# Evaluation of Mechanical Properties of Banana and S-glass Fiber Reinforced Hybrid Nano Silica Composite

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**Abstract:**

The aim of the present work is to evaluate the Mechanical Properties of Banana and S-glass Fiber Reinforced Hybrid Nano Silica Composite. The glass and other synthetic fiber reinforced polyester composites shows slight Improvement in the mechanical properties of the composite when compared with the natural fiber reinforced composite but their applications are limited because of high cost of fabrication. So to overcome the cost of fabrication a new hybrid composite is fabricate with 50% of natural fiber and 50% of synthetic fiber. The new composite is fabricated by reinforcing the stacking layers of woven banana and s-glass fibers with the polyester resin as matrix and nano silica as filler material. Different samples were prepared by changing the stacking sequence of fiber placed in the composite and weight percentage of nano silica powder that is mixed into the resin. The fabrication is done by hand lay-up method. The mechanical properties like tensile strength, flexural strength, tensile modulus, and flexural modulus were studied. Morphological study is done through scanning electron microscope to observe the fibers pull out, stacking of fibers and the behavior of matrix in hybrid composite. With the change of weight percentage of nano silica and the stacking sequence of fibers in the composite shows the improvement in mechanical properties.

**Key words:** stacking sequence of fibers, polyester resin, nano silica.

## 1. Introduction:

A composite material generally consists of two are more macro constituents with different chemical composition and having a distinct interface which separates each other. The constituents are also insoluble in each other. The consistent which is harder and stronger than the other consistent is called as reinforcement which is a discontinuous phase and the other constituent is called as a matrix which is a continuous phase. The discontinuous phase may consist of one or more phases. Nano or micro powders can be taken as filler material in the matrix. There are three types of matrix materials they are metal matrix, ceramic matrix and polymer matrix out of which polymer matrix has wide applications. The reinforcement may be fibrous or non-fibrous. The fibers which are extracted from plants and other living species are called natural fibers and man-made fibers are called as synthetic fiber. The fiber, mainly acts as the load carrying members in the composite.

By the combination of two or more different types of fibers as reinforcement in a matrix we obtain a hybrid composite material. The hybridization of natural fiber and synthetic fibers shows a significant strength value and low cost of fabrication. Natural fiber shows moderate mechanical properties, but they available abundantly and at very low cost, whereas synthetic fiber possess high mechanical properties but they are high in cost. The fabrication of new hybrid composite of high strength and low cost of fabrication is madden by combining the both synthetic and natural fibers as reinforcement in this composite. With this we can reduce 50% cost of production and we can obtain a significant strength value.

Banana fiber is the waste product of banana cultivation, which is extracted from the stems of banana trees. So, it is abundantly available at low cost. Banana shows an energy saving replacement of synthetic fibers. It is a natural bast fiber which has a wide range of applications and it can be developed into mats, ropes and twines, but it uses only 10% of its pseudo stem.

A number of extremely fine fibers of glass will constitute a glass fiber. It is available at moderate cost when compared to other synthetic fibers. They are significantly less brittle, very strong and relatively lightweight when used in composite. They are mainly used in building a thermal insulation.

Silicon dioxide nano particles also known as silica nano particles or nano silica. They are a great deal of research due their stability and they have very low level of toxicity. Nano silica powder is appears to be in the form of white powder. Nano silica is a good additive to the plastics and rubbers. It is also used as strengthening filler for composites Concrete and other construction composites.

Polymer matrixes are mainly categorized into three types, they are thermosets and thermoplastics. Polyester resin is a thermosetting polymer. It is adequately resistant to water, a variety of chemicals, temperature and ageing. It has good wetting properties of glass fibers and they are mainly used in sheet molding compounds, bulk molding compounds. It is very popular for their simple fabrication methods and low cost.

From the references [1] has studied the mechanical properties and tribiological behavior of nano filler reinforced polymer nano composites with different stacking sequence of the fiber. The mechanical properties increase as a weight percentage of nano powder increases up to three weight percentage of nano powder. The study says that the stacking sequence and weight percentage of nano filler are important factors for tensile and flexural strengths. Many studies show that hybrid composite mainly contains either natural fiber or synthetic fibers as reinforcement which gives moderate mechanical properties. A less number of studies have been carried on the both natural and synthetic fibers reinforced hybrid composites with the nano filler material. Therefore, the aim of the present study is to fabricate a new type of composite with woven banana and s-glass reinforced hybrid polyester composite with nano silica as filler material.

## 2. Methodology:

### *2.1 Material:*

To fabricate the laminated hybrid composite used in this study uses the following material and the composites with stacking sequence and percentage of mass are represented in table 2. The physical properties of banana and s-glass fiber are shown in table 1.

- Polyester resin: - The general polyester resin is used and is mixed with catalyst (MEKP) and hardener (cobalt) for curing.
- Banana fiber: - The banana fiber used in the woven mat form.
- S-glass fiber: - The S-fiber used in the woven mat form.

