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DEVELOPMENT AND ANALYSIS OF GLASS FIBRE REINFORCED POLYMER COMPOSITE MATERIAL WITH DIFFERENT ORIENTATION AND ADDITIVES

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Abstract: The purpose of this study is to evaluation of the mechanical characterisation such as tensile, compression and bending test and modal analysis of prepared specimen. This study focus on preparation and testing of Polyester resin using glass fibre for different orientation apon additives CaSiO3 and SiC. The Mechanical properties of the polyester changes gradually by changing the layers of fibres and for different orientation of glass fibre and by adding additives the property differs. The laminate is prepared according to rule of mixture and specimens are prepared as per ASTM standard, different layers of glass fibres are one, two, three and four layers and the orientation of glass fibre is 0o, 30o, 60o, and 90o. The glass fibre used is in fabric form. The modal analysis for prepared specimen was carried out to find first five natural frequencies and corresponding mode shapes, for both the composites plate with additives Calcium Silicate and Silicon Carbide.The natural frequency of the composites is found to improve the vibrational nature of prepared specimen. The natural frequency is high for the composite plate which has additive silicon carbide and can be employed for low frequency range applications. The natural frequency found higher for calcium silicate additive and can be employed for high frequency range.
Keywords: Glass fibre/Polyesters composites, Mechanical characterisation of polyester, orientation of glass fibre, additive.

I. INTRODUCTION

Composite materials are the materials which are the mix of two or more materials each having divergent properties. At the point when these materials are joined that gives properties, which are more helpful than utilizing singular material property. The most essential trademark is it gives specific strength and specific stiffness property. The Composites are a standout amongst the most generally utilized materials due to their versatility to various circumstances and relative utilize and simplicity of mix with different materials to fill particular need and gives attractive properties. Composites that forms heterogeneous structures which meet the needs of specific design and capacity, loaded with wanted properties which confine the degree for characterization. Fibres or Particles inundate in grid of another material would be the best case of modern day composite materials, which are for the most part auxiliary.

The reinforcing fiber or fabric gives quality and firmness to the composite material, while the grid gives inflexibility. Reinforcing fibres are found in various structures from long ceaseless fiber to woven fabric to cleaved fiber and mat. Every arrangement results in various properties. The Properties are emphatically rely on upon the route by which fiber are laid into composites.

1.1 Selection of Polymer Matrix composite.

The selection of polymer matrix composites mostly depend on the following,

- Selection of matrix material
- Selection of reinforced material

1.1.1 Selection of matrix material

In spite of the fact that it is absolutely genuine that the high quality of composite is for the most part because of the fibre reinforcement, the hugeness of network material can't be belittled as it give support for the fibres and backing the fiber from conveying loads.

1.1.1.a) Factors Considered For Selection of Matrix

1. The matrix should have a mechanical quality relating with that of the reinforcement i.e. both ought to be all around coordinated.
2. The framework ought to be anything but difficult to use in a chose manufacture process.
3. Smoke prerequisites.
4. Life expectancy.
5. The resultant composite must be cost effective.
6. The matrix ought to confront the administration conditions like temperature, dampness, environment, scraped area by dust particles.

1.1.1.b) Advantages of Polyester resin

- Long lasting and robust.
- Does not discolour badly.
- Relatively economical.
- Work well on concrete.
- Essentially two components in one container.

1.1.1.c) Disadvantages of Polyester resin

- Moisture in surface is a chief factor and damage.
- Difficult to determine whether mixed properly.
- Peroxide catalyst is very reactive oxidizer.
- Flush solvent is flammable and hazardous waste.

1.1.2 Selection of Reinforced Material

Reinforcement commonly serves to fortify the composites and enhances the general mechanical properties of the matrix. The disperse stage is typically harder and more grounded.

Fibres Forms

Fibres are available in three forms: Continuous, Woven and

Chopped
In this project, used woven fibres which are in cloth form, the picture shown is below.

Figure 1: Glass fibre in mat form.

