

# **Study of flexural and compressive strength of glass fiber reinforced graphite composite**

A THESIS SUBMITTED IN PARTIAL FULFILLMENT  
OF THE REQUIREMENTS FOR THE DEGREE OF

## **BACHELOR OF TECHNOLOGY IN CERAMIC ENGINEERING**

SUBMITTED BY

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**NATIONAL INSTITUTE OF TECHNOLOGY  
ROURKELA  
2013**

**CERTIFICATE**

This is to certify that the thesis entitled, “**Study of flexural and compressive strength of glass fiber reinforced graphite composite**” submitted by **SATISH KUMAR** in partial fulfillment of the requirement for the award of **Bachelor of Technology Degree in Ceramic Engineering** at **National Institute of Technology, Rourkela** is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/ Institute for the award of any Degree or Diploma.

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## **ACKNOWLEDGEMENT**

With deep regards and profound respect, I would like to express my deep sense of gratitude and indebtedness to Prof. **DEBASISH SARKAR**, Department of Ceramic Engineering, NIT Rourkela, my mentor, for his invaluable guidance, motivation, constant inspiration and valuable suggestions. It would have not been possible for me to bring out this thesis without his help and encouragement. I express my sincere thanks to **Prof. S.K PRATIHAR**, Head of the Department of Ceramic Engineering, and NIT Rourkela for providing me necessary facilities in the department. Further, I would like to thank all the faculty members and staff of Department of Ceramic Engineering, NIT Rourkela for their invaluable support and help. Submitting this thesis would have been a vast job, without the constant help, encouragement, support and suggestions from seniors, especially Mr. Reddy , Mr. Raju for their round the clock help without any hesitation. Although it will be difficult to record my appreciation to each and every one of them in this small space; I will feel guilty if I miss the opportunity to thank laboratory Members of Department of Ceramic Engineering, N.I.T. Rourkela. I would like to thank all the faculty members and staff of other departments of NIT Rourkela for their invaluable support and help. Last but not the least I want to thank almighty lord for the successful completion of the project work.

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## ABSTRACT

The attempt of this work is to development of glass fiber reinforced graphite composite by the addition of binder solid pitch. Different physical properties such as bulk density, apparent porosity, flexural strength and compressive strength are assessed with respect to different binder content and glass fiber reinforcement. Binder content is increasing with increment of fiber reinforcement, which ultimately increasing the porosity or decreasing the bulk density. Highest flexural strength  $128 \text{ kg/cm}^2$  is obtained under optimum 0.5 wt. % fibers and 20 wt. % binder content. Optimum content of glass fiber follows crack wake bridging mechanism and enhancement of flexural strength. Highest compressive strength  $118 \text{ Kg/cm}^2$  is observed in presence of 0.5 wt% fibers and 25 wt% binder pitch. More fiber content jumbled up during mixing and develops non-uniform matrix which reduces the mechanical properties enormously at even green stage.

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# CHAPTER-1

# INSIGHT

## 1.1 Introduction:

When two or more materials having different properties are combined together, they form another class of material generally designated as composite material. In general, the properties of composite materials are enhanced in many respects, to those of the individual constituents. That's why; composites are attracting the researchers and industries. In a composite, there are two categories of constituent materials one is matrix and obviously another is reinforcement. The matrix phases are to transfer stresses between the reinforcing fibers and also to protect them from mechanical environmental damage while reinforced phases enhance mechanical properties of composite. Generally, reinforcing materials are strong with low densities while the matrix is usually a ductile/tough material. Our concern regarding selection of materials for matrix and reinforced phases is to take their superior properties.

