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Shellfish shell as a Bio-filler: Preparation, characterization and its effect on the mechanical properties on glass fiber reinforced polymer matrix composites

Lawrence J Fernandes[1*], Vinay B U[2], Kiran Prakasha A[2], Pavitra Ajagol[2]
[1, 2] *Assistant Professor, Mechanical Engineering, Sahyadri College of Engineering and Management, Mangalore, India.*
***Email: lawfds85@gmail.com**

ABSTRACT
In this study, waste shellfish shell (SS) are used as bio filler, which is having a significant odor and, having its high content of calcium carbonate ($CaCO_3$). The particles of shellfish shell (SS) was prepared from the sea shellfish shell by crushing, grinding and shearing emulsification. Shellfish shell (SS) filler was introduced on glass fiber reinforced polymer matrix composites. The different volume percentage of SS filler in polymer such as 0%, 5%, 10% and 15% are used. E-glass reinforced epoxy matrix filled with SS_p is fabricated by using hand lay-up technique. The attempt has been made in this work to study the mechanical properties like ultimate tensile strength, flexural strength and hardness of the fabricated composites.

KEYWORDS: *E-glass fiber (GF), epoxy, mechanical properties, shellfish shell particulates (SS_p).*

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I. INTRODUCTION

Polymers and their composites are gaining wide scope in many engineering applications such as navel applications, aerospace structures, spaceship structures, gears because of high modulus and high toughness, resistance to corrosion, good tribological properties and so on [1]. However polymeric composites are susceptible to mechanical damage, when subjected to tension, compression and flexural loads resulting in interlayer delamination [2]. Thus nowadays lot of research is going towards enhancing the mechanical properties of the composites. Works are reported mainly enhancing the properties by varying the fiber volume fraction, orientation and so on [3]. Recent development in this field is improving mechanical properties by adding secondary reinforcements called fillers.

In case of thermoset polymeric matrices, epoxy matrices are most widely used as structural applications and also in other industrial applications due to its high resistance to corrosion and chemicals, good thermal, mechanical properties [4, 5]. Epoxy (E) resins are increasingly used as matrixes in composite materials in many applications, such as aerospace, automotive, structure application, shipbuilding and electronic devices, because of their low creep, good adhesion to many substrates and high strength, low viscosity, and low shrinkage during curing [6].The high performance of continuous fiber (e.g. carbon fiber, glass fiber) reinforced polymer matrix composites is well known and documented [7].

The mechanical properties of a material are those properties that involve a reaction to an applied load. The mechanical properties of a composite determine the range of usefulness of a material and establish the service life that can be expected. The variation in the properties can be due to the change in the microstructure of fiber/filler and matrix reinforcement. Fillers increase stiffness, fracture toughness, and high temperature load-bearing capability, decrease shrinkage and improve the appearance of composites (8-10). Many investigations have been made on the potential of the natural fibers as reinforcements for composites and in several cases the result have shown that the natural fiber composites own good stiffness but the composites do not reach the same level of strength as the glass fiber composite [11].

M. Muthuvel et al [12] determined the mechanical properties such as tensile, impact and flexural test of hybrid glass/jute fiber reinforced epoxy composites in the forms of lamina and laminates. The adoption of this design allowed for a cost reduction of 20% and a weight saving of 23% compared to the current commercial solution.

Amiya Kumar et al. [13] developed an epoxy based hybridized composite material comprising of glass fiber, jute fiber and red mud as filler material and evaluated its mechanical properties and observed that flexural strength, tensile strength and density of the material increases with increase in number of layers of reinforcement.

Biswas and Alok Satapathy [14] carried out a study on bamboo fiber and glass fiber reinforced epoxy matrix composites filled with different weight proportions of red mud and their mechanical properties shows improvement by the addition of red mud. Erosion tests were also carried out and it showed good results to prove red mud as a potential filler along with polymer matrix composites. S.M. Sapuan [15] dealt the tensile and flexural properties of banana fiber reinforced with epoxy. The statistical analysis carried out, showed an increase in mechanical properties.

Srivastava and Wahne [16] organized a systematic experimental study and concluded that particulate fillers have the potential of improving the mechanical properties and wear resistance of the glass fibre reinforced epoxy composites.

This is because the filler in particle form enrich the bonding strength between the fibre and matrix.
Aruniit et al. [17] studied to find out how the filler percentage in the composite influences the mechanical properties of the material. Ibrahim [18] investigated the effects of reinforcing polymer with glass and graphite particles on enhancing their flexural properties. Shellfish cultivation is expanding worldwide, due to its demand in seafood consumption and directly resulting in generating a large volume of shell waste, where it becomes a health hazard and contributes to a deterioration of environments. SS fillers using shell waste as polymer filler could thus offer advantages of cost reduction and composite properties improvement.

The aim of this study is to characterize the mechanical properties of Shellfish shell (SS) filled glass fiber reinforced PMC. The composites were prepared through hand lay-up technique. The specimens were characterized by mechanical tests.

II. MATERIAL AND EXPERIMENTAL DETAILS

2.1. Materials

The composites were made from E-glass fiber and commercially available LAPOX (L-12) along with hardener K-6. The filler used is Shellfish shell, having high content of calcium carbonate (CaCO3), which exhibits favorable mechanical and chemical properties at high temperatures for many applications.

2.2 Surface Modification

The shellfish shell (SS) was first washed by water to remove the residual meat and attachments, then dried. The dried shellfish shell is ground to particulate form. Later, shellfish shell particles was immersed in 4% (w/v) NaOH solution for 48 h to remove the stratum corneum. It was then washed with deionized water until neutralization and dried. The dried powder was subjected to fine grinding and different size particles are separated using sieve shaker.