The above picture demonstrates the glass fiber in material structure. E-glass woven stand mat are bi-directional fabric. E-glass woven stand mat are very much coordinated with numerous pitch framework, for example, polyester, vinyl ester, epoxy, and phenolic tars. E-glass woven stand mat are superior fortification generally utilized as a part of hand lay-up and robot forms for the manufacture of pontoons, vessels, planes, and car parts, furniture and games things.

Selection of filler materials:

Calcium silicate ($CaSiO3$)

Calcium silicate ($CaSiO3$) is viewed as a potential bioactive material. Passive fire protection. High temperature insulation.

Properties of Calcium silicate

- Low density high strength
- Superior chemical inertness
- Low thermal expansion

Applications

- Fixed and moving turbile components
- Seals, bearings
- Ball valve parts

Silicon Carbide SiC

Electronic silicon carbide is the main substance compound of carbon and silicon. It was initially created by a high temperature electro-concoction response of sand and carbon. SiC is a phenomenal rough and has been delivered and made into pounding haggles abresive items for more than 100 years.

Properties of Silicon Carbide

- High thermal conductivity
- High hardness and high elastic modulus
- Excellent thermal shock resistance

Applications

- Hot gas flow liners
- Heat exchangers, Semiconductor process equipment.

II. PROBLEM FORMULATION

From the literature review it is observed that, glass fibre reinforced with polyester resin matrix, composites give good tensile strength when fibre are oriented in different angles. Instead of fiber kept in same orientaion apon adding additive i.e., Calcium Silicate and Silicon Carbide, will gives more strength as learned from the past literature report. The mechanical properties will change with change in composition. So different composition apon adding additive material has taken for this experiment.

2.1 OBJECTIVE OF PROJECT

- To prepare specimens for testing as per ASTM standard values.
- The mechanical properties of the polyester polymer changes steadily by changing the layers of glass fiber and also with orienting the glass to certain angle.
- The polyester resins are mixed with a filler material calcium silicate/silicon carbide that improves the mechanical properties of the material.
- Mechanical test are conducted.
- To study the vibration behaviour of the prepared laminate.

III. METHODOLOGY

3.1: Fabrication of composite laminates

Experimental Methodology

- Preparation of mould.
- Preparation of composite laminates for different orientations of glass fibre.
- Cutting the laminates as per ASTM standards.
- Tests are conducted to evaluate mechanical properties of prepared laminates.
- Comparing the mechanical properties of prepared laminates.
- Conduct Modal analysis test for prepared specimen.

The hand layup method is one of the efficient processes for developing of PMC's products. In this method, an operator places resin and reinforcement in or on the mould by using hand layup equipment.

3.2 Laminate and Specimen Preparation.

The steps to fabricate the laminates are as follows:
Step1: Calculations(according to the Rule of Mixture)
Step2: Selection of Mould.
Step3: Preparation of Matrix Material.
Step4: Preparation of Reinforcement.
Step5: Preparation of laminates.

3.2.1 Analytical Calculation

The principal step is to ascertain the amount of material required for fabrication. Calculations of parameters and measuring the materials are finished by method for electronic weighing machine. According to ASTM standard, for the preparation of laminate, the density of the laminate should be known. Hence we know that Density is given by the ratio of mass to volume. The composite specimen can be fabricated according to the ASTM standards. For the fabrication Hand layup method can be done. Different ply construction can be done as shown in the table.1 As we know the Density and volume of the laminate, therefore the mass of the laminate can be calculated.