Graphite is a light weight and it can stand near to 1000 °C in atmosphere. Several attempts have been made to improve the mechanical properties of graphite materials. One of the methods is pitch-based carbon fibers/carbon composites can obtain high mechanical strength [1]. The manufacturing process is complex, which restricts their wide application. There are many developments to enhance the mechanical properties of graphite. High strength graphite is processed by from a mixture of particulate fillers which is prepared by carbon precursor at 400-600 °C in the presence of carbonizable binder and green carbonizable fibers in a concentration of less than 2 % filler [2]. By Selective Laser Sintering (SLS) is also used to enhance its flexural strength. Reinforcing polymer with glass and graphite particles also give good increase the flexural strength. The epoxy matrix in carbon fiber/epoxy composites with graphite nanoparticles as filler enhances the mechanical properties. Glass fiber (GF) itself has enough mechanical strength. GF and Carbon/Graphite fiber with epoxy resin gives superior mechanical strength. These developments attract others to use graphite in different form with different fiber materials to modify its mechanical strength and make its use at different locations. In this context, this research work is focused on the preparation of glass fiber reinforced graphite composite and optimization of glass fiber and binder content in relevance to mechanical properties such as flexural and compressive strength.

## **CHAPTER-2**

# **LITERATURE REVIEW**

## 2.1 An overview

The Carbon – Carbon (C/C) composite is light weight which shows exceptional high strength and stiffness due to combination of carbon-fiber reinforcement in carbon matrix. But the mechanical and refractory property of bulk graphite is not desirable because graphite is very flaw sensitive (brittle) and it's difficult to fabricate into large sizes and complex shapes. To overcome these difficulties the "two phase principle of material structure and strength" is followed [3]. Addition of pitch as a binder in graphite based composite is beneficial in some extent. A liquid-crystalline transformation occurs through pitch in the temperature range about 350 and 550°C [4]. This transformation leads to an optically anisotropic liquid crystal known as the carbonaceous mesophase, which has high bulk density due to the matrix density and approaches the value for single-crystal graphite, 2.26 g/cm<sup>3</sup> [5]. It enhances the densification efficiency to fabricate dense compacts and composites. The incorporation of fiber in a matrix phase such as epoxy resin enhances its mechanical properties and improves other property such as thermal and electrical properties. Carbon fiber reinforced composites (CFRC) with metals shows flexural modulus and ultimate flexural strength as 82±6 GPa and 1154±65 MPa, respectively which is found to decrease with thermo cycling. Carbon fibre reinforced epoxy/clay nanocomposites (CFRENCs) are manufactured through hot melt lay-up with autoclave process. The interlaminar fracture toughness is increased by 85% at 4 phr (peak height ratio) nanoclay in epoxy. On addition of small amount of (2 phr) into the epoxy of carbon/epoxy composites can enhance the flexural strength by 38% [6]. The mechanical properties of unidirectional sisal-reinforced epoxy composites on fibre treatment, a relationship between optimized fiber treatment and performance improvement of sisal composites has also been observed [7].

The carbon fiber and glass fiber reinforced polyamide-6 and polyamide-6/clay nanocomposites was investigated and observed that the mechanical and thermal properties of the polyamide-6/clay nanocomposites were superior to those of polyamide-6 composite in terms of the heat distortion temperature, tensile and flexural strength and modulus without sacrificing their impact strength. The mechanical properties of polyamide-6/clay nanocomposites are enhanced at 10 wt. % glass fiber or carbon fiber reinforced polyamide-6 [8]. The tensile properties of composites of polypropylene (PP) reinforced with short glass fibers (SFG) and short carbon fibers (SCF) were investigated and noted that increase in fiber volume fraction that

decreased in mean fiber length. The tensile strength and modulus of SGF/PP and SCF/PP composites with varying fiber volume fraction and mean fiber length were reported. It was found that the fiber efficiency factor decreased with increasing fiber volume fraction, carbon fiber showed corresponding lower fiber efficiency factors than glass fiber due to its more brittle nature of carbon and the fiber efficiency factor for the composite modulus was much higher than that for the composite strength. It was also observed that the tensile failure strain of the composites decreased with an increase in fiber volume fraction [9]. Glass fiber reinforced composite shows enough increase in longitudinal stiffness. Composite consists of a resinous matrix material with fibrous reinforcing in an appropriate proportion. Carbon fiber of high modulus with glass fiber gives enhanced property.

