

# Utilization of Wollastonite/ Quasi Isotropic S2 Glass Fiber Doped in to Epoxy on Mechanical and Thermal Properties

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## ABSTRACT

Study focused on the performance of injection moulded short Wollastonite filler and chopped glass fiber reinforced hybrid epoxy composites. Results showed that hybridization of glass fiber and Wollastonite was found to be comparable to that of epoxy glass fiber composites. Analysis of fiber length distribution in the composite and fracture surface was performed to study fiber breakage fracture mechanism. The simultaneous compounding of epoxy with two fillers was done to obtain a hybrid composite. The mechanical properties of hybrid, injection molded, chopped glass fiber/Wollastonite/epoxy composites have been investigated by considering the effect of hybridization by these two fillers. This system is expected to have considerable mechanical properties. It has been found that the tensile, flexural, and impact properties of the filled epoxy were higher than those of unfilled epoxy. The hybrid effects of the tensile strength and modulus were studied by the rule of hybrid mixtures (RoHM) using the values of single fiber composites.

**Keywords:** Epoxy; Wollastonite; S2 glass fiber; characterization; DSC; TGA

## 1. INTRODUCTION

The need of development of new materials to meet the challenges for innovative applications in the scientific and technological fields has become a very much essential in the recent days. The present conventional materials are unable to fulfill all the conditions and the requirements such as higher strength, heat distortion temperature and light weight with low cost. In order to achieve the above requirements an attempt has been made in the technology to find a novel material called 'Composite' whose constituents will act synergistically to solve the need of the applications. As we cross the threshold into the 'Composite material age', it becomes increasingly important to understand the properties, performance, cost and potential of the composites. Composite is one such material, which has revolutionized the concept of high strength. A wide range of particulate materials are used in the composites. These new

advanced materials with specific properties have led to the development of better cheaper polymer composites. The natural fibers like coconut fiber, banana fiber, sisal fiber, sansevaeria cylindrica fiber, sugarcane fiber etc. which is having low density with good strength can be used as reinforcing agent to strengthen the composite [1-20]. Not only the natural fiber but also sometimes synthetic fibers like various types of Glass fiber, Almond fiber, Carbon fibers which is having high strength with low density can also be used as reinforcing agents. Any powdered material can also be used as fillers. The most commonly used fillers are various grades of  $\text{CaCO}_3$ , talc, various types of silica, talc, Graphite, Montmorillonite clay (nano size) etc now recently Wollastonite powder is used as filler and S2 Glass fiber as reinforcing agent.

S2-Glass fiber (alumino silicate glass without CaO, whereas high MgO content with high tensile strength) with is a light weight (density  $2.43\text{g/cm}^3$ ), extremely strong and robust material. The Tensile strength of S2 glass material is 4890 MPa, compressive strength is 1600 MPa. Although the strength properties are somewhat lower than carbon fiber, it is less expensive. Its bulk strength and weight properties are also very favorable when compared to metals, and it can be easily formed during molding process. The plastic matrix may be epoxy, a thermosetting plastic (most often polyester or vinylester) or thermoplastic [21-30].

Wollastonite is calcium in silicate mineral ( $\text{CaSiO}_3$ ) that may contain small amounts of iron, magnesium, and manganese substituting for calcium. It is usually white. It forms when impure lime stone or dolostone is subjected to high temperature and pressure some times in the presence of silica-bearing fluid as skarns or contact metamorphic rocks. Associated minerals include garnets, vesuvianite, diopside, tremolite, epidote, plagioclase feld spar, pyroxene and calcite. Some of the properties that make Wollastonite so useful are its high brightness and whiteness, low moisture and oil absorption, and low volatile content. Wollastonite is used primarily in ceramics, friction products (brakes and clutches), metal making, paint filler and plastics. In our current work Wollastonite is chosen as natural filler in the second composition [31-42].

In the present work, epoxy polymer matrix was filled with Wollastonite mineral filler and same was reinforced with quasi-isotropic S2 glass fiber used for preparing the epoxy hybrid composites. After the composite been prepared, its performance was evaluated by means of mechanical and thermal properties. Tensile, flexural, impact and DSC and TGA properties are tested and optimized.

## 2. MATERIALS

In the present work commercially available Epoxy (Thermosetting plastic), S2 glass fiber and Wollastonite powder is used.

