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Effects of Fillers on Mechanical Properties and Fracture Toughness of E-Glass Fibre Epoxy Composite

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Abstract

The present work describes the effect of filler on mechanical properties of glass/epoxy composite. E-glass fibre is used as reinforcement, embedded in Huntsman Ly 556 epoxy matrix using Ht 972 as hardener and Nano clay as filler in preparation of the composite using the hand lay-up technique. The effects of fillers on mechanical properties were studied by conducting the tests. With addition of filler, Tensile, Flexural, Impact and Fracture toughness increases. The highest values of tensile, flexural, impact and fracture toughness were observed at a filler percentage of 2.5 wt%. The mechanical property of E-glass/epoxy composites decreases at 5 wt%. To obtain the maximum strength in composite, the filler percentage in the composite to be kept within 5 wt%.

Keywords: *E-glass fibre, fillers, mechanical properties, fracture toughness, epoxy resin*

1. INTRODUCTION

The use of polymeric materials has become very popular in engineering applications, As a result, a continuous improvement in fiber/matrix, development in innovate fabrication techniques offers possibilities for major roles in design, manufacturing and energy conservation. Glass fibres are the reinforcement agent embedded in the epoxy matrix, which give an excellent mechanical property. However, their final properties are mainly dependent on the strength and stability of the epoxy-fiber interface.

Glass fibres are most common fibre used in the polymeric fibre reinforced composites. The main advantage of glass fibre is its low cost, high tensile strength, low chemicalresistance and excellent insulating properties. Among its disadvantages are its low tensile modulus, somewhat high specific gravity etc. Two types of glass fibres are used in fibre reinforced polymeric composite. They are E-glass and S-glass.

E-glass has the lowest cost among all commercial fibres. [1][2]

Epoxy resins are mostly used in aerospace structure for high performance applications. The extensive use of epoxy resins in industry is due to, the ease of processing, excellent mechanical properties in composites, high hot and wet strength properties. The epoxy resins are superior to polyester resins due to their mechanical properties and better resistance to degradation by water and other solvents and also gives better adhesion to reinforcing fibre. [2]

Fiber-reinforced polymers are composite material consists of fibre of high strength reinforced into the matrix material forming a composite which possesses high strength and stiffness when compared to the otherorientation and matrix also transfers load uniformly onto the fibres and protects fibres from environmental damages due to changes in the temperature. [2]

Fibre reinforced polymer (FRP) composites are widely used in automotive, aircraft industries, manufacturing of spaceships etc. Composite mainly consists of thermoplastic or thermo set resin based on application and a fibre reinforcement chosen to achieve desired results as required for specific application. Epoxy resins are widely used as a matrix material for many fibre reinforced composites. Fibre reinforced plastics are widely used in aircraft and structural parts because they possess good mechanical properties and physical properties such as high specific strength and stiffness. Another important application of using FRP’s is in electronic industry, used for producing printed wiring boards. [2]

2. EXPERIMENTAL PROCEDURE

2.1 Material composition

An Epoxy Huntsman Ly556 is used as a matrix material (Fibre Poly Glass Pvt Ltd, Bangalore) in the composite.

Table1: Material composition

Sl No	Sample	Composition by wt%		
		Fibre	Epoxy	Filler
1.	G-E	55	45	0
2.	G-E (NC 2.5%)	55	42.5	2.5
3.	G-E (NC 5%)	55	40	5

E- glass fibre used as reinforcing material (Fibre Poly Glass Pvt Ltd, Bangalore) with having the highest volume fraction in the composite. Ht 972 is used as hardener (Poly Glass Fibre Pvt Ltd, Bangalore). Nano clay is used as filler material (M/s Global Nanotech, Mumbai). The fibre used is a 360gsm bidirectional, fibres being aliened at an angle of 90° with each other. The volume fraction of 55-45 (55% Glass fiber-40% epoxy resin) was kept for composite. The fibre percentage is kept constant and matrix percentage was varied along with filler. The filler added was 2.5wt% and 5wt %. The details are listed in the Table 1. [3]

2.2 **Specimen preparation**

Hand lay-up is a simple method for composite production. Due to the economical aspect and simplicity of hand- layup technique, this technique is being used in medium and small scale industries.

