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Influence of Resin and thickness of Laminate on Flexural Properties of Laminated Composites

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Abstract— Fiber reinforced plastics have been widely used for manufacturing aircraft and spacecraft structural parts because of their particular mechanical and physical properties such as high specific strength and high specific stiffness. The present investigation was undertaken to determine the influence of Resin & Thickness of Laminates on glass fiber Epoxy, graphite fiber Epoxy and Carbon fiber Epoxy laminates with glass fiber Polyester, graphite fiber polyester and carbon fiber polyester resin under 3- point bend test. the composite laminate specimens are prepared using the vacuum baggage technique and the specimen are subjected to 3 point bending load on a simply supported pins and the investigation is carried out as per the ASTM D790 standards. Flexural properties evaluated are flexural strength and stiffness of the composites system appropriate conclusions was drawn. The purpose of this work is to experimentally analyze the progressive failure process of laminated composites subjected to flexural loads, Flexural loading causes stresses in the composites, which vary through the thickness and reinforcement material used. This research indicates that Flexural strength is mainly dependent on the Type of Resin used & thickness of laminated polymer composites.

Index Terms— **Laminate, Flexural Strength, Resin, Three point bending, Stiffness.**

I. INTRODUCTION

In the recent decades the application of laminated composites are finding increasing in Transportation vehicles, aviation industries ,marine and aerospace, due to their Low thermal expansion, low corrosion resistance, high strength to weight and stiffness to weight ratios. The majority of engineering composites materials in demanding applications consists of continuous fibers of glass, Graphite or carbon reinforcement in thermosetting epoxy polymer. There has been a tremendous advancement in recent days. The mechanical property of the composite becomes complex with the addition of fibers. When subjected to compression, tension and flexure tests polymeric composites are susceptible to mechanical damages that can lead to interlayer delamination. Catastrophic failure of the component