S2-Glass fiber ( alumino silicate glass without CaO but high MgO content with high tensile strength) with is a light weight (density  $2.43\text{g/cm}^3$ ), extremely strong and robust material. The Tensile strength of S2 glass material is 4890 MPa, compressive strength is 1600 MPa. Although the strength properties are somewhat lower than carbon fiber, it is less expensive. Its bulk strength and weight properties are also very favorable when compared to metals, and it can be easily formed during molding process. The plastic matrix may be epoxy, a thermosetting plastic (most often polyester or vinylester) or thermoplastic.

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the presence of silica-bearing fluid as skarns or contact metamorphic rocks. Associated minerals include garnets, vesuvianite, diopside, tremolite, epidote, plagioclase feldspar, pyroxene and calcite.

## 2. 1. Preparation of Composites

The Wollastonite powder in the ratio of (1gm, 2gm, 3gm, 4gm & 5gm) is mixed separately in the epoxy resin of 50 gm weight. The 2gm wt of S2 glass fiber is placed randomly in the mould (300 x 300x 3 mm<sup>3</sup>) and the mixture of epoxy with different weight ratios of Wollastonite along with the hardener (catalyst) is injected into the mould using Injection moulding apparatus. The mixture of epoxy, Wollastonite and hardener is stirred well using ultra sonic sonicator. The composites are cured at room temperature for 24 hours.

## 2. 2. Mechanical tests

Tests for determining tensile and flexural properties were conducted on computer controlled Instron 4301 type universal testing machine. For tensile test, standard dumbbell specimen were maintained from cast sheet and tested according to ASTM D 638. The cross head speed was 50 mm/min. Flexural properties were determined by three point bending method as per ASTM D 790. The test speed was maintained between 1.3 to 1.5 mm/min. Izod impact strength was determined using Izod Charpy digital impact tester, as per ASTM D 256. Shore D hardness test was conducted according to ASTM D 2240. A minimum of five specimens were tested in each case to obtain average value.

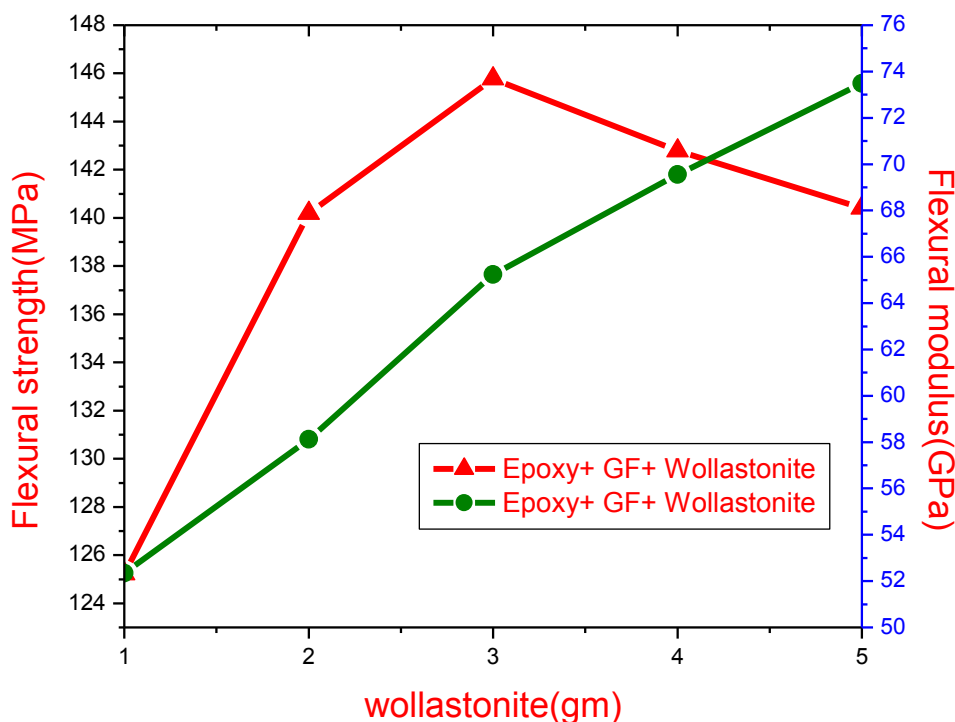
## 2. 3. Thermal Properties

Thermogravimetric analysis (TGA) of the samples was done using Netzsch Model STA 409 PC with heating rate of 10 °C/min in nitrogen atmosphere. Dynamic mechanical analysis (DMA) was performed using Netzsch (DMA 242C) dynamic mechanical analyzer in the three-point bending mode at a frequency of 10 Hz and amplitude of 120  $\mu$ m over the temperature range of 20-180 °C at a heating rate of 2°C/min.