Table 1. Physical properties of banana and S-Glass fiber

| Physical Properties | Banana fiber | S-Glass fiber |
|---|---|---|
| Density (g/cm$^3$) | 1.3 | 2.4 |
| Tensile strength(MPa) | 54 | 4700-4800 |
| Flexural modulus(GPa) | 2-5 | 4.5-4.9 |
| Young's modulus(GPa) | 3.48 | 86-93 |

Table 2. Stacking sequence and weight fractions (%) of fiber and resin in the composite

| Stacking sequence | Wt.% of fibers | | Fiber weight fraction(%) in composite | Polyester resin weight fraction(%) in composite |
|---|---|---|---|---|
| | Banana | S-glass | | |
| BGGB | 50 | 50 | 26 | 74 |
| GBBG | 50 | 50 | 26 | 74 |
| GBGB | 50 | 50 | 26 | 74 |

G= Woven S-glass fiber and B= Woven Banana fiber.

### *2.2 Fabrication:*

Firstly, the surface the mold is cleaned with thinner solution and was allowed to dry for 10 minutes. Now applying the grease as releasing agent to all sides of the mold and the base plate. A few minutes is given to mold to get it set for mold lay-up. The polyester resin, catalyst and hardener are mixed in 100:1.5:1.5 proportion and nano silica is used as filler material the curing time of the resin is observed carefully from the chart of laboratory that are usually notified. The care must take, so that the resin does not cure in the curing vessel itself. A constant watch over is maintained while mixing of resin, hardener, catalyst and nano silica using a stopwatch. The woven banana fiber mat is cleaned gently and is kept in the sunlight for 1-2 hours. The size of the laminate which is to be fabricated is restricted to 200mmx170mmx3mm. Every laminate consists of four layers of fibers out of which two layers are woven banana fiber and two layers are s-glass fiber. The laminate is prepared by placing the fiber mats one over the other in the polyester resin which is mixed up with nano silica. The fabrication is done by the hand lay-up method. Similarly, different laminates were prepared by changing the stacking sequence of fibers and weight percentage of nano silica. Now all the hybrid composite laminates were cured under the general loading conditions for 12 hours. The woven banana fiber and s-glass fiber used in the fabrication are given in Figure. 2.2.1, Figure 2.2.2.

Figure. 2.2.1 Woven Banana fiber

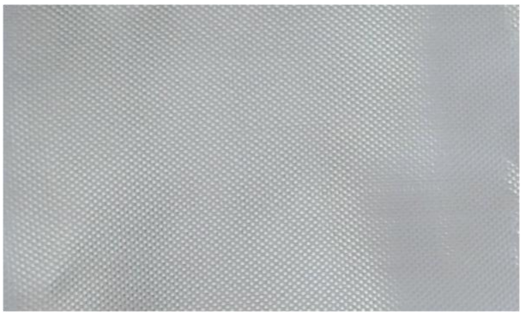

Figure. 2.2.2 Woven S-glass fiber

## 3. Mechanical properties of hybrid composite:

### *3.1 Tensile test:*

The flat tension test specimens were prepared according to the ASTM D638M-89 and the length of the specimen is 160mm. The test is carried out on the Tensometer, by means of applying load with a crosshead speed of 10mm/min on the specimen until the results are observed before specimen gets failure. Five samples of each laminate were tested to get the mean values. The same method is followed for all the tensile test specimens of different compositions to get the mean tensile strength and tensile modulus values from the mean load and elongation values. The tensile test specimens before and after the tests are given in Figure. 31.1. and Figure. 3.1.2.

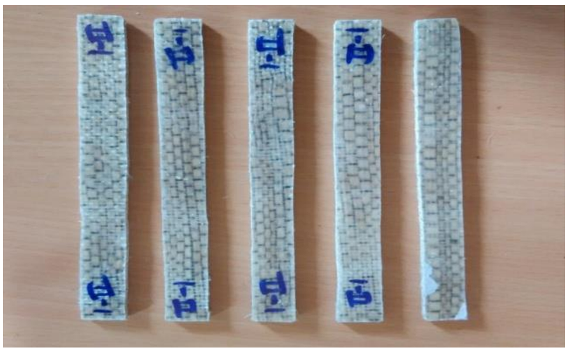

Figure.3.1.1.Tensile test specimens before fracture

Figure. 3.1.2 Tensile test specimens after fracture

### *3.2 Flexural test:*

The flat flexural test specimens were prepared according to the ASTM D638M-89 and the length of the specimen is 100mm. The test is carried out on the tensometer, by means of 3-point flexural loading method. The load is applied with a crosshead speed of 10mm/min on the specimen until the results are observed before specimen gets failure. Five samples of each laminate were tested to get the mean loading and slope of bending curve values. The same method is repeated for all the nine laminates and the results are compared. The flexural test specimens before and after the tests are given in Figure. 3.2.1 and Figure. 3.2.2.