Different class of two or three phase composite especially fiber reinforcing has several advantages to enhance the mechanical properties. Glass fiber is one of them. Graphite matrix itself has relatively less strength and hence this research work will focus on the enhancement of mechanical properties preferentially flexural strength and compressive strength through glass fiber reinforcement and binder pitch.

## **2.2 OBJECTIVE**

- To develop a glass reinforced graphite composite by addition of binder solid pitch
- To optimize the bulk density of such composites
- To optimize the flexural strength with respect to binder content and fiber reinforcement
- To optimize the compressive strength with respect to binder content and fiber reinforcement

## 2.3 Materials used:

### 2.3.1 Flake Graphite (FG)

It is an allotrope of carbon, occurs as isolated, flat, plate-like particles with hexagonal edges. Each carbon atom is attached to three others on the same plane and only three out of four valence electrons are used in carbon-carbon bonding. The fourth valence electron remains loosely between the planes. This free electron accounts for the electrical conductivity of graphite. The lack of carbon-carbon bonding between adjacent planes enables them to slide over each other making graphite soft, slippery and useful as a lubricant. Its bulk density is between 1.3-1.95 g/cc and porosity varies in between 7-53 %.

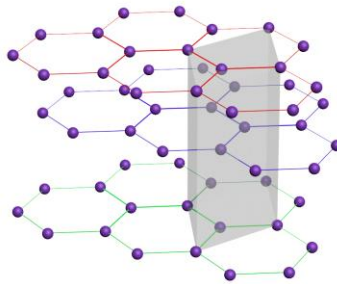


Fig .No 1 . Structure of Graphite

### 2.3.2 Glass Fiber (GF):

It consists numerous fiber of glass, formed by silica in textile fashion. It is a common reinforcement material for poly matrix composite. The main constituents of glass fiber is  $\text{SiO}_2$  with oxides of Ca,P,B,Al,Fe and others according to requirement. It is an isotropic materials having lower thermal expansion coefficient than that of steel. There are many types of glass fiber such as E-Glass, S-glass, and C-Glass. Among them E-Glass is generally used as a reinforcing material due its good mechanical and electrical properties, having tensile strength 3445 MPa, compressive strength 1080 MPa, density  $2.58\text{g/cc}^3$  and softening point  $846^\circ\text{C}$ . On increasing temperature its strength and modulus can degrade. The Glass-reinforced plastic (GRP) is popular with increased compressive strength and less weak tensile strength.



Fig .No 2. Glass fiber

### **2.3.3. Pitch**

Binder Pitch is produced from the processing of high temperature coal tar. It is a black solid material and consists of a complex mixture of predominantly aromatic hydrocarbons. It exhibits an extensive softening range rather than a defined melting temperature. The main source of pitch is coal tar and petroleum. The major application area of pitch is industrial electrode production, but preparation of carbon fiber, graphite and composite is also possible. The process of converting a pitch material to graphite & other high performance carbon comprises an intermediate phase called meso-phase. Pitches & meso-phase like polymers are the thermo-plastic systems. During processing, binder pitch becomes highly thermo plastic to form a homogeneous mixture with the filler.

# Chapter 3

# Experimental

### 3.1 Sample Preparation:

20g of sample of Flake Graphite (FG) and Glass Fiber with varying composition was prepared. Pitch was considered as a resin materials with varying composition of 20%,25% and 30% of wt.%.