# 3. RESULTS AND DISCUSSION

## 3. 1. Flexural properties

Results of the variation of flexural strength and flexural modulus of composites with filler content are shown in Figure 1. The flexural strength of epoxy filled Wollastonite and S2 glass fiber composites increased up to 3gm of Wollastonite powder (145.78-3.53 MPa). The increase in strength is mainly due to good filler matrix interaction, which is due to platy nature of the fillers. Platy filler have high aspect ratio and this increase the wet ability of the fillers by the matrix, thus creating fewer micro voids between the filler and the matrix. The Wollastonite powder, which has a higher surface area due to its small particle size, tends to agglomerate and this result in the reduction of surface interaction between the epoxy and Wollastonite. This explains the reduction in the flexural strength of Wollastonite powder filled epoxy composites (> 3gm of Wollastonite) at higher filler loading [7,10,12,18].



**Fig. 1.** Flexural strength and Flexural modulus variations for different proportions of composites.

**Table 1.** Flexural properties of different proportions of Epoxy filled Wollastonite and S2 - Glass fiber reinforced hybrid composites.

Name of the sample	Flexural strength MPa	Flexural modulus GPa
Epoxy (50gm) + Wollastonite (1gm) + S2-glass fiber (2gm)	125.23 +/- 1.34	52.34 +/- 2.37
Epoxy (50gm) + Wollastonite (2gm) + S2-glass fiber (2gm)	40.19 +/- 2.82	58.12 +/- 1.22
Epoxy (50gm) + Wollastonite (3gm) + S2-glass fiber (2gm)	145.78 +/- 3.53	65.24 +/- 2.56
Epoxy (50gm) + Wollastonite (4gm) + S2-glass fiber (2gm)	142.78 +/- 1.34	69.56 +/- 1.43
Epoxy (50gm) + Wollastonite (5gm) + S2-glass fiber (2gm)	140.41 +/- 1.59	73.48 +/- 1.25

The variation of flexural modulus of Wollastonite in epoxy is shown in the Figure 1. Flexural modulus of Wollastonite is 50GPa. Progressive increase of Wollastonite content in epoxy resin progressively increases the flexural modulus.

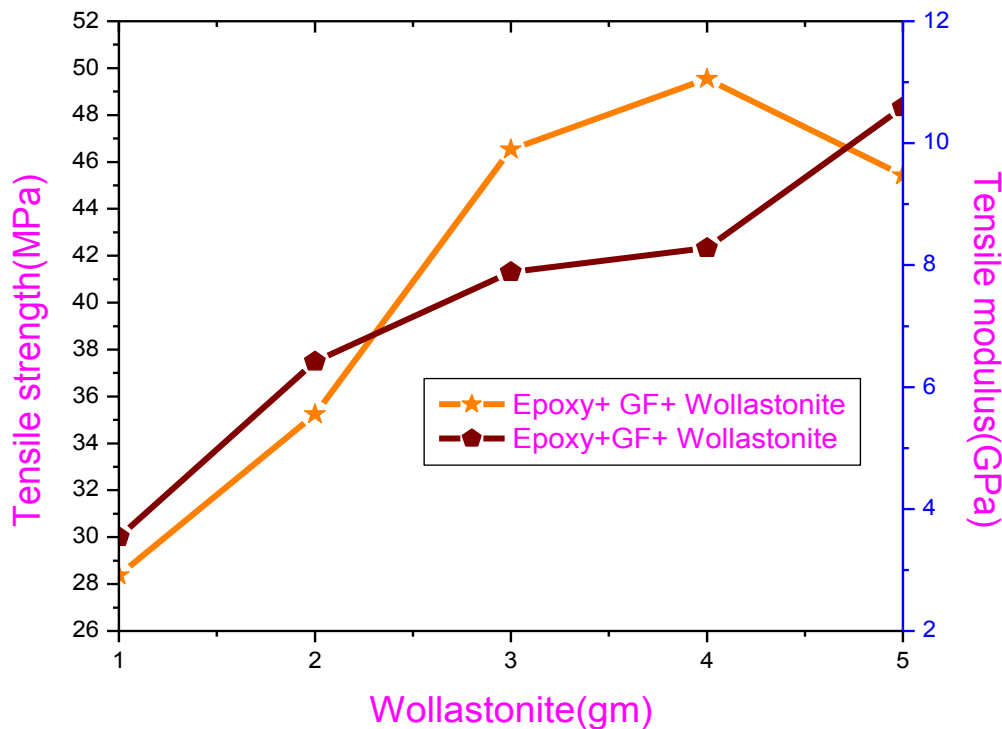
Flexural modulus of all types of the composite studied are found to increase linearly with increasing filler content in the matrix, indicating the positive toughening effect. The increased modulus is due to the presence of dispersed rigid particles.