2.2. Experimental procedure

A hand lay-up technique has been adopted for making Glass-epoxy (GE) and SS_p GE composites. In the present study, a 7-mil E-glass plain weave fabric reinforcement material is used. The epoxy resin is mixed with the hardener in the ratio (10:1) by weight. The matrix system consists of a medium viscosity epoxy resin (LAPOX L-12) and a room temperature curing polyamine hardener (K-6) supplied by ATUL India Ltd, Gujarat, India. The filler material is shellfish shell of particle size 150µm. The geometry of composite 300mm X 300mm X 3mm was fabricated. The cured materials are cut to yield test specimens in accordance of ASTM standards. Tensile test has been conducted according to ASTM D 3039, Flexural test has been conducted to ASTM D 2344 and Hardness has been measured interms of HRC, value in accordance of ASTM E10. The details of the material combination and percentage of filler materials are given in Table 1.

Table 1. Details of samples prepared

Code	Vol.% SS_p filled	Matrix	Vol. %	Reinforcement	Vol. %
A	0	Epoxy	50	GF	50
B	5	Epoxy	45	GF	50
C	10	Epoxy	40	GF	50
D	15	Epoxy	35	GF	50

III. RESULTS AND DISCUSSION

3.1 Tensile Strength

The tensile strength of the composite materials depends upon the strength and modulus of the fibers, the strength and chemical stability of the matrix, the fiber matrix interaction and the fiber length.

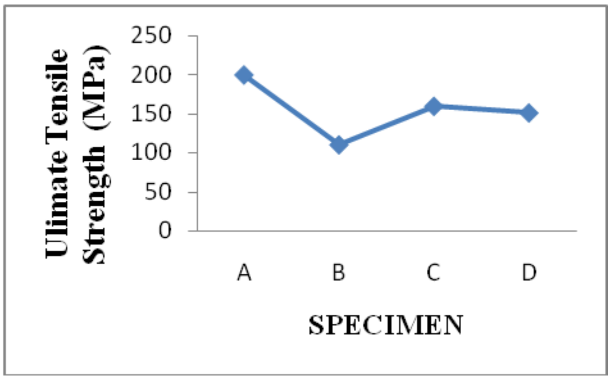

Figure 1. Ultimate Tensile Strength for different composition of composite

From Fig. 1. it is observed that composite filled by (10% Vol.) SS_p exhibited maximum ultimate strength (159.64MPa) when compared with other filled composites but lower than the un-filled composite this may be due to good particle dispersion and strong polymer/filler interface adhesion for effective stress transfer but further increase in filler content (up to 15 % Vol.), the tensile strength is found to be less this is due to more filler material distribution in the material.

3.2 Flexural strength

The flexural behavior of polymer composites in different volume percentages of SS_p (0%, 5%, 10%, and 15%) is presented. The flexural test was carried out on computerized universal testing machine, as per the ASTM standards. The test specimens are prepared as per ASTM D790 (125X3.2X12.7) mm. The four specimens were subjected to flexural test and their values were reported. The experimental results indicated that composite filled by (10% Vol.) SS_p, exhibited maximum flexural strength (194.50MPa). The reduction of flexural strengths is observed with increase in addition of SS_p, this may the fillers disturb matrix continuity and reduction in bonding strength between filler, matrix and fiber.

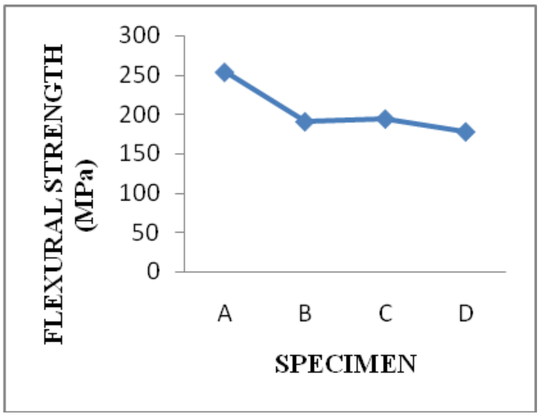

Figure 2. Flexural strength for different composition of composite

3.3 Hardness

The hardness values shown in Fig. 3 indicated that increase in filler content increases the hardness. The addition of filler content increases the hardness of composite material due to increase in the resistance strength of polymer to plastic deformation. In this case, the polymeric matrix phase and the solid filler phase would be pressed together and touch each other more tightly.

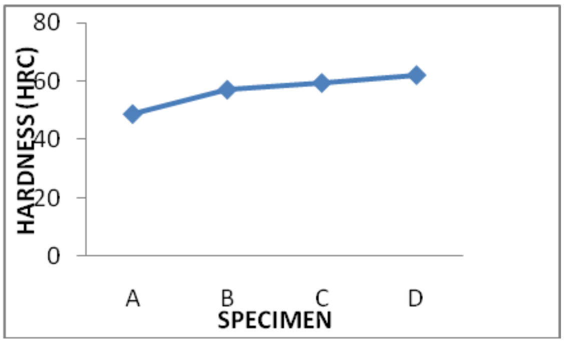

Figure 3. Hardness for different composition of composite

IV. CONCLUSION

Experimental investigation on tensile, flexural and hardness of shellfish shell reinforced polymer composites with different volume percentages of shellfish shell particles have been carried out in the present research work. The conclusions drawn from the present work are, the maximum tensile strength and maximum flexural strength is obtained for 10% Vol. of SS_p among all the different volume percentages. Composite filled by 15% Vol. of SS_p exhibited maximum hardness number, this may be due to uniform dispersion and decrease in inter particle distance with increasing particle loading in the matrix results in increase of resistance to indentation.

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