**Table for sample with varying composition of FG, GF and Pitch**

<b>Sample No.</b>	<b>Flake Graphite (%)</b>	<b>Glass Fiber(%)</b>	<b>Pitch (%)</b>
<b>S1</b>	<b>100</b>	<b>0</b>	<b>20</b>
<b>S2</b>	<b>99.50</b>	<b>0.50</b>	<b>20</b>
<b>S3</b>	<b>99.00</b>	<b>1.00</b>	<b>20</b>
<b>S4</b>	<b>98.50</b>	<b>1.50</b>	<b>20</b>
<b>S5</b>	<b>100</b>	<b>0</b>	<b>25</b>
<b>S6</b>	<b>99.50</b>	<b>0.50</b>	<b>25</b>
<b>S7</b>	<b>99.00</b>	<b>1.00</b>	<b>25</b>
<b>S8</b>	<b>98.50</b>	<b>1.50</b>	<b>25</b>
<b>S9</b>	<b>100</b>	<b>0</b>	<b>30</b>
<b>S10</b>	<b>99.50</b>	<b>0.50</b>	<b>30</b>
<b>S11</b>	<b>99.00</b>	<b>1.00</b>	<b>30</b>
<b>S12</b>	<b>98.50</b>	<b>1.50</b>	<b>30</b>

Table No. 1 Sample composition



Fig No. 3 Specimen of FG-GF reinforced composite

### 3.2 Preparation method:

In beginning the composition was considered as according to Table 1. After weighing, all the mixed material kept in a beaker and heated it for 10-15 minute and mixed it properly, then poured the mixture into a die preferably in hot state and pressed it through uniaxial hydraulic press for 90 seconds under 8 ton of pressure.

### 3.3 Tests performed

#### 3.3.1 Flexural strength:

It is a measurement of stress required to cause failure in bending. It is also known as Modulus of Rupture, having unit  $\text{Kg/cm}^2$ . In this experiment 3 point bending method was used.

The mathematical expression for Flexural strength calculation is:

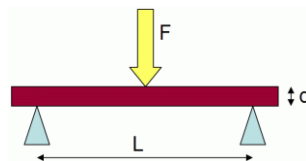


Fig.no.4 Three point bending method

$$F.S = \frac{3PL}{2bd^2}$$

Where,

P= axial load applied

L= length support span

b= width

d= thickness

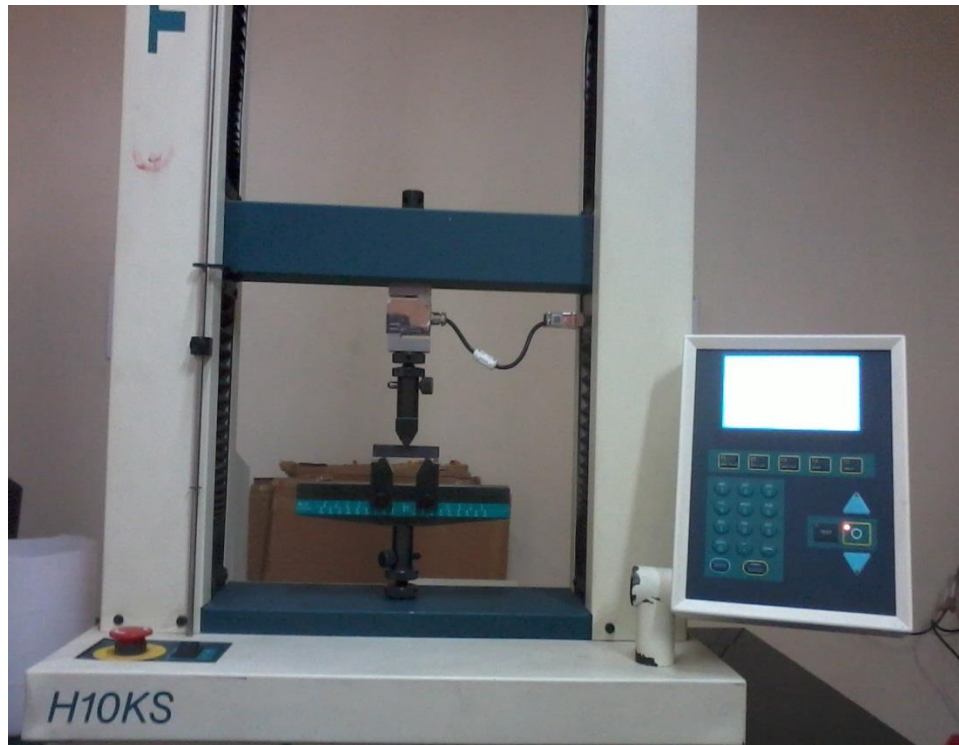


Fig.no. 5 Universal Testing Machine

### 3.3.2 Compressive Strength:

It is a material property which is maximum force per unit area before failure occurs.

$$CCS = P/A$$

P=Load

A=Area

Unit is in  $Kg/cm^2$ .