The presence of Wollastonite particles might have stiffened the matrix inducing the increase observed in the modulus. It was assumed, that the space between the Wollastonite particles was filled with the matrix minimizing the presence of voids and bubbles consequently leading to increase in modulus [19,25].

### 3. 2. Tensile Properties

The tensile strength and tensile modulus of the different composites investigated are shown in the Figure 2. Pure Epoxy shows the tensile strength of 22 MPa. The tensile strength of Wollastonite powder filled epoxy was shown in the Table 2.

The tensile strength of Epoxy composites increase with the Wollastonite content up to 4 gm and on further addition of Wollastonite powder (> 4gm) the tensile strength decreases. The improvement in tensile strength is caused due to limited mechanical restraint and the filler particle size. The decrease in the ultimate tensile strength is due to improper wetting of Wollastonite powder at higher filler content [28,39].



**Fig. 2** Tensile Strength and Tensile modulus variations for different specimens of composites.

**Table 2.** Tensile Strength and Tensile modulus for different specimens.

Name of the sample	Tensile strength MPa	Tensile modulus GPa
Epoxy (50gm) + Wollastonite (1gm) + S2-glass fiber (2gm)	28.37 +/-1.07	3.54 +/-1.54
Epoxy (50gm) + Wollastonite (2gm) + S2-glass fiber (2gm)	35.25 +/-2.88	6.42 +/-0.67
Epoxy (50gm) + Wollastonite (3gm) + S2-glass fiber (2gm)	46.54 +/-3.21	7.89 +/-0.59
Epoxy (50gm) + Wollastonite (4gm)+ S2-glass fiber (2gm)	49.54 +/-1.44	8.28 +/-0.32
Epoxy (50gm) + Wollastonite (5gm) + S2-glass fiber (2gm)	45.43 +/- 1.89	10.59 +/-0.29

Filler may enhance or deteriorate the impact properties of composites. Impact strength is an indication of tolerability for a sudden impact. When a composite is subjected to an impact, rapid crack propagation is initiated through the material. Improvement in impact strength is due to the limited cross linked network structure of the cured resin.

The Wollastonite powder particle is tracer to move within the matrix and correspondingly, the matrix is free to stretch around particles. The stress transfer rate becomes very low, which leads to a lowest impact strength. In the filled composites, as filler loading increases the tendency of agglomerates also increase, interfacial adhesion becomes weaker leading to the weaker interfacial region. These agglomerates then acts as strength concentration points or crack initiation sites. Therefore reduction in the impact strength with increasing filler content is expected.

### 3. 3. Thermal Analysis

#### 3. 3. 1. Differential Scanning Calorimetric (DSC)

The DSC test is carried out to find the glass transition temperature of different composites. Glass Transition temperature ( $T_g$ ) of composites increase with increase in Wollastonite powder in the Epoxy matrix. The glass transition temperature is more for 5gm Wollastonite filled composite. The variation of glass transition temperature for different composites is shown in the Figure 4.

#### 3. 3. 2. Thermo Gravimetric Analysis (TGA)

Thermo gravimetric analysis (TGA) of the samples was done using Netzsch Model STA 409 PC with heating rate of 10 °C/min in nitrogen atmosphere. Dynamic mechanical analysis (DMA) was performed using Netzsch (DMA 242C) dynamic mechanical analyzer in the three-point bending mode at a frequency of 10 Hz and amplitude of 120  $\mu$ m over the temperature range of 20-180 °C at a heating rate of 2 °C/min [12,18].