A mold must be used for hand layup parts unless the composite is to be joined directly to another structure. The mold can be as simple as a flat sheet or have infinite curves and edges. For some shapes, molds must be joined in sections so they can be taken apart for part removal after curing. Before lay-up, the mold is prepared with a release agent to insure that the part will not adhere to the mold. Reinforcement fibers can be cut and laid in the mold. The lay-up technician is responsible for controlling the amount of resin and the quality of saturation.

The composite is prepared using hand lay- up technique. The bi-directional fibre mat is stacked one after another with the epoxy in between each fibre mat. To obtain a composite of 3mm thickness, number of fibre layers used are 9 and for 8 mm composite thickness, the layer of fibres obtained are 24. The composite is then

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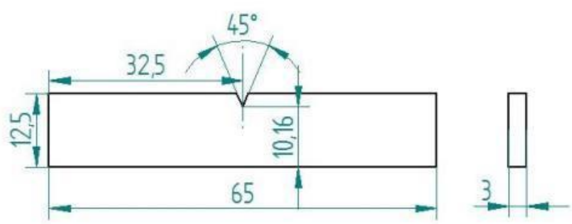
cured in the oven at a temperature of 160°C for 1 hour, then the composite is hot pressed at a pressure of 250 kg/cm2 (23.5 MPa). After the composite hardens, it is cut into a required dimension. [3]

2.3 Mechanical Tests

i. Impact test

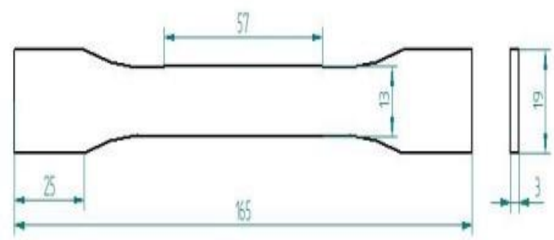
The Izod impact test was conducted according to ASTM D256 using impact test machine (International Equipment). A notch was prepared with an included angle of 45° on the sample having a thickness of 3mm. The width and length of the sample are 12.5mm and 65mm respectively.



2.4 ***Fig 1: Impact test specimen***

ii. Tensile test

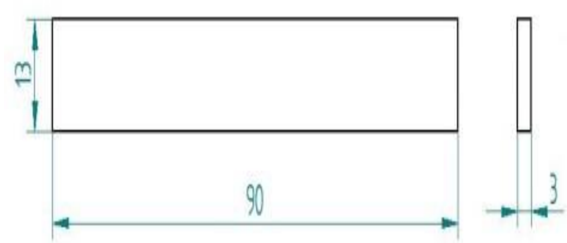
The tensile test was carried as per ASTM D638 using the Universal testing machine (KALPAK, capacity-100KN). The test speed was set at 5 mm/min. The dimensions of the tensile test specimen are length 165mm, width 19mm and thickness 3mm as shown in the figure. The tensile modulus and strength was noted from the load- displacement diagram.



2.5 ***Fig 2 Tensile test specimen***

iii. Flexural test

The flexural test was conducted to determine the flexural properties of glass- epoxy composite by three point bending test was performed according to ASTM D790 using Universal testing machine (KALPAK, capacity-100KN) under room temperature. The test speed was set at 2mm/min. The test specimen has a span length of 90mm, width of 13mm and thickness 3mm as shown in the figure.



