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Behavior of Epoxy Composites under Tensile and Compressive Loading with Different Reinforcements

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Abstract: Epoxy composites are most widely used as composite materials in the majority of applications, thus the characterization of these materials for various loading and geometric configuration has become a primary concern to designers. The present work describes the mechanical characterization of epoxy composites consisting of epoxy resin, glass fibre, graphite and filler materials such as alumina, quartz and silica. Experiments like tensile test, and compressive test were conducted to find the significant influence of filler material on mechanical characteristics of fabricated composites. The test results show that with increase in filler volume fraction of alumina & silica there is a reduction in tensile & compressive strength, on the other hand the trend is different in case of quartz where, there is considerable increase in tensile & compressive strength with increase in percentage of quartz. The specimen code S1 has highest tensile & compressive strength of 26.82 and 117.68 Mpa respectively and the lowest tensile & compressive strength is for specimen A2 of 10.49 and 76.94 Mpa respectively. Further the SEM pictures unambiguously demonstrate how the initiation, propagation and termination regions have distinct appearances whose features vary with filler content, thereby demonstrating that fillers do influence the crack at all stages. The fractured facets obtained by using SEM clearly show that in all the cases the mode of fracture is brittle in nature.

Keywords: Composites, Epoxy, Fillers, Tensile Strength, Compressive Strength.

I. INTRODUCTION

Composites make a very broad and important class of engineering materials. These materials are extensively used in the variety of applications, like in aerospace industry, civil, construction, automobiles, chemical and other miscellaneous sectors [1-3].

Composites became very popular among material scientists as they provide ample scope to get modified properties by using varying components, different processing methods, and the expediency of replacing components with cheaper alternatives [4]. Epoxy resins are widely used as matrix in many fiber reinforced composites; they are a class of thermoset materials of particular interest to structural engineers owing to the fact that they provide a unique balance of chemical and mechanical properties combined with wide processing versatility. Epoxy resins are characterized by excellent mechanical and thermal properties, high chemical and corrosion resistance, low shrinkage on curing and the ability to be processed under a variety of conditions [5]. Within reinforcing materials, glass fibers are the most frequently used in structural constructions because of their specific strength properties.

Glass fiber reinforced epoxy composites results in an attractive combination of physical and mechanical properties which cannot be obtained by monolithic materials [6, 7]. These are widely used due to ease of availability of glass fibers and economic processing techniques adopted for production of components. Developments are still under way to tailor their properties for extreme loading conditions. One way to improve the strength of the FRP composites is to add various filler materials. These filler materials act as additional reinforcing components and enhance their mechanical properties. The properties of these composites depend on the type and size of the filler material used [8, 9]. Addition of silicon carbide, alumina, and titanium carbide improves hardness, strength and wear resistance of the composites [10, 11]. Graphite particles improve erosive wear resistance of glass fiber epoxy composites [12-16]. In the present work an attempt is made to study the

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effect of filler material in epoxy glass fiber reinforced composites.

II. EXPERIMENTATION

2.1 Materials for Composites

The matrix material used in this work was the medium-viscosity epoxy resin diglycidyl ether of bisphenol-A (commercial trade name, LY 556) along with a room-temperature curing hardener (HY 951) supplied by Hindustan Ciba-Geigy Limited, Bombay. The fibres used were E-glass, short fibres having a diameter of 10 µm and a length of 6 mm, thus yielding a high aspect ratio. The density of the fibres was 2.54 g cm-3. The particles used are amorphous graphite powder of 100-150 mesh, amorphous silica (Sio2) of PH 3-3.5, quartz sand No. 10 Min and Aluminum oxide (Al2o3) active neutral LR of PH 7.0 supplied by s.d. fine-chem. limited Mumbai.

The specimen composition with fibers, fillers and for different volume fractions are given in table 1.

Table 1. The specimen composition and their volume fractions.

Sp. Code	Specimen Composition			
	Epoxy	Graphite	Glass fiber	Alumina
A1	87%	5%	5%	3%
A2	85%	5%	5%	5%
A3	80%	5%	5%	10%
	Epoxy	Graphite	Glass fiber	Quartz
Q1	87%	5%	5%	3%
Q2	85%	5%	5%	5%
Q3	80%	5%	5%	10%
	Epoxy	Graphite	Glass fiber	Silica
S1	87%	5%	5%	3%
S2	85%	5%	5%	5%
S3	80%	5%	5%	10%

2.2 Specimen Preparation

The work involves Preparation of moulds and specimen by varying volumetric fractions of epoxy and fillers (silica, quartz & alumina), while glass fibre and graphite volumetric fraction being fixed. The Calculated volume of materials is mixed and uniformly compacted within the designed mould and allowed for curing at room temperature about 48 hours. The mould is then being separated into parts and the specimen is taken out.

2.3 Test Matrix

The total number of specimen that was prepared for the tests and the types of the tests are indicated in the table 2 below.

Table 2. The No. of specimen under study.