Figure. 3.2.1 Impact test specimens before fracture

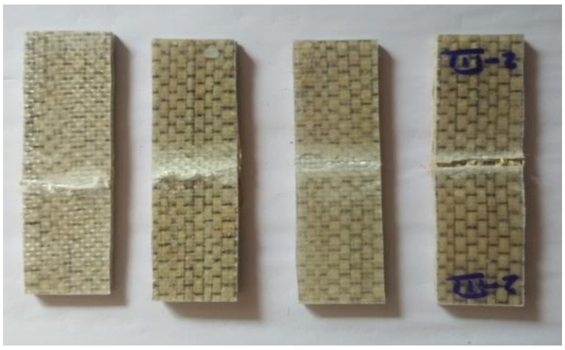

Figure. 3.2.2 Impact test specimens after fracture

## 4. Results and discussions:

In the above methodology total 9 laminates were prepared by changing the stacking sequence of fibers and weight percentage of nano silica. Five samples for tensile test and 5 samples for flexural test from each laminate are tested as per standard ASTM methods. The results are observed and strength, modulus values are calculated. The values are tabulated in the table 3.

Table. 3 Mechanical Properties of hybrid composite with addition of nano silica

| Composite Sample | Tensile Strength (MPa) | Flexural Strength (MPa) | Tensile Modulus (GPa) | Flexural Modulus (GPa) |
|---|---|---|---|---|
| Polyester | 19.76 | 35.5 | 0.23 | 0.88 |
| BGGB+1wt.% nano silica | 91.2 | 281.33 | 4.43 | 5.14 |
| BGGB+2wt.% nano silica | 101.44 | 345.34 | 4.16 | 4.74 |
| BGGB+3wt.% nano silica | 112.64 | 176 | 3.36 | 4.5 |
| GBBG+1wt.% nano silica | 93.97 | 238.67 | 3.31 | 3.01 |
| GBBG+2wt.% nano silica | 96.64 | 268 | 3.5 | 4.15 |
| GBBG+3wt.% nano silica | 100.1 | 321.33 | 4.6 | 3.5 |
| GBGB+1wt.% nano silica | 98.93 | 304 | 3.21 | 3.14 |
| GBGB+2wt.% nano silica | 102.99 | 380 | 3.31 | 5.3 |
| GBGB+3wt.% nano silica | 101.49 | 302.67 | 4.8 | 3.03 |

G= Woven S-glass fiber and B= Woven Banana fiber.

### *4.1 Tensile strength and tensile modulus:*

The Tensile strength and tensile modulus values are observed and the corresponding graphs are plotted. The graph for tensile strength and tensile modulus of BGGB hybrid composite laminate is given in Figure. 4.1.1. And Figure. 4.1.2. Respectively. From the graph it is observed that the tensile strength is maximum at 3wt. % nano silica and is minimum at 1wt. % nano silica. The tensile modulus value is maximum at 1wt. % nano silica and minimum at 3wt. % nano silica.

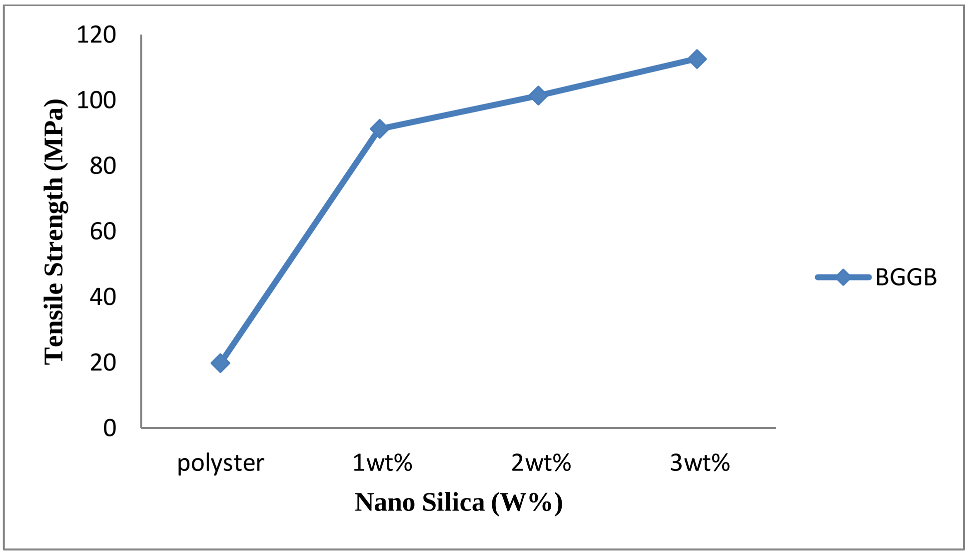


Figure. 4.1.1. Tensile Strength Variation for Different wt. % of Nano Silica.