Table 3.1: Composition of composite material to prepare laminate

S.No	Matrix	Reinforcement Fiber	Additive	Method of fabrication
1	Polyester	Glass fibre	Calcium	Hand

	resin (60%)	(36%)	silicate (4%)	layup process
2	Polyester resin (60%)	Glass fibre (36%)	Silicon carbide (4%)	Hand layup process

Density of matrix i.e., polyester resin = 1.13g/cm^3
Density of reinforcement i.e., glass fibre = 2.5 g/cm^3
Density of additive i.e., calcium silicate = 0.29 g/cm^3
Density of additive i.e., silicon carbide = 3.21 g/cm^3
Rule of Mixture: Formula for the rule of mixture is as follows
$V_c = V_f + Vp + V_a$
V_c = Volume of composite material
V_f = Volume of glass fibre
Vp = Volume of polyester resin
V_a = Volume of additive

$$\frac{m(c)}{\rho(c)} = \frac{m(f)}{\rho(f)} + \frac{m(p)}{\rho(p)} + \frac{m(CaSiO\ 3)}{\rho(CaSiO\ 3)}$$

OR

$$\frac{m(c)}{\rho(c)} = \frac{m(f)}{\rho(f)} + \frac{m(p)}{\rho(p)} + \frac{m(SiC)}{\rho(SiC)}$$

$m_{(c)}$ = mass of composite material
ρ_c= Density of composites and respectively,

IV. SPECIMEN PREPARATION

A. Tensile test: Tensile test was performed to calculate the ultimate tensile strength. Specimen dimensions are 228mm in length, 25mm in width and 4mm thickness.

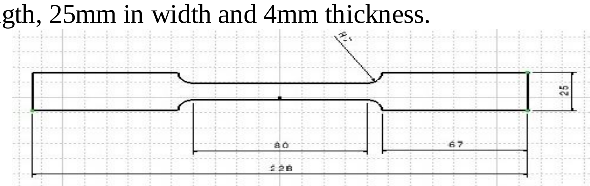


Figure 2: Tensile test specimen

Table 4.1: Requirement for Tensile test specimen for additive calcium silicate

Raw material	Quantity
Polyester resin	16.824grams
Glass fibre	10.09grams
Ca_2SiO_3	1.12grams

Table 4.2: Requirement for Tensile test specimen for additive silicate carbide

Raw material	Quantity
Polyester resin	19.937grams
Glass fibre	11.937grams
SiC	1.326grams

Figure 3: Tensile test specimen with additives calcium silicate or silicon carbide.

B. Compression test: In this test the material is compressed till the material is able to withstand not causing fracture in the material. The specimen dimensions are 127mm in length, 10mm in width and 4mm in thickness.

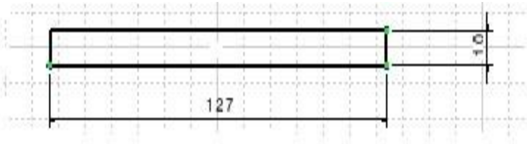


Figure 4: Compression test specimen.

Table 4.3: Requirement for Compression test specimen for additive calcium silicate

Raw material	Quantity
Polyester resin	3.744grams
Glass fibre	2.246grams
CaSiO3	0.249grams

Table 4.4: Requirement for Compression test specimen for additive silicate carbide

Raw material	Quantity
Polyester resin	4.428grams
Glass fibre	2.656grams
SiC	0.295grams

Figure 5: Compression test specimen with additives calcium silicate or silicon carbide.

C. Bending test: The specimen dimensions are 80mm in length, 20mm in width and 4mm in thickness.

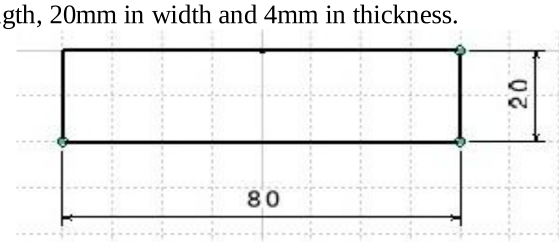


Figure 6: Bending test specimen.

Table 4.5: Requirement for Bending test specimen for additive calcium silicate

Raw material	Quantity
Polyester resin	5.904grams
Glass fibre	3.542grams
$CaSiO_3$	0.393grams

Table 4.6: Requirement for Bending test specimen for additive silicate carbide

Raw material	Quantity
Polyester resin	6.816grams
Glass fibre	4.189grams
SiC	0.465grams

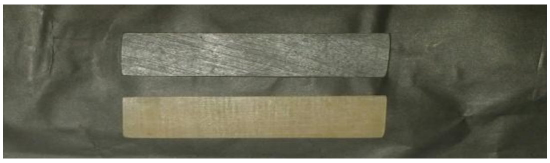


Figure 7: Bending test specimen with additives calcium silicate or silicon carbide.

