EFFECT OF GRAPHENE REINFORCEMENT ON THE FLEXURAL STRENGTH OF A THERMOSET EPOXY COMPOSITE

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Abstract - *In this study the effect of Graphene incorporation in different proportions into polymer epoxy was analysed. The graphene epoxy composite was prepared using hand lay-up technique and cured under room temperature and Graphene in varying weight fractions such as 0.1%, 0.3%, 0.5%.Three point bending test was conducted on the prepared specimens and the experimental results clearly showed enhancement in the flexural strength and flexural modulus. From the results it was seen that addition of Graphene increases the surface to volume ratio hence enhances the mechanical properties of the composite. Thus significant rise in mechanical properties by incorporation of graphene into composites was obtained compared to neat epoxy.*

***Key words*:** Graphene, Polymer Composite, Three point bending test.

1. INTRODUCTION

A composite material is mixture of more than one distinct constituent in which all the constituents are present in sensible ratios and poses unique properties so that the end composite is remarkably different from each of the constituents. The composite is a material with enhanced physical properties in comparison to the properties of the individual constituents.

It is difficult to imagine modern life without polymers because polymers are used as basic material from carry bags to rockets. Polymer is a macromolecule having very high molecular weight formed by combination of huge number of small molecules. PMC's are the composites that use polymer based resin as the matrix material and some form of fibres implanted in the matrix as reinforcements.

Graphene is the allotrope of carbon in the form of 2-D atomic shell, it is also the building block other allotropes including graphite, charcoal etc. Graphene is very effective at low loading fractions. It offers wide range of strength and stiffness depending upon its manufacturing process and its applications in specific areas.

Epoxy graphene composites are well known because of their outstanding ability to produce light and stiff materials with many other enhanced features. A major drawback with the use of graphene in epoxy matrix is agglomerating property of Graphene after mixing. The methods used to overcome this problem are dissolving graphene in solvent,

Functionalization and Sonication. These methods lead to excess wastage of graphene. In this study dispersion of graphene without dissolving in solvent was achieved and non-functionalized graphene was used to fabricate the composites. The mechanical properties of composite by reinforcing with graphene oxide in different ratios and accordingly the tensile strength, impact strength increased [1]. The addition of amino functionalized graphene oxide in to the epoxy yielded better fracture toughness, fracture energy and young's modulus [2]. Composites having better interfacial interactions in between graphene and matrix will exhibit enhanced mechanical properties even without dispersing graphene in better and stable way [3].

2. MATERIALS AND METHODS

Graphene used in this study was research grade graphene produced by Chemical exfoliation proprietary method supplied by United Nanotech Innovations Pvt Ltd Bangalore. The advantages of research graphene are high aspect ratio, easy handling, very thin exfoliated sheet, high purity.

Table -1: Properties of Graphene

Bulk density	0.24g/cc
Carbon purity	>99%
Diameter in X & Y directions	5-10 micron
Thickness avg in Z direction	5-10 nm
Surface area	150 m^2/g

The matrix used was Bisphenol A from the family of epoxy materials, supplied by Naptha Resins Bangalore. The resin acts as the matrix for the composite to bind the composite materials together and transfer the load acting on the composite to fibres in the composite material.

Table -2: Properties of Bisphenol A

Density	1.2 g/cm^3
Young's modulus	3.79 Gpa
Melting temperature	149-160^0
S.G. of the epoxy	1.19-1.20
Poisons ratio	0.37

Composite specimens were prepared by using hand lay-up method. Four different types of composite specimens were prepared with 0.00%, 0.1%, 0.3%, and 0.5% weight percentage of Graphene as the reinforcement. Composite slabs were cured for about 24 hours at room temperature and then removed from the mould. Cured composites were further cut in required dimension with the help of HITACHI PDA 100D Hand cutting machine available at Gogte Institute of Technology, Belgaum. These specimens were used for three point bending test.

Fig - 1 Samples prepared for testing

2.1 Three- point bending test

Standard test methods for flexural properties of polymer matrix composite materials according to which specimen were prepared and bending tests were performed. The test specimens were prepared according to the standards as mentioned in ASTM D790-02.

Modulus of elasticity in bending E_f, flexural stress σ_f, flexural strain ϵ_f were determined using Universal Testing Machine of make Fine Spavy and Associates and Engineers Pvt Ltd available at Gogte Institute of Technology. The Flexural stress and Flexural modulus were determined using the following formulae.

$$\text{Flexural stress} = \frac{3x\ F\ x\ L}{2\ x\ b\ x\ h^2} \qquad \text{eqn (1)}$$

$$\text{Flexural modulus} = \frac{F\ x\ L^3}{4\ x\ b\ x\ d\ x\ h^3} \qquad \text{eqn (2)}$$

Where F is the load applied in N, L is the span length in mm, b is the width in mm, h is the thickness in mm, and d is the deflection of the specimen in mm.