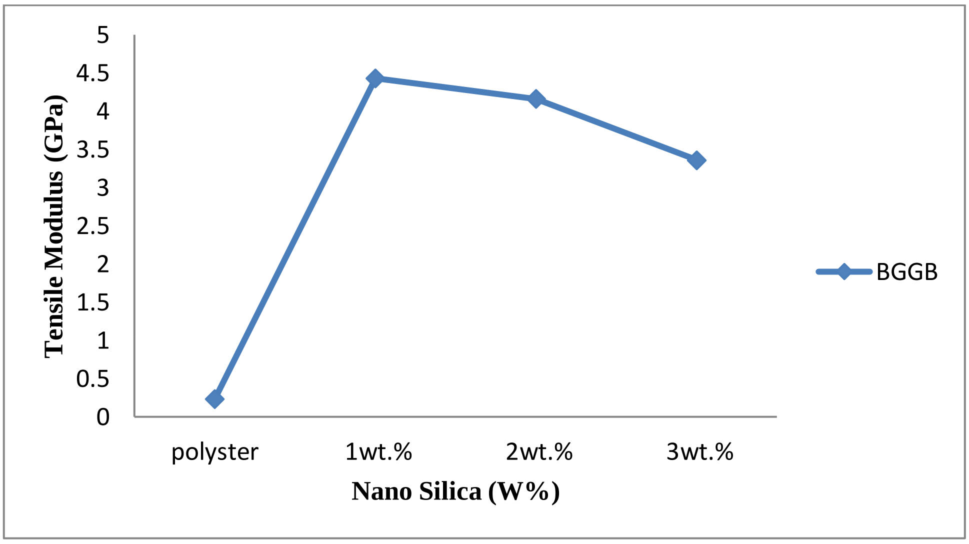


Figure. 4.1.2. Tensile Modulus Variation for Different wt. % of Nano Silica.

Now the graph for tensile strength and tensile modulus of GBBG hybrid composite laminate is given in Figure. 4.1.3 and Figure. 4.1.4 respectively. From the graph it is observed that the tensile strength is maximum at 3wt. % nano silica and is minimum at 1wt. % nano silica. The tensile modulus value is maximum at 3wt. % nano silica and minimum at 1wt. % nano silica.

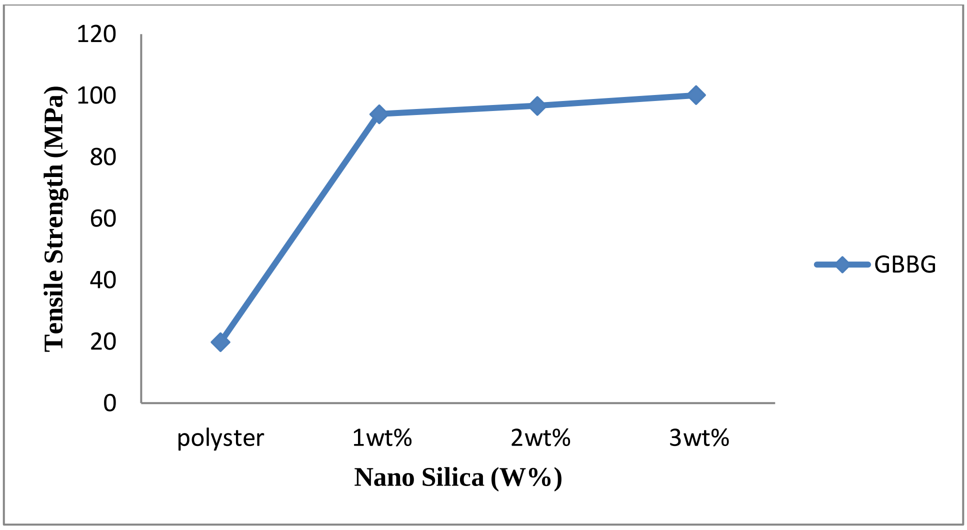


Figure. 4.1.3. Tensile Strength Variation for Different wt. % of Nano Silica.

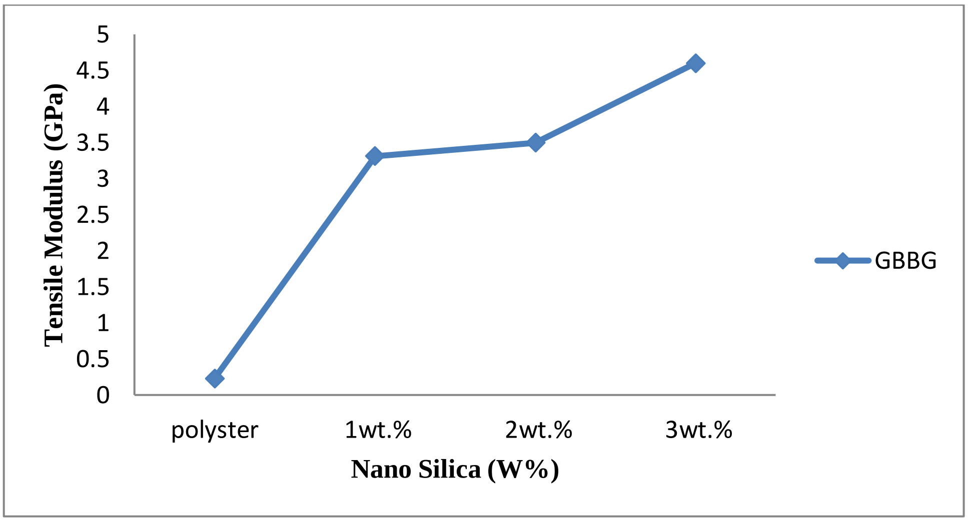


Figure. 4.1.4 Tensile Modulus Variation for Different wt. % of Nano Silica.

Now the graph for tensile strength and tensile modulus of GBGB hybrid composite laminate is given in Figure. 4.1.5 and Figure. 4.1.6 respectively. From the graph it is observed that the tensile strength is maximum at 2wt. % nano silica and is minimum at 3wt. % nano silica. The tensile modulus value is maximum at 3wt. % nano silica and minimum at 1wt. % nano silica.