V. MODAL ANALYSIS

Dimension 300*300*5mm

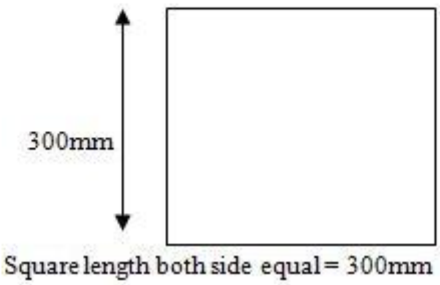


Figure 8: Specimen for Modal Analysis

A cantilevered rectangular symmetric plate polyester resin reinforced with glass fibre having different orientation along with the additive calcium silicate and silicon carbide having measurements 300x300x5mm is as appeared in Figure 8.

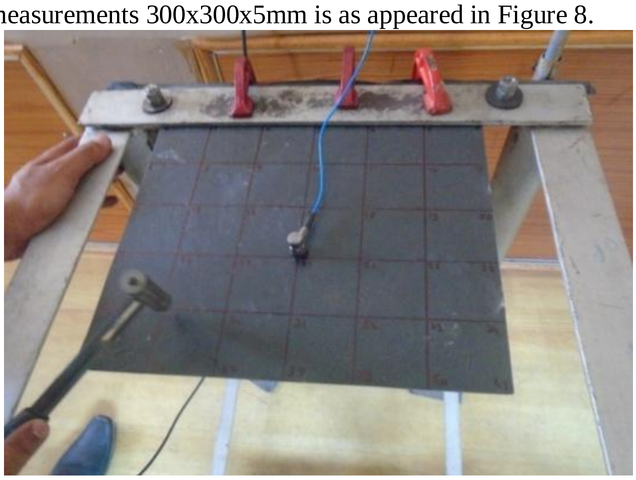


Figure 9: Modal analysis specimen placed testing

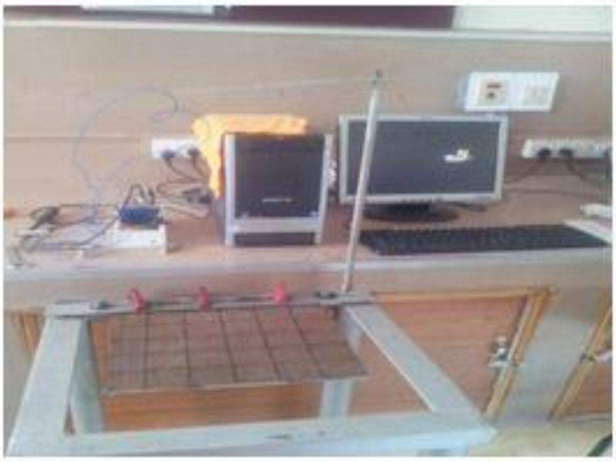
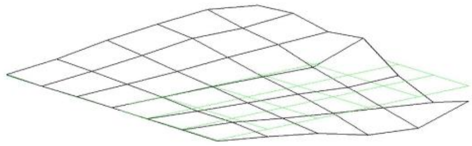


Figure 10: Experimental set up modal analysis

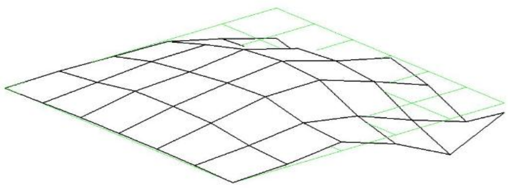
5.1 MODAL ANALYSIS FOR COMPOSITE PLATE WITH ADDITIVE $CaSiO_3$