Fig - 2 Specimen loaded for testing

3. RESULTS AND DISCUSSIONS

Flexural or transverse rupture strength is material property, i.e stress a material can withstand just before it yields. This includes the evaluation of bending strength and bending modulus for different samples. The bending strength and bending modulus for different samples are summarized in the below table.

Table -3 Bending test results

Sl no	Materials	Bending strength (Mpa)	Bending modulus (Gpa)
1	Neat epoxy	88	0.968
2	Epoxy+0.1wt% Graphene	98.33	1.56
3	Epoxy+0.1wt% Graphene	99.97	1.75
4	Epoxy+0.1wt% Graphene	106.63	2.01

Effect of 0.1wt% graphene

Epoxy resins are brittle nature due to its three dimensional molecular structure. With addition of Graphene into the epoxy we can obtain localized reinforcement so that composite withstands more load compared to neat epoxy. Addition of 0.1wt% Graphene enhanced the pure epoxy strength by adhering to epoxy as the reinforcement. The flexural properties obtained showed an increment of about 10.4% and 37% in bending strength and bending modulus respectively

Effect of 0.3wt% graphene

With the incorporation of 0.3wt% Graphene the neat epoxy resin properties are enhanced as the graphene percent increases the materials stiffens. The bending strength and bending modulus obtained with the increment of about 11.9% and 44.68% respectively

Effect of 0.5wt% graphene

The bending strength and bending modulus obtained for the epoxy reinforced with 0.5wt% of Graphene, showed an increment of about 17.4% and 50% respectively in comparison to neat epoxy. Incorporation of Graphene into the epoxy increases the surface area to volume ratio. Graphene with its capability of high endurance to deformation during loading, provides flexibility thus it was possible to achieve a better performance with less weight fraction addition of Graphene into the epoxy.

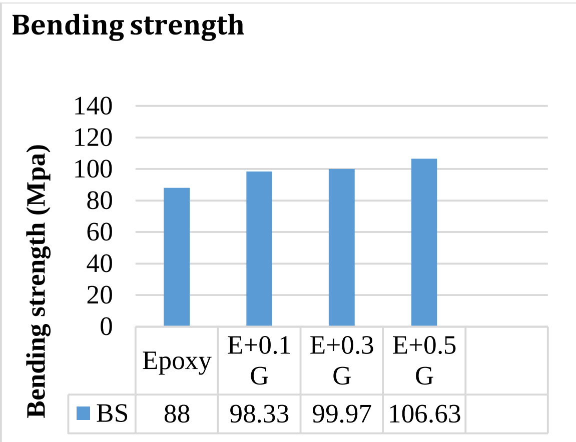

Chart - 1: Bending test results comparison

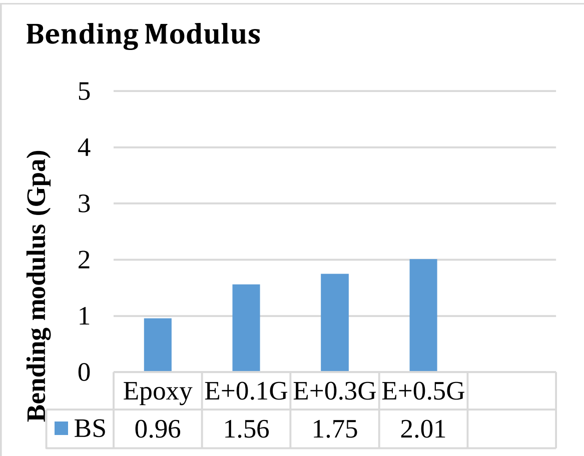

Chart - 2: Bending modulus comparison

From Chart1 and Chart 2 it was observed that composite made with 0.5% Graphene gives improved bending strength and bending modulus in comparison to neat epoxy and other combinations of epoxy/graphene composites.

4 CONCLUSION

Graphene as nano filler has potential to enhance the composites due to its exceptional mechanical properties and compatibility. The graphene nano particles build up leading to accumulation and increase in particle size, thus influencing the mechanical properties [5-6]

Addition of Graphene into epoxy in different weight fractions as 0.1%, 0.2%, 0.3% graphene enhanced the pure epoxy strength by adhering to epoxy as the reinforcement. Better flexural properties obtained were with 0.5% and increment of about 17.4% and 50% respectively in bending strength and modulus. Graphene with its capability of high endurance to deformation during loading, provides flexibility thus enhances more loading ability [7-8-9]. The significance of homogeneous property of the graphene epoxy composite was demonstrated by an increase in the flexural strength and flexural modulus.

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