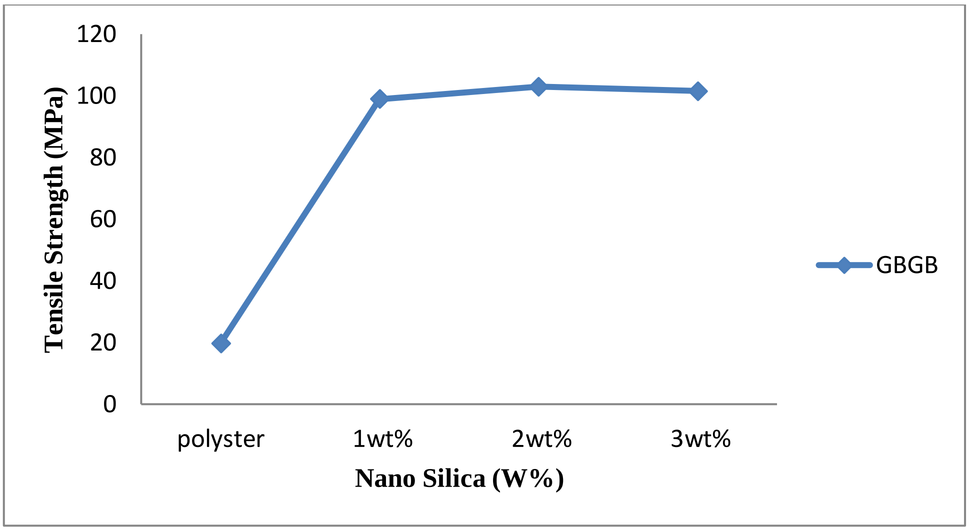


Figure. 4.1.5 Tensile Strength Variation for Different wt. % of Nano Silica.

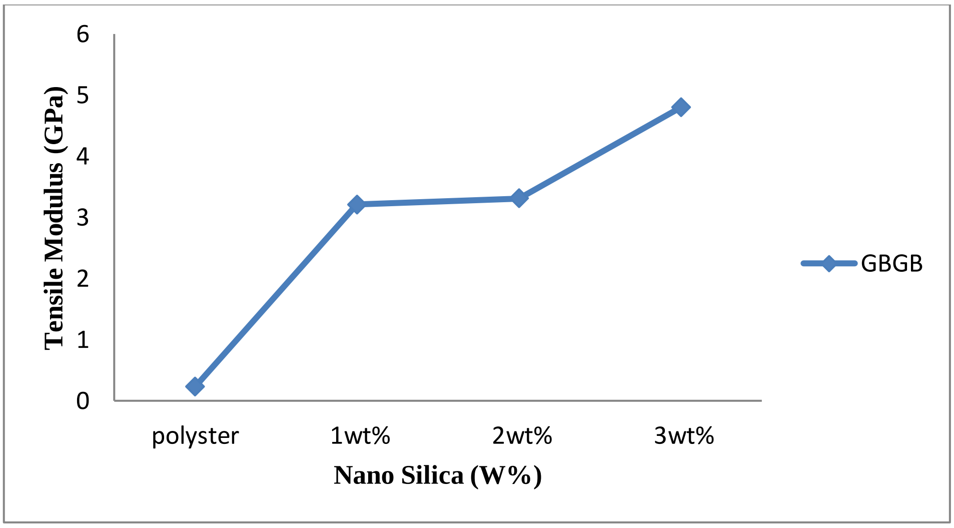


Figure. 4.1.6 Tensile Modulus Variation for Different wt. % of Nano Silica

*4.2 flexural strength and flexural modulus:*

The flexural strength and flexural modulus values are observed and the corresponding graphs are plotted. The graph for flexural strength and flexural modulus of BGGB hybrid composite laminate is given in Figure. 4.2.1 and Figure. 4.2.2 respectively. From the graph it is observed that the flexural strength is maximum at 2wt. % nano silica and is minimum at 3wt. % nano silica. The flexural modulus value is maximum at 1wt. % nano silica and minimum at 3wt. % nano silica.

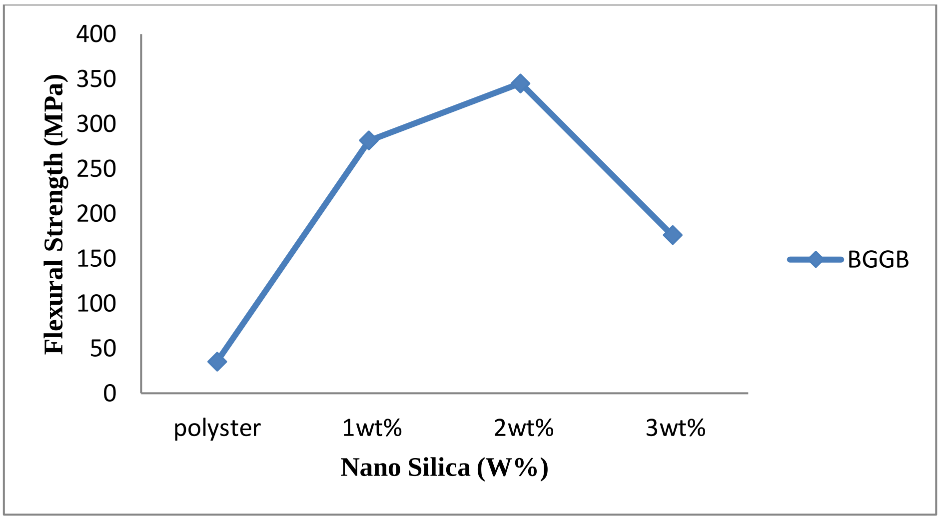


Figure. 4.2.1 Flexural Strength Variation for Different wt. % of Nano Silica.