1st Mode Shape: Bending Nature
1st Natural Freq: 22.983 Hz

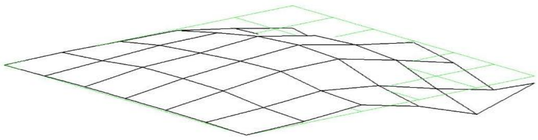
2nd Mode Shape:Twisting Nature
2nd Natural Freq:50.602 Hz



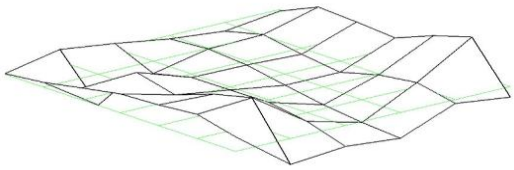
3nd Mode Shape:Double Bending Nature
3rd Natural Freq:123.176 Hz



4th Mode Shape:Combination of bending twisting
4th Natural Freq:150.241 Hz



5th Mode Shape:Complex mode
5th Natural Freq: 253.373Hz



5.2 MODAL ANALYSIS FOR COMPOSITE PLATE WITH ADDITIVE SiC

1st Mode Shape: Bending Nature
1st Natural Freq: 29.63 Hz

2nd Mode Shape:Twisting Nature
2nd Natural Freq: 63.23 Hz

3nd Mode Shape:Double Bending Nature
3rd Natural Freq:104.98 Hz

4th Mode Shape:Combination of bending twisting Nature
4th Natural Freq: 197.39 Hz

5th Mode Shape:Complex Nature
5th Natural Freq: 247.4Hz

VI. RESULTS

6.1 Tensile Test:

The Tensile Test is directed for the specimen of polyester matrix composite for various layers of glass fiber and for the diverse introduction of the glass fiber with the test speed 5.00mm/min and the outcomes is noted down. The diagram is created for the tested qualities as shown in figure 6.1.

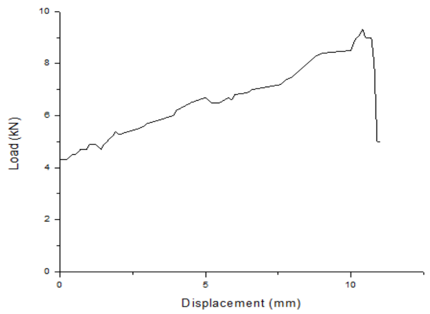


Figure:11: Tensile test Graph (load Vs Displacement)for composite along with additive CaSiO3.

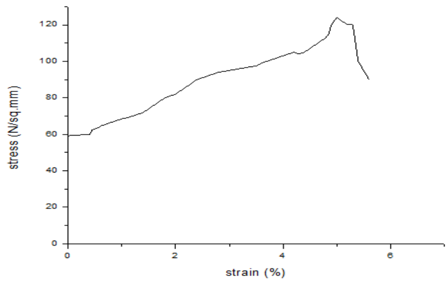


Figure 12 : Tensile test Graph (stress Vs strain) for composite along with additive CaSiO3.

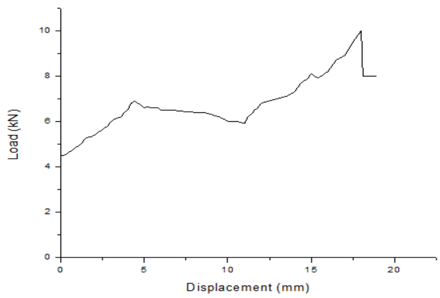


Figure 13 : Tensile test Graph (load Vs Displacement)for composite along with additive SiC

Table 6.1: Tensile test Results

	Peak load (kN)	Ultimate tensile stress(kN/sq.mm)
Composite material with additive Ca_2SiO_3	9.32	0.124
Composite material with additive SiC	10	0.133

6.2 Compression Test:

The Compression Test is conducted for the specimen of polyester matrix composite for different layers of glass fibre and for the different orientation of glass fibre with the test speed 5.00mm/min and the results are noted down. The graph is obtained for the tested values as shown below.