2.6 ***Fig.3 Flexural test specimen***

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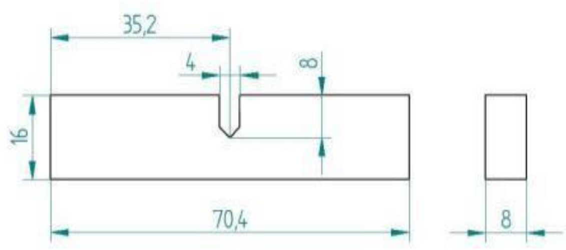
iv. Fracture toughness

The fracture test was conducted to determine the fracture toughness of the material. The three point bending test was performed according to ASTM D5045 using Universal testing machine (KALPAK, capacity-100KN) under room temperature. The test speed was set at 2 mm/min. The Sl No Sample Composition by wt% Fibre Epoxy Filler 1. G-E 55 45 0 2. G-E (NC
2.5%) 55 42.5 2.5 3. G-E (NC 5%) 55 40 5
dimension of the test specimen are, length 70.4mm, width 16mm and thickness 8mm as shown in the figure.



*2.7 **Fig 4: Fracture test specimen***

v. Impact strength

It is the ability of the material to resist the fracture under stress applied at high speed. The specimens are deformed within a short time and therefore exposed to high strain rates. The impact strength is determined using the Izod test apparatus, in which the test specimen is clamped vertically to a cantilever beam and broken by a single swing of the pendulum released from the fixed distance from the specimen clamp The composite with 2.5wt % Nano clay filler has the highest impact strength compared to 0wt% and 5wt%. From the results it concludes that the maximum impact strength can be obtained when the filler percentage is below 5wt%. With increase of filler percentage more than 5wt %, the composite attains the brittle property thus resulting in lesser impact strength. The impact strength of E-glass fibre epoxy composite with Nano-clay filler is shown in figure and table.

RESULTS AND DISCUSSIONS

*2.8 **Table 2: Impact test results***

Sl No	Materials	Impact energy (J)	J/m
1.	G-E	4.83	1888.05
2.	G-E (NC 2.5%)	5.2	2126
3.	G-E (NC 5%)	4.55	1753.05

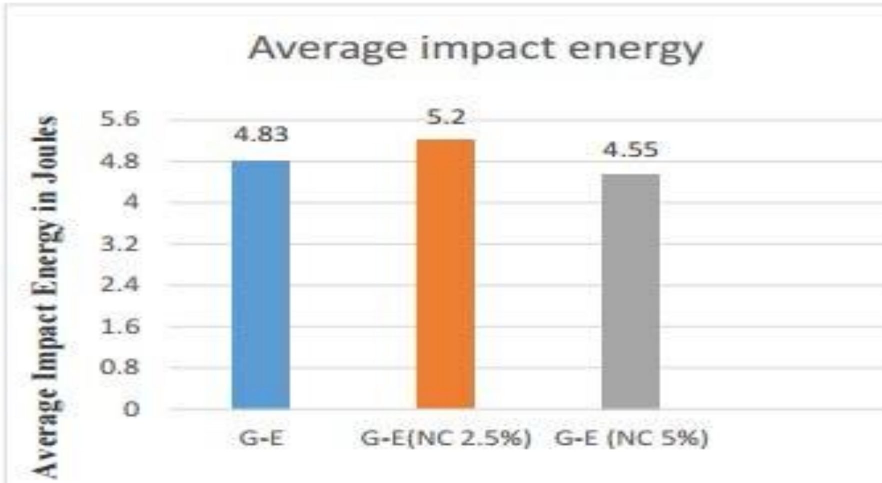


Fig 1: Impact energy vs filler wt% Table 3: Tensile strength

Sl No	Materials	Peak load (N)	UTS (N/mm^2)
1.	G-E	10757.6	286.64
2.	G-E (NC 2.5%)	11236.75	323.01
3.	G-E (NC 5%)	12662.65	311.2

Tensile properties

Tensile properties provide information about the behavior of the material when it is subjected to stretching or pulling force before it fails. In this work, the mechanical properties such as tensile, flexure and impact were used to evaluate the strength and toughness E-glass/epoxy composites filled with Nano-clay filler. The Ultimate tensile strength increases with increase in filler percentage. The UTS has a maximum value at 5wt%, compared to 0wt% and 2.5wt%. The ultimate tensile strength of composite is shown in figure 2, 3 and table 3.