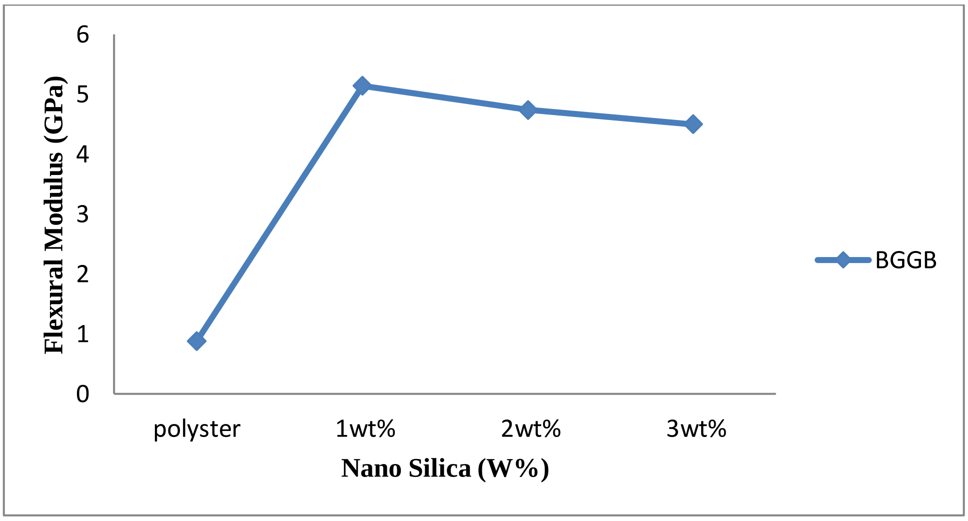


Figure. 4.2.2 Flexural Modulus Variation for Different wt. % of Nano Silica

Now the graph for flexural strength and flexural modulus of GBBG hybrid composite laminate is given in Figure. 4.2.3 and Figure. 4.2.4 respectively. From the graph it is observed that the flexural strength is maximum at 3wt. % nano silica and is minimum at 1wt. % nano silica. The flexural modulus value is maximum at 2wt. % nano silica and minimum at 1wt. % nano silica.

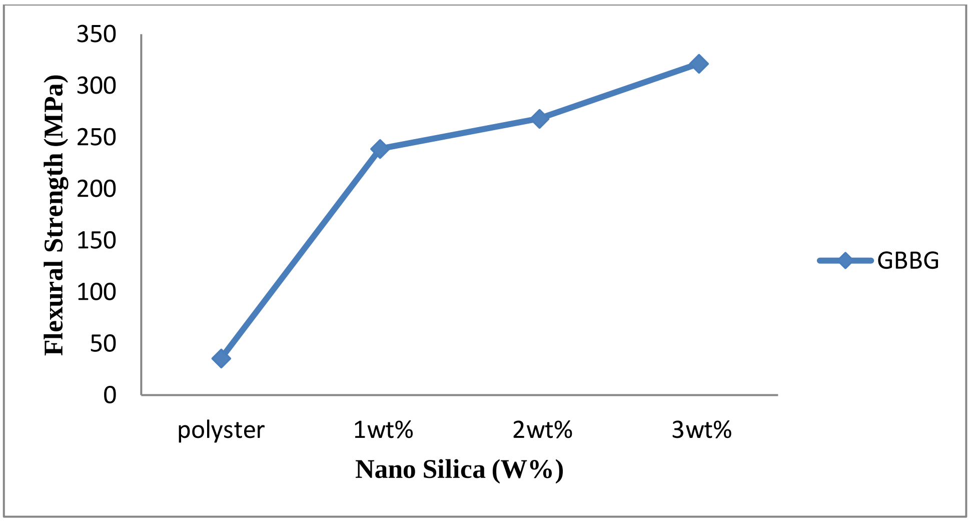


Figure. 4.2.3 Flexural Strength Variation for Different wt. % of Nano Silica.