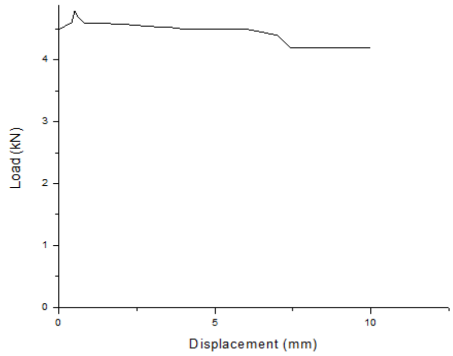


Figure 14 : Compression test Graph (load Vs Displacement)for composite along with additive CaSiO3.

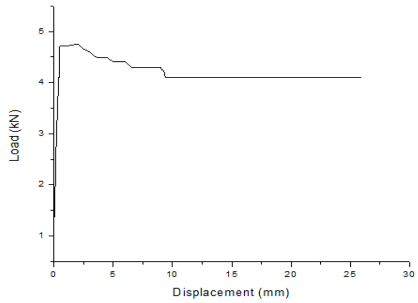


Figure 15: Compression test Graph (load Vs displacement)for composite along with additive SiC

Table 6.2: Compression test Results

	Peak load (kN)	Ultimate tensile stress(kN/sq.mm)
Composite material with additive Ca_2SiO_3	4.8	0.120
Composite material with additive SiC	4.76	0.119

6.3 Bending Test:

The Bending Test is conducted for the specimen of polyester matrix composite for different layers of glass fibre and with the different orientation of the glass fibre with the test speed 5.00mm/min and the results obtained is noted down. The graph is generated for the tested values which are shown below.

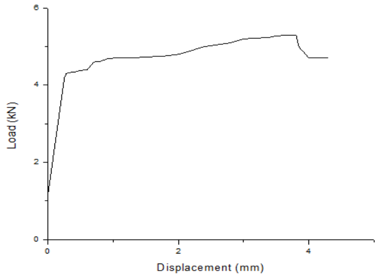


Figure 16 : Bending test Graph (load Vs Displacement)for composite along with additive $CaSiO_3$

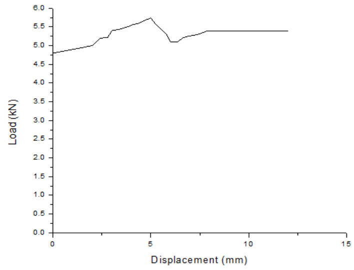


Figure 17 : Bending test Graph (load Vs Displacement)for composite along with additive SiC

Table 6.3: Bending test Results

	Peak load (kN)	Maximum Bending Moment (kN.mm)
Composite material with additive Ca_2SiO_3	5.28	7.92
Composite material with additive SiC	5.74	8.61

VII. DISCUSSION

7.1: Tensile test:

The tensile strength for the different additives has been delineated in the form of graph below,

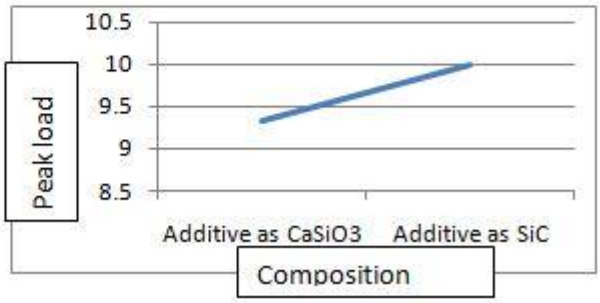


Figure 18: Tensile test result graph(peak load Vs composition)

From the graph that the peak load is more for composite having silicon carbide.