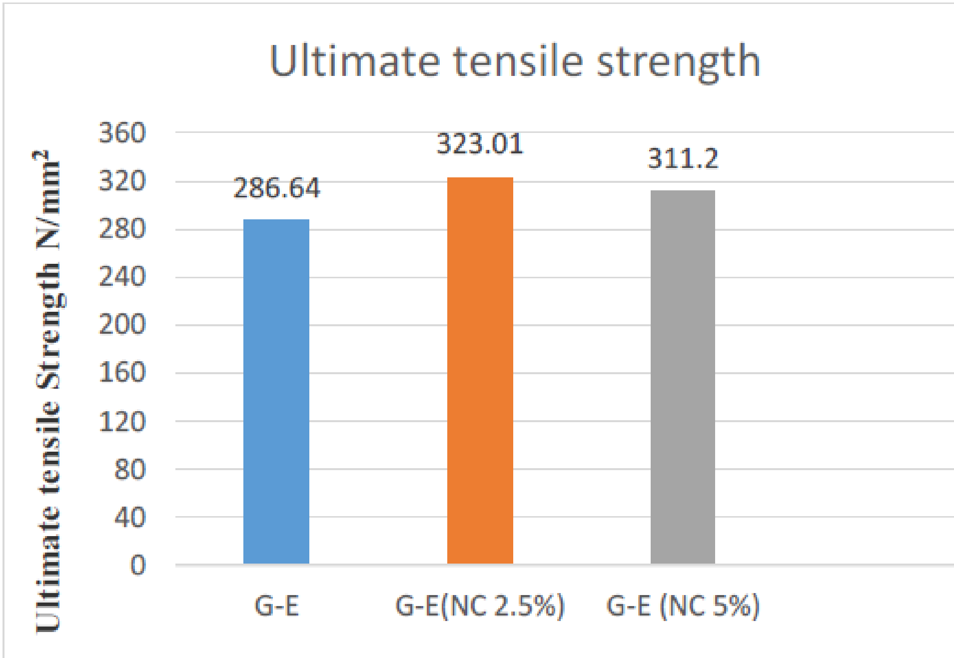


Fig. 2: Bar chart showing ultimate tensile strength

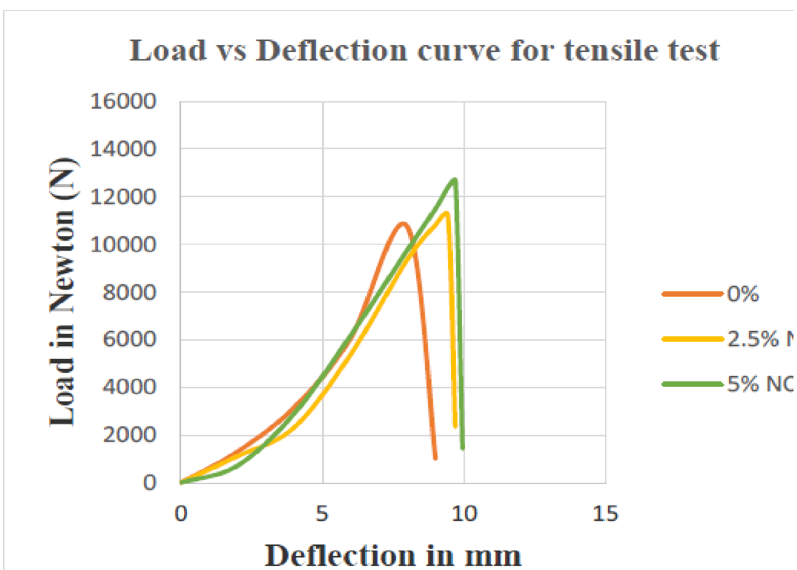


Fig.3 Load vs deflection curve for tensile test

Flexural properties

Flexural properties provide information about the behaviour of material in bending. The tested result of flexural strength and flexural modulus values of E-glass/epoxy composites with varying percentage of Nano clay in wt. % is shown in Table. The composite with 2.5 wt% Nano clay filler has the highest flexural strength. The flexural strength decreases at filler percentage 5 wt%.