### **3.3.3 Bulk density and Apparent porosity:**

Bulk density (BD) is the property of powder, granules which are sintered to form a green body. It is mass of powder and granules of a material divided by the total volume that they occupy including particle, interspace, and internal pore volume.

Apparent porosity is the percentage of the total volume of a material occupied by both open and closed pores.

To measure bulk density and apparent porosity of the mentioned composites, the dry weight of specimen was first measured. Then they were soaked in boiling water inside a beaker and after 90 minutes the specimens were taken out and soaked weight were calculated. After that the suspended weight was measured in water.

$$\mathbf{B.D=D/W-S}$$

$$\mathbf{A.P=W-D/W-S}$$

Where

D=Dry Weight

S=Suspended Weight

W =Soaked Weight

# **Chapter 4**

# **Results**

# **And**

# **Discussion**

## 4. Results and Discussion

### 4.1. Bulk Density and Apparent Porosity:

Flaky Graphite (FG) (wt. %)	Glass Fiber (GF) (wt. %)	Binder content (wt. %)	Bulk Density	Apparent Porosity (%)
100	0	1) 20	1.80	3
		2) 25	1.70	4.49
		3) 30	1.65	4.59
99.50	0.5	1) 20	1.76	4.02
		2) 25	1.65	8.96
		3) 30	1.64	8.47
99.00	1.00	1) 20	1.78	7.84
		2) 25	1.60	10.48
		3) 30	1.63	10.51
98.50	1.50	1) 20	1.74	9.99
		2) 25	1.66	11.77
		3) 30	1.61	12.73

Table No. 2 Bulk density and apparent porosity of FG-GF reinforced composite with varying binder content

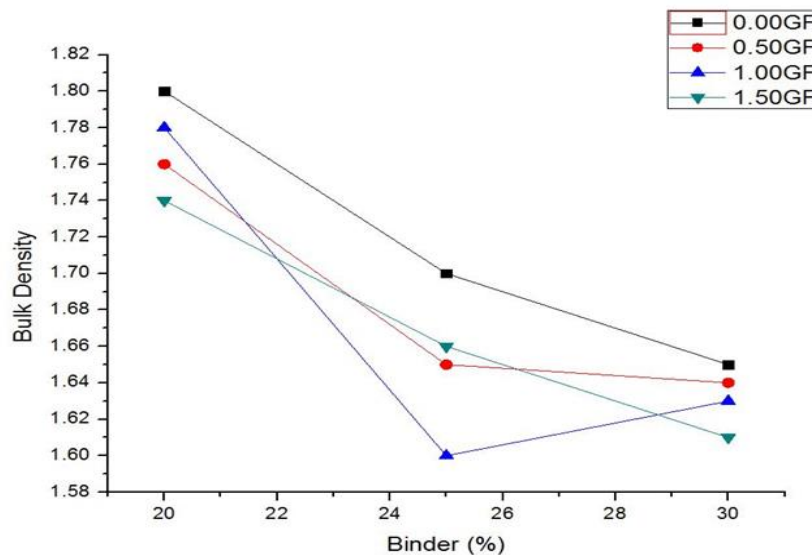


Fig. 6 Bulk density of FG-GF reinforced composite with varying binder content

The BD is decreasing with increasing binder content; maximum is 1.80 at 100% FG, 0%GF and 20% binder content. But at 99% FG, 1% GF and 25 % binder content BD has been decreased.