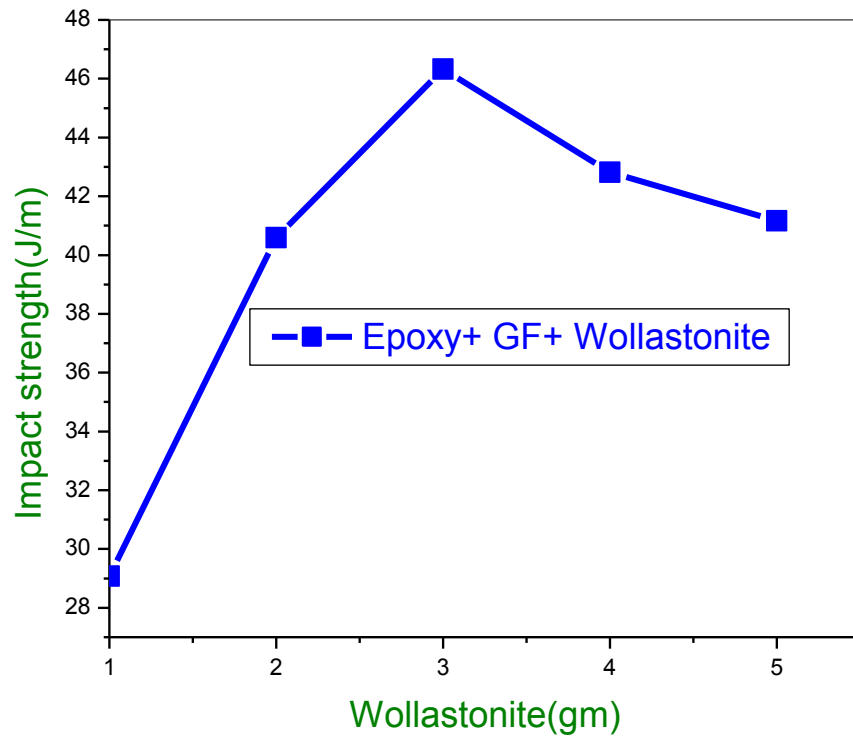


Fig. 3. Impact strength variation of various composites.

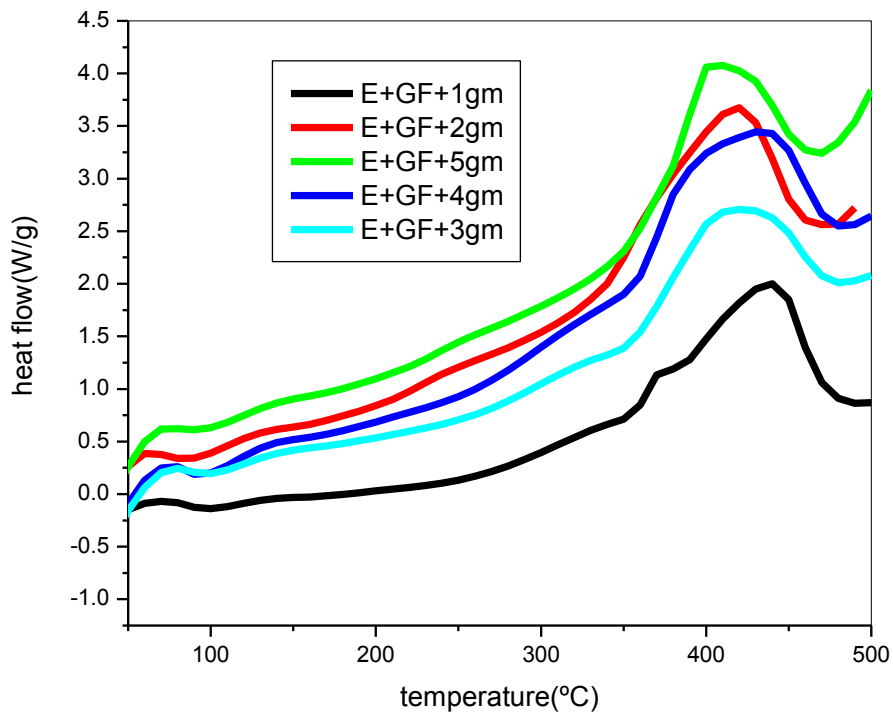


Fig. 4 Graph showing the Glass transition temperature for different composites.