Table 4: Flexural strength

Sl No	Materials	Flexural Strength GPa
1.	G-E	21.01
2.	G-E (NC 2.5%)	28.41
3.	G-E (NC 5%)	27.54

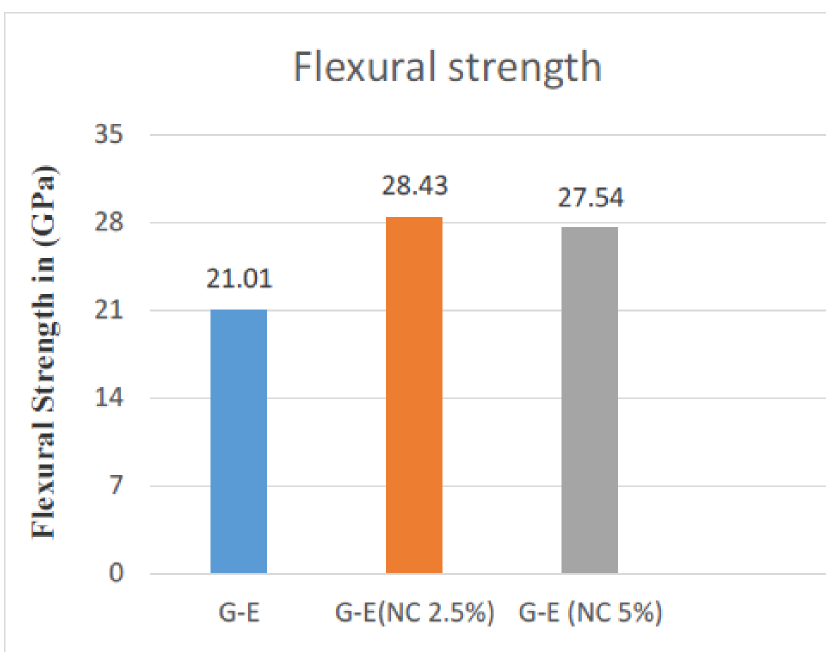


Fig. 4: Bar chart showing flexural strength

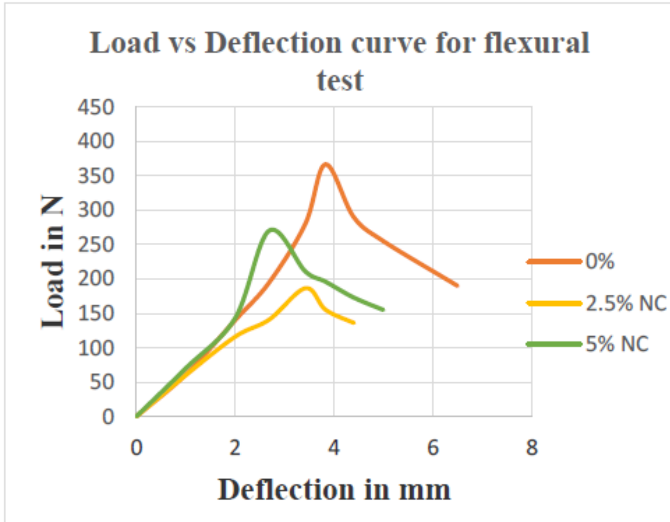


Fig.5 load vs. deflection curve for flexural test

Table 5: Fracture toughness

Sl No	Materials	Peak load (N)	Fracture toughness (MPa √m)
1.	G-E	1220.5	9.37
2.	G-E (NC 2.5%)	1606.61	13.46
3.	G-E (NC 5%)	1129.1	9.55