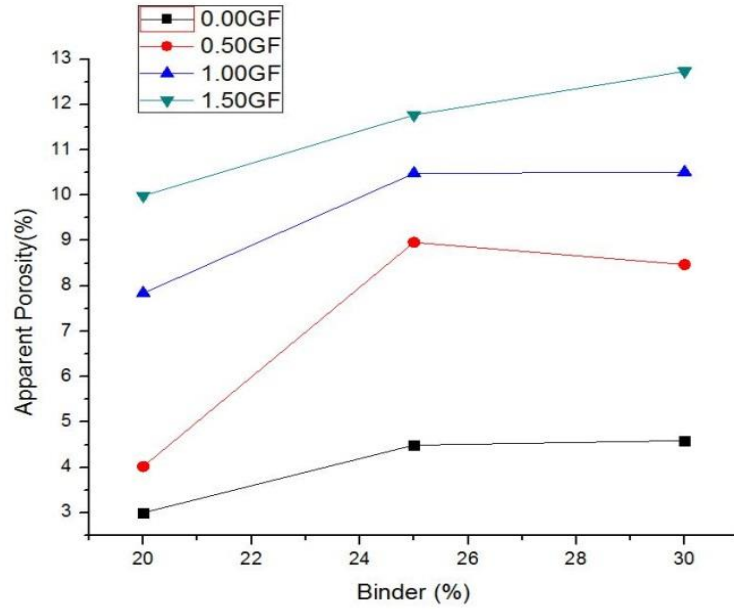


Fig. 7 Apparent porosity of FG-GF reinforced composite with varying binder content

AP is generally increasing as the binder content increases, but at 99.50% FG, 0.50% GF and 30% binder content there is a slight decrease in AP. Highest AP at 98.50% FG, 1.50% GF and 30% binder content is 12.73%.

## 4.2. MOR behaviour of flake graphite-fiber composite

Flaky Graphite (%)	Glass Fiber content (%)	Binder content (%)	MOR of Graphite-fiber Kg/cm <sup>2</sup>
100	0	1) 20	115.94
		2) 25	127.14
		3) 30	118.06
99.50	0.5	1) 20	128.79
		2) 25	114.59
		3) 30	111.63
99.00	1.00	1) 20	95.55
		2) 25	121.83
		3) 30	109.59
98.50	1.50	1) 20	88.92
		2) 25	109.59
		3) 30	128.26

Table 3. MOR behaviour of FG-GF reinforced composite with varying binder content

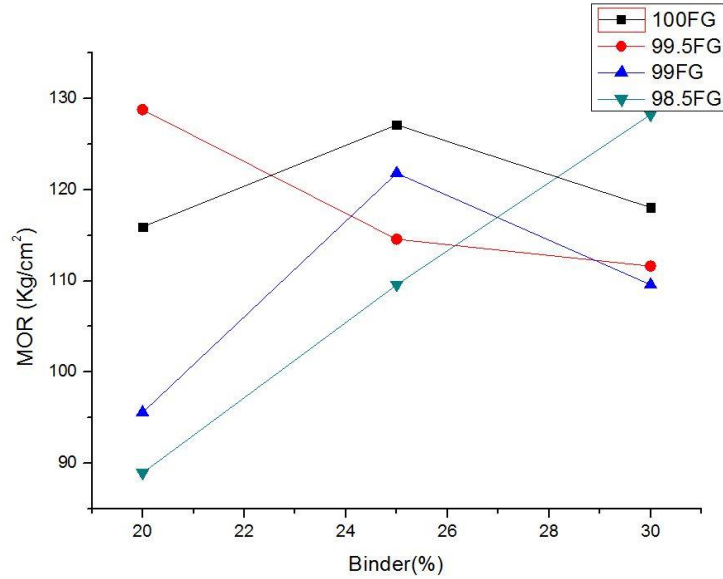


Fig. 8. MOR behavior of FG-GF reinforced composite with varying binder content

From the above graph we can see at for 100% FG and 0% GF the maximum MOR was found,  $127.14 \text{Kg/cm}^2$  at 25% binder content and lowest at 30% binder content, 118.06. For 99.50% FG and 0.50% GF we found maximum MOR at 20% binder content and minimum at 30% binder content. At 99% FG and 1% GF we found maximum MOR at 25% and minimum at 20% and at 98.50% FG and 1.50% GF maximum MOR at 30% and minimum at 20%.