Test	No of Specimen									Total No. Of Specimen
	1	2	3	1	2	3	1	2	3	
Tension	2	2	2	2	2	2	2	2	2	18
Compression	2	2	2	2	2	2	2	2	2	18

Compression and tensile testing of the fabricated samples are tested using the Universal Testing Machine and study of microstructure was carried out for specimens before and after testing.

The tensile test is carried to determine the tensile strength of the composite specimen prepared. Tensile test details.

ASTM standard : D638

Machine : UTM

Specimen Used : Cylindrical

Specimen dimension : ϕ19mmx240mm

The compression test is carried out to obtain the compression strength of composite specimen prepared.

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Compression test details.

ASTM standard : D695-90

Machine : universal testing machine

Specimen used : cylindrical

Specimen dimension :ϕ19mmx48mm

III. RESULTS AND DISCUSSIONS

The test specimen was loaded to the machine and subjected to gradual load up to breaking load of the specimen and the corresponding results are noted. Based on experimental results for different hybrid composite specimens obtained by conducting tensile and compressive tests on specimens, strengths are estimated.

3.1 *Mechanical Properties of Composites*

The tailoring of well-bonded, durable interphases between the matrix and reinforcement has become a critical concern. The mechanical properties of fibre, graphite and fillers reinforced composites are dependent upon the stability of the interfacial region between the matrix, fibre and filler surfaces. The various mechanical properties of composite specimen under study are shown in table 3.

Table 3. Mechanical Properties of Composites under Study

Sp. Code	Tensile Strength σU N/mm2	Compressive Strength σU N/mm2
A1	15.74	85.68
A2	10.49	76.94
A3	13.98	82.19
Q1	13.98	83.93
Q2	17.48	92.68
Q3	10.49	87.43
S1	26.82	177.68
S2	23.46	147.51
S3	20.11	90.52

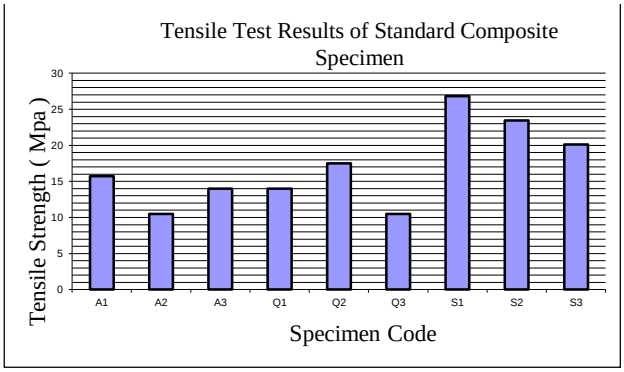

Fig. 1 Tensile Test Results of Standard Composite Specimen with Different Reinforcements

The tensile strengths of composite specimen with different reinforcements are plotted in the above Fig. 1.It is observed that with increase in filler volume fraction of alumina & silica there is a reduction in tensile strength. On the other hand the trend is different in case of quartz where, there is considerable increase in tensile strength with increase in percentage of quartz. The concentration of the filler, shape of particles, the manner in which the particle pack and the adhesion degree are very important to determine the strength and stress-strain behavior of the composite specimen. It is clear that the specimen code S1 has highest tensile strength of 26.82 Mpa and the lowest tensile strength is for specimen A2 & Q3 of 10.49 Mpa.

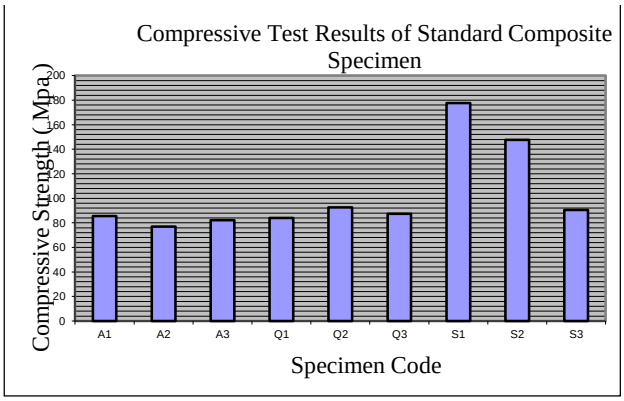

Fig. 2 Compression Test Results of Standard Composite Specimen with Different Reinforcements.

The Compressive strength of composite specimen with different reinforcements is plotted in the above Fig. 2. It is observed that with the increase in filler

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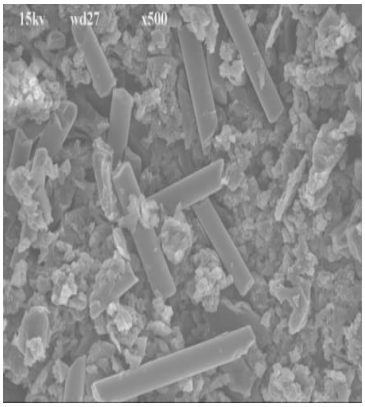
volume fraction of alumina & silica there is a reduction in compressive strength, but the margin of reduction in Silica is large in comparison to alumina. On the other hand the trend is different in case of quartz where, there is considerable increase in compressive strength with increase in percentage of quartz. It is clear that the specimen code S1 has highest Compressive strength of 177.68 Mpa and the lowest Compressive strength is for specimen A2 of 76.94 Mpa.