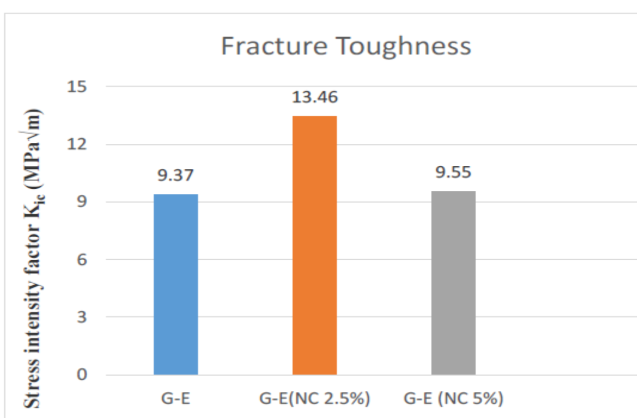


Fig. 6: Bar chart showing fracture toughness

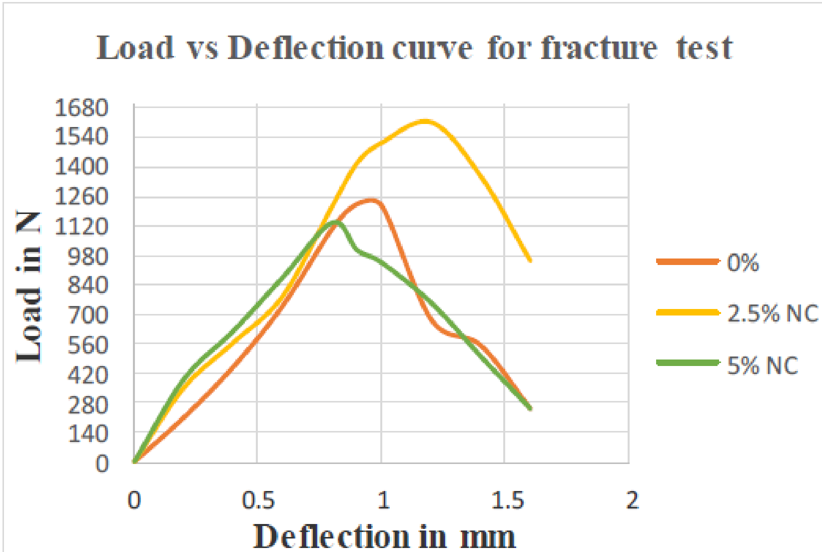


Fig. 7: load vs deflection curve for fracture test

Fracture toughness

Fracture toughness is a property which describes the ability of a material containing a crack to resist fracture. Fracture toughness of a material is determined from the stress intensity factor (K) at which a thin crack in the material begins to grow. It is denoted KIc and has the units of Pa√m. The fracture toughness of E-glass/epoxy composite with varying percentage of filler is shown in Table 5 and Figure 6 and 7.

3. SEM (SCANNING ELECTRON MICROSCOPE) ANALYSIS

SEM test is carried to determine the micro-structure characteristics of materials present in the composites. SEM test helps in identifying failure analysis of solid inorganic materials. The test is done at high magnification, which generates high resolution images and helps in measuring objects and very small features. The signals generated during SEM test produce an image and provide information of the sample which includes external morphology (texture), orientation of materials which makes the sample.