### 4.3 Compressive strength:

Flaky Graphite (%)	Glass Fiber content (%)	Binder content (%)	CCS of Graphite-fiber Kg/cm <sup>2</sup>
100	0	1) 20	107.47
		2) 25	114.60
		3) 30	70.90
99.50	0.5	1) 20	92.73
		2) 25	118.02
		3) 30	91.37
99.00	1.00	1) 20	65.99
		2) 25	90.53
		3) 30	71.11
98.50	1.50	1) 20	78.55
		2) 25	92.83
		3) 30	88.97

Table. 4 Compressive strength of FG-GF reinforced composite with varying binder content

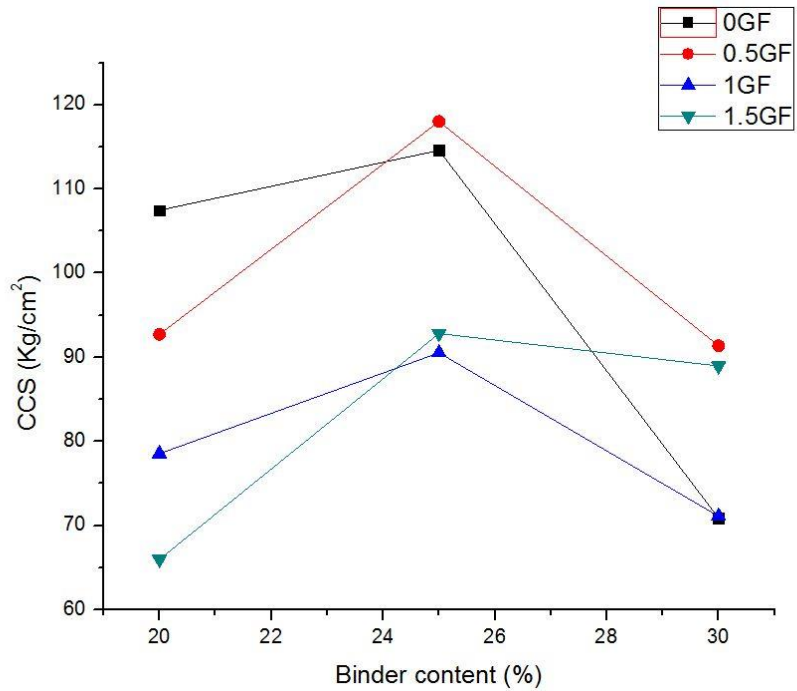


Fig. No. 9 Compressive strength of FG-GF reinforced composite with varying binder content

As increasing the binder content CCS increases and decreases at 30% binder content. 118.02 Kg/cm<sup>2</sup> is the highest CCS can be observed at 99.50% FG, 0.50% GF and 25 % binder content.

# Chapter 5

## Conclusion and References

## Conclusion

1. Binder content is also increasing with increment of fiber reinforcement, which ultimately increasing the porosity or decreasing the bulk density.
2. Highest flexural strength  $128 \text{ kg/cm}^2$  is obtained under optimum 0.5 wt. % fibers and 20 wt. % binder content.
3. Optimum content of glass fiber follows crack wake bridging mechanism and enhancement of flexural strength.
4. Highest compressive strength  $118 \text{ Kg/cm}^2$  is observed in presence of 0.5 wt% fibers and 25 wt% binder pitch.
5. More fiber content jumbled up during mixing and develops non-uniform matrix which reduces the mechanical properties enormously at even green stage.

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