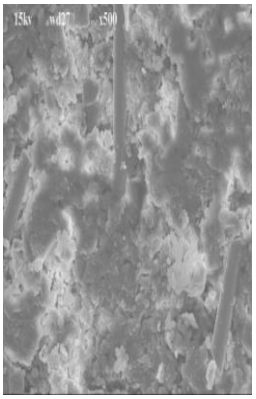
From the mechanical test results, it can be summarized that specimen S1 has good dimensional stability it is mainly due to presence of silica. The compressive and tensile strength of the entire composite specimen under test varies from 76.94-177.68 Mpa and 10.49-26.82 Mpa. The standard specimen S1 ensures maximum compressive and tensile strength of 177.68 Mpa and 26.82 Mpa respectively. Similarly the specimen A2 has the lowest compressive and tensile strength of 76.94 Mpa and 10.49 Mpa respectively.

3.2 Analysis of Microstructure

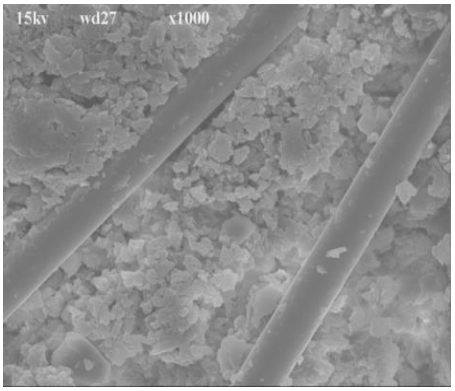
The microstructure of the prepared specimens is identified by the microscopic study of the scans of the specimen surfaces obtained by Scanning Electron Microscope (SEM). The microscopic observation of the scans is made to identify mainly the microstructure, bonding and the grain boundary of the untested specimens. Also the micro mechanism of fracture has been studied with the aid of SEM scans of fractured specimens.



(a). Specimen S1



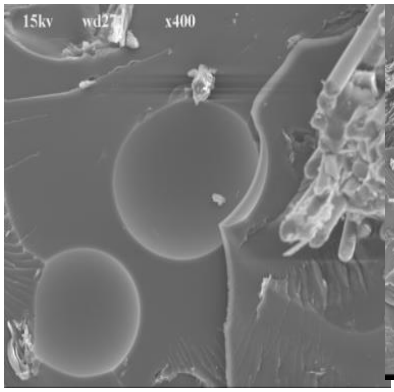
(b). Specimen A1



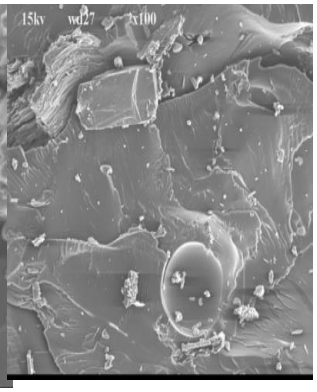
(c). Specimen Q2

Fig 3 Microstructure of Specimen Before Testing

It can be clearly revealed from the fig 3 (a), (b), (c) that the bonding of the particulates of the tested materials is precise. It can be seen from fig (a), the presence of voids at the grain boundary separation between the glass fibres and other particulates, these voids are due to the bonding which is bit poor with respect to glass fibres. In the other two cases also the same thing is repeating. As far as the uniformity of the specimen characteristics is concerned, it is observed that the glass fibres are in random orientation and it is observed that distribution of particulates and fibres are improper or non uniform, because of this reason, specimen exhibits different characteristics at different points.



(a). Tensile Tested Specimen A1



(b). Compression Tested Specimen Q2

Fig. 4 Fractographs of Tested Specimens

The fractured facets clearly show that in all the cases the mode of fracture is brittle in nature. The Fig 4 (a) shows the grain boundary of the tensile tested specimen A1 and also shows the fracture features in

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the highest-fibre-bearing epoxy resin composite. The Fig. (b) Shows the brittle mode of fracture of the compression tested Q2 specimen, also shows the crack propagation.

IV. CONCLUSION

Compression and tensile tests were conducted on three different compositions of epoxy composites consisting of epoxy resin, glass fibre, graphite and filler materials such as alumina, quartz and silica. Based on the experimental data and fractographic study, following conclusions was made.

- Higher the volume of Epoxy resin greater will be the compressive strength.
- On comparison it is found that the compressive strength of hybrid composite specimen with silica is superior to specimen with alumina and quartz.
- The SEM pictures unambiguously demonstrate how the initiation, propagation and termination regions have distinct appearances whose features vary with filler content, thereby demonstrating that fillers do influence the crack at all stages.
- The fractured facets obtained by using SEM clearly show that in all the cases the mode of fracture is brittle in nature.

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