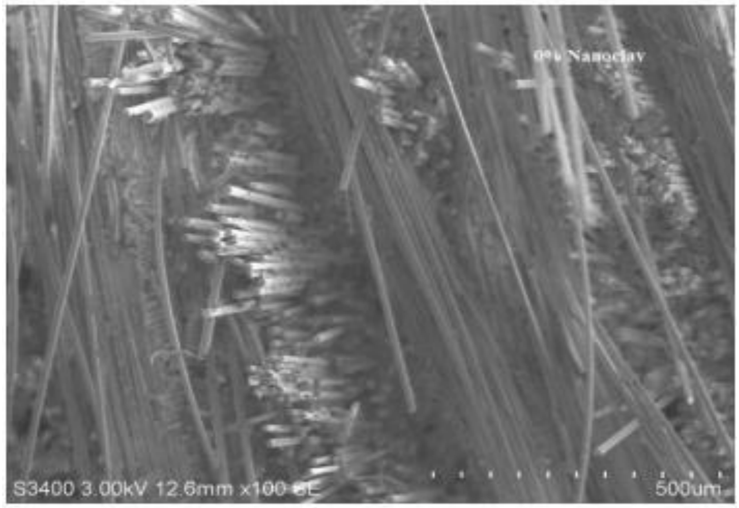


Fig. 7: 0 wt% and 5 wt% nano clay in composites

Figure 4.8(a) and 4.8(b) shows the scanning electron micro graphs of composite containing 0 wt% and 5 wt% of Nanoclay. From both the figures the surface properties can be observed, which shows more Nanoclay particles in the composite containing 5 wt% Nanoclay. When SEM micro graphs compared with the mechanical results, more percentage of Nanoclay in the composite make it brittle thus resulting in decrease in the mechanical properties. Due to this, the mechanical properties showed decrease in the value at filler percentage of 5 wt% while the maximum values were obtained at filler percentage of 2.5 wt%

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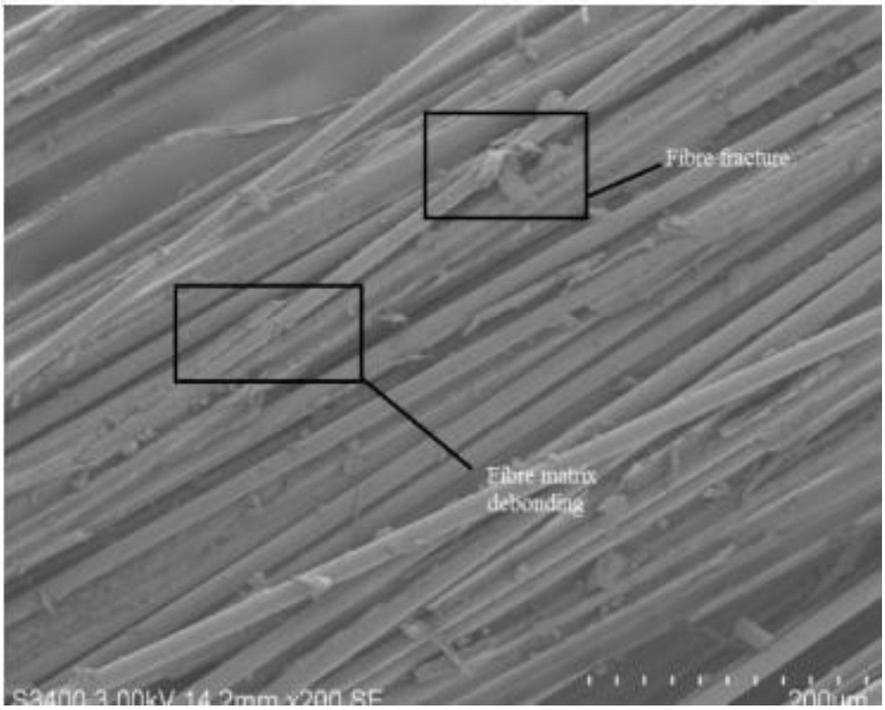

Fig. 8: Fiber fracture and fiber matrix debonding

4. CONCLUSION

Glass epoxy composites with varying amounts of Nano clay were fabricated. Fracture toughness, tensile, flexural and impact properties of the Nano clay-E-glass epoxy composites were measured. The following are the important findings observed from the test.

- Tensile, Impact, Flexural and Fracture toughness increases with addition of filler material.
- The highest values of mechanical properties were obtained at a filler percentage of 2.5wt%.
- The values of mechanical properties of E-glass/epoxy composite decreased at filler percentage of 5 wt%.
- With increase in filler percentage in the composite, the strength gets reduced and the composite attains the brittleness property.
- To obtain the maximum strength in composite, the filler percentage to be kept within 5 wt%.

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