modulus (MPa)	Flexural Strength(MPa)	Flexural Modulus (MPa)	Impact Strength J/m2
0	27	1198	27	1710	2100
4	31	1350	32	1880	2150
8	34	1420	36	1920	2170
12	36	1560	38	2100	2200
16	39	1295.2	41	2150	2170
20	36	1205.4	37	1990	1910

The plots (Fig 1 – Fig. 2) also revealed that the tensile modulus and flexural modulus of the composites were influenced significantly by the addition of filler material, an improvement in the tensile modulus and flexural modulus were observed as 30% and 25% respectively at 16% v/v CSP. Poor adhesion between the matrix and filler at high volume fraction of the filler could be the reason for reduction in the mechanical properties of CSP/Epoxy composite.

B. Fractography Study

SEM images of the broken surface of the test samples were taken to study the interface characteristics of the composites and they are presented in Fig 4 (a) – Fig 4 (f). The figures exhibited poor distribution of the CSP at 20% v/v in the Epoxy matrix, which leads to the poor stress transfer between the matrix and filler particles [15]. Voids and imperfect surface features were observed at 4% filler loading. Accumulation of particulate fillers was also seen in the SEM image of 20% CSP loaded Epoxy.

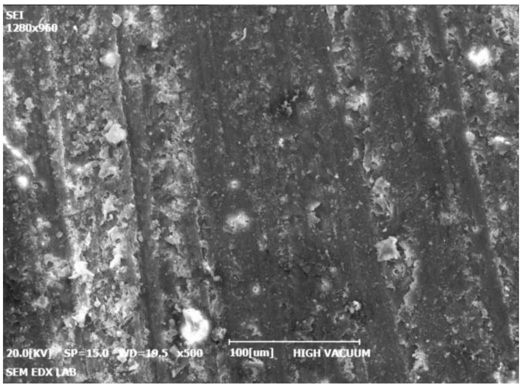

Fig. 4 (a)SEM image of 4% CSP/ Epoxy composite (Tensile test specimen).

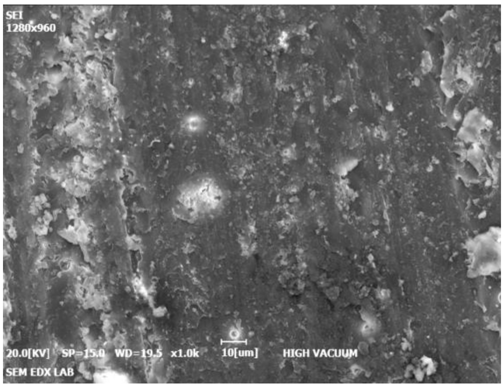

Fig. 4 (b) SEM image of 4% CSP/ Epoxy composite (Flexural test specimen).

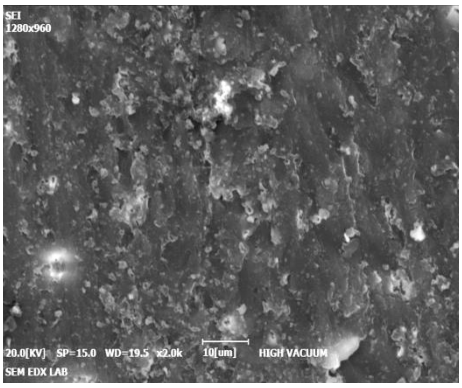

Fig.4 (c) SEM image of 16% CSP/ Epoxy composite (Tensile test specimen).

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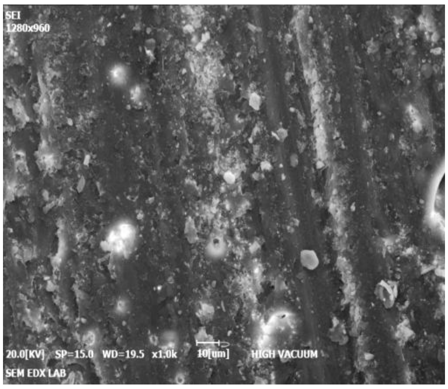

Fig.4 (d) SEM image of 16% CSP/ Epoxy composite (Flexural test specimen).

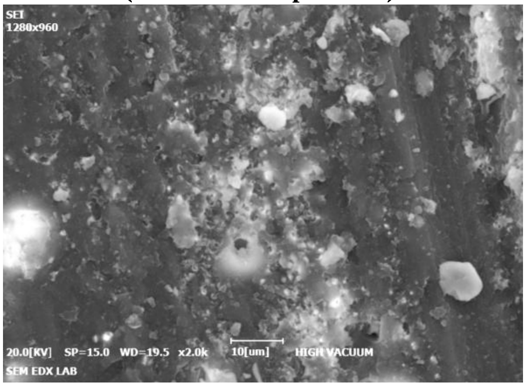

Fig.4 (e) SEM image of 20% CSP/ Epoxy composite (Tensile test specimen).

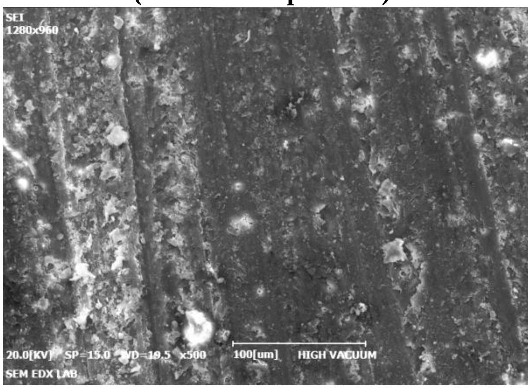

Fig.4 (f) SEM image of 20% CSP/Epoxy composite (Flexural test specimen).

IV. CONCLUSION

The effect of craft shell powder (CSP) on the mechanical properties of Epoxy resin wasstudied. CSP/Epoxy Composites were fabricated by incorporating CSP at various filler loading. Addition of filler had minor effect on the tensile strength and flexural strength due to particulate nature of the reinforcement, whereas tensile modulus and flexural modulus have shown an improvement of 30% and 25% respectively. Better mechanical properties were obtained for a volume fraction of 16% v/v CSP in the Epoxy matrix. SEM images of the tensile and flexural fractured surfaces were also taken to study the morphological features of the composites.

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