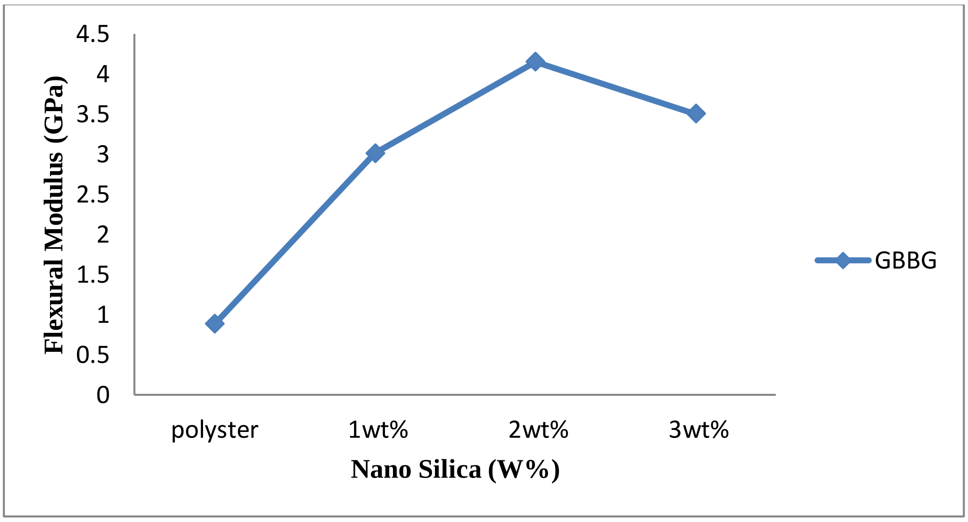


Figure. 4.2.4 Flexural Modulus Variation for Different wt. % of Nano Silica.

Now the graph for flexural strength and flexural modulus of GBGB hybrid composite laminate is given in Figure. 4.2.5 and Figure. 4.2.6 respectively. From the graph it is observed that the flexural strength is maximum at 2wt. % nano silica and is minimum at 3wt. % nano silica. The flexural modulus value is maximum at 2wt. % nano silica and minimum at 3wt. % nano silica.

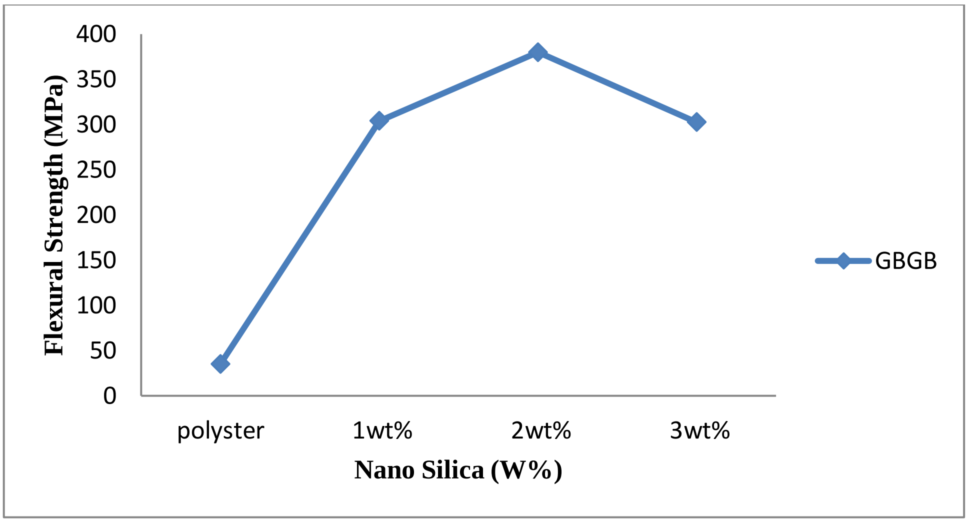


Figure. 4.2.5. Flexural Strength Variation for Different wt. % of Nano Silica.

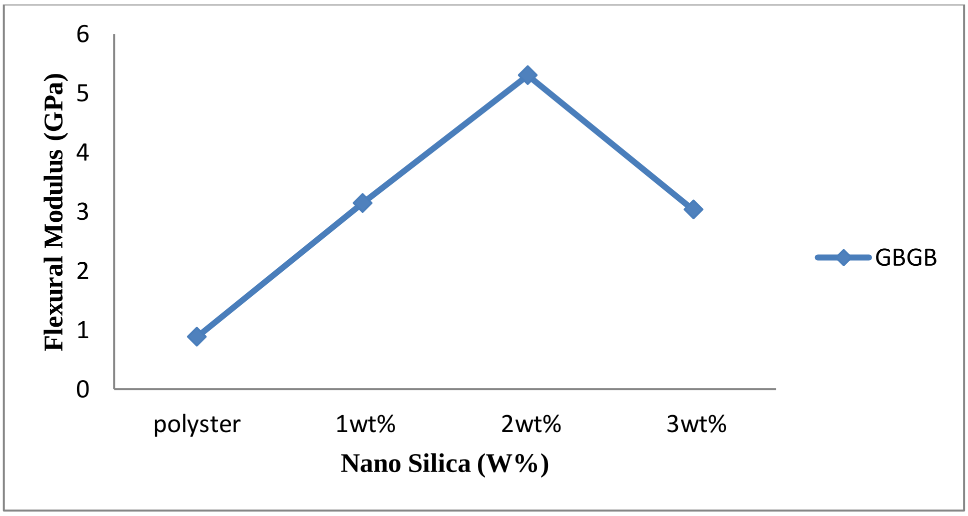


Figure. 4.2.6. Flexural Modulus Variation for Different wt. % of Nano Silica.