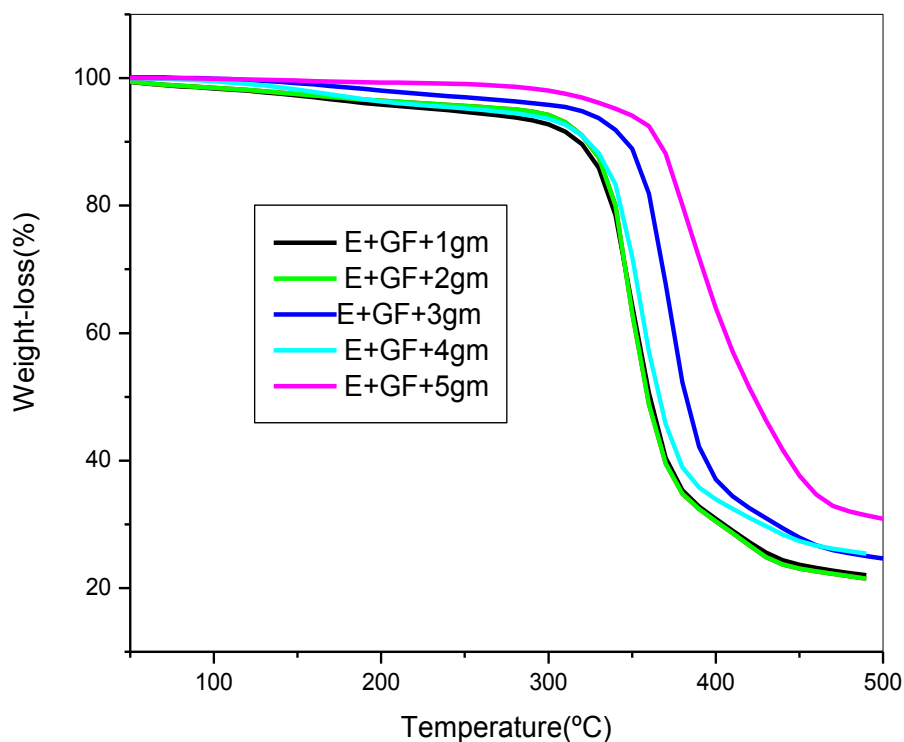


Fig. 5. Thermo Gravimetric Analysis for different composites.

Table 3. Impact strength of for various specimens.

Name of the sample	Impact strength J/m
Epoxy (50gm) + Wallostonite (1gm) + S2-glass fiber (2gm)	29.08+/-1.09
Epoxy (50gm) + Wallostonite (2gm) + S2-glass fiber (2gm)	40.59+/-0.86
Epoxy (50gm) + Wallostonite (3gm) + S2-glass fiber (2gm)	46.32+/-0.58
Epoxy (50gm) + Wallostonite (4gm) + S2-glass fiber (2gm)	42.82+/-0.79
Epoxy (50gm) + Wallostonite (5gm) + S2-glass fiber (2gm)	41.42+/-0.58

Thermo gravimetric curves of Epoxy filled S2 glass fiber and different amounts of Wallostonite is shown in the Figure 5. From these curves, maximum weight loss temperature for the different composites can be studied. From the figures it is very clear that Wallostonite filler allows more heat to flow. Increase in the Wallostonite filler in the composites provides good thermal stability to the materials.



#### 4. CONCLUSION

Quasi-isotropic glass fiber reinforced and Wollastonite filled epoxy hybrid composites were developed and tested for mechanical and thermal properties. Wollastonite was dispersed in to the matrix with various proportion such as 1, 2, 3, 4, 5 gm by keeping glass fiber as a constant. Due to less moisture content and more metallic nature particle was attributed the improved thermal stability for 5gms Wollastonite filled epoxy hybrid composites. Thermal stability as increased for the same sample up to 50 °C when compared with the 1gm Wollastonite filled composites. It was observed in the DSC analysis that due to increased viscosity of the specimen at 5gm as a result of that decreased glass transition temperature was observed when compared with 4gm Wollastonite filled composites. Tensile and flexural modulus was increased linearly due increased ductility. Impact strength was increased up to 3gm after that it was started getting down. On other hand flexural strength was optimized at 3gm whereas at 4gm tensile strength was optimized. These types of composites can be used fuel tanks, automobile and airplane bodies for fuel economy.

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