7.2: Compression test:

The compression strength for the different additives has been delineated in the form of graph below,

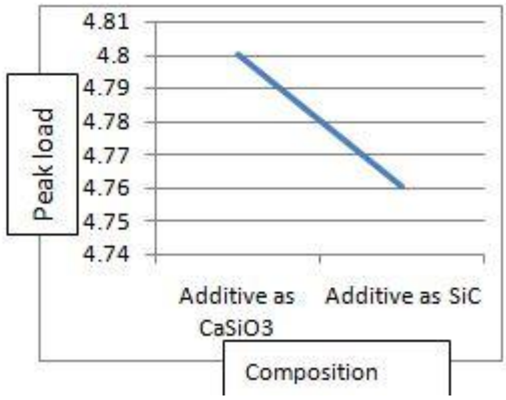


Figure 19: Compression test result graph(peak load Vs composition)

From the graph that the peak load is more for composite having calcium silicate.

7.3: Bending test:

The Bending strength for the different additives has been delineated in the form of graph below,

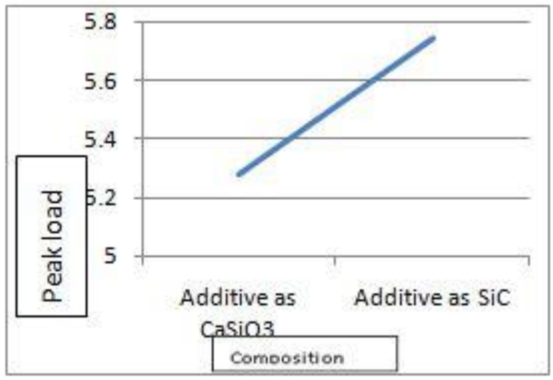


Figure 20: Bending test result graph(peak load Vs composition)

From the graph that the peak load is more for composite having silicon carbide.

7.4: Modal Analysis

Table 7.1: Obtained Natural frequencies for composite plate with additives CaSiO3 and SiC

	Natural frequency($CaSiO_3$)	Natural frequency(SiC)
Mode1: Bending nature	22.983 Hz	29.63 Hz
Mode2: Twisting nature	50.602 Hz	63.23 Hz
Mode3: Double bending nature	123.176 Hz	104.98 Hz
Mode4:Combination of bending and twisting	150.241 Hz	197.39 Hz
Mode5: Complex nature	253.373Hz	247.4Hz

The natural frequency of the composites is found to improve the vibrational nature of prepared specimen. The natural frequency is high for the composite plate which has additive silicon carbide and can be employed for low frequency range applications. The natural frequency found higher for calcium silicate additive and can be employed for high frequency range.

VIII. CONCLUSION

Laminate for different orientation of glass fibre with different layers of glass fibre reinforced polyester matrix composite is prepared. The composite laminate is prepared for glass fibre for 00 300, 600 and 900 orientation with additive calcium silicate and silicon carbide. The specimens are prepared according to ASTM standards values for tensile, compression and bending test and for modal analysis test. The Mechanical Characterisation like Tensile, Compression and Bending test was conducted and modal analysis for prepared specimen was also conducted. From the results obtained it can be concluded that,

- For tensile test, the results shows that the Peak load maximum for composite having additive silicon carbide.
- For compression test, the results shows that the Peak load maximum for composite having additive calcium silicate.
- For bending test and the results shows that the Peak load maximum for composite having additive silicon carbide.
- The modal analysis for prepared specimen was carried out to find first five natural frequencies and corresponding mode shapes, for both the composites plate with additives Calcium Silicate and Silicon Carbide.
- The natural frequency of the composites is found to improve the vibrational nature of prepared specimen. The natural frequency is high for the composite plate which has additive silicon carbide and can be employed for low frequency range applications.
- The natural frequency found higher for calcium silicate additive and can be employed for high frequency range.
- It can be concluded that for low operating frequency applications, SiC is better since its natural frequencies are higher.
- It can also be concluded that for high operating frequency applications, $CaSiO_3$ is better since its natural frequencies are higher in that range.

FUTURE SCOPE

Increase number of layers of glass fibres can be added to study the characteristic change in the specimen. Different filler materials can be added to study the characteristic change in the specimen. The specimen can be prepared for different orientations of glass fibres. The specimen can be tested for hardness test, electric conductivity or resistance test and fire test.

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