*4.3 Scanning Electron Microscope:*

The following figures show the morphological study of the hybrid composites through scanning electron microscope. The fiber pull out from the matrix, fractured fibers, cracking of resin, internal structure and voids are observed through the images of scanning electron microscope. Figure. 4.3.1. Shows the woven banana fiber pullout from the resin under loading. Figure. 4.3.2. Shows the cracking of matrix besides fiber under loading conditions. Figure. 4.3.3. Shows the arrangement glass fiber in the matrix. Figure. 4.3.4. Shows the glass fiber full out from the matrix under loading. With this morphological study we observe the behavior of the banana fiber, glass fiber and matrix in the hybrid composite.

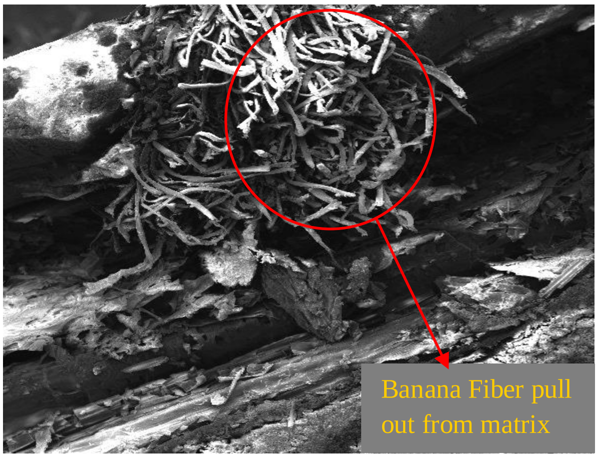


Figure. 4.3.1. Fiber pullout under loading.

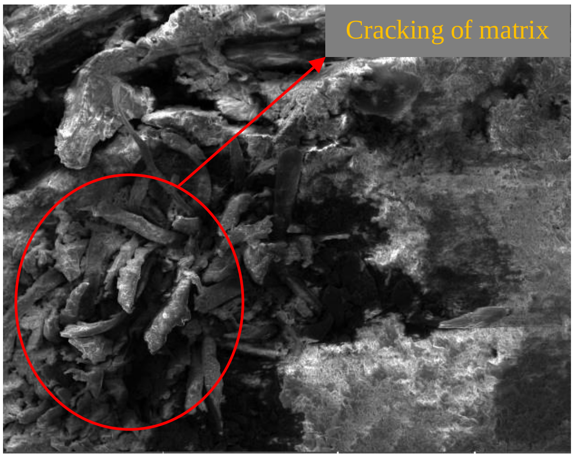


Figure. 4.3.2. carcking of matrix under loading.

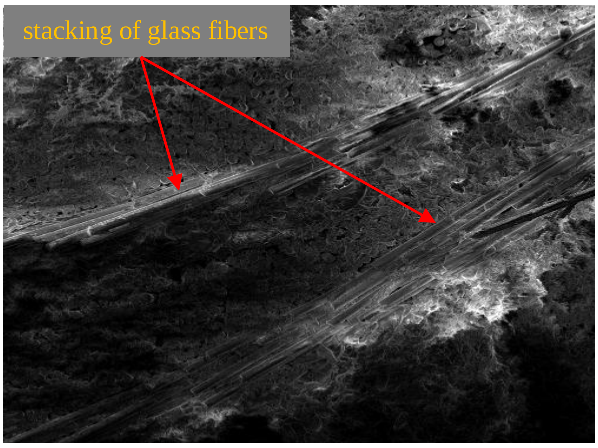


Figure. 4.3.3. Stacking of glass layers in the matrix.


Figure. 4.3.4. Glass fiber pullout under loading.

## 5. Conclusions:

In the present study, the hybrid composite laminates were fabricated with low cost having an overall light weight and good mechanical property. The tensile and flexural properties of hybrid composite laminates with different stacking sequence of fibers were evaluated and the following observations were made from this study.

- The tensile strength comparisons of different hybrid composite laminates reveal that stacking sequence of BGGB hybrid composite laminate with 3 wt.%. Of nano silica has 112.64 MPa exhibits higher tensile strength than other hybrid composite laminates. This is because of two layers of s-glass is placed in between the two layers of banana fiber forms a stronger layer in that laminate. This also shows that as the percentage of nano-powder increases the tensile strength is also increased, but further increase may cause the failure because of its brittle nature.
- Similarly, the comparison of flexural strength reveals that the stacking sequence of GBGB hybrid composite laminates with 2 wt. %. Of nano silica as filler material exhibits higher flexural strength as 380 MPa. The stacking sequence GBGB the load

is distributed among all the fibers and also as the nano silica increases fibers become brittle in nature so, they are failure at 3 wt. % of nano silica.

- Morphological study is done through scanning electron microscope. The fibers pull out from the composite, stacking of fibers and the behavior of matrix in hybrid composite are observed.
- This paper shows that the stacking sequence or placing of fiber in the composite plays an important role in obtaining the good mechanical properties. Thus, it can be concluded that replacing of 50% of synthetic fiber with natural fiber gives high mechanical strength as that of complete synthetic fiber reinforced composites. It also shows that the fabrication of composite is of low cost and applications also increase, when compared to synthetic fiber. These results gave good opportunities to fabricate new type of composite with low cost of fabrication and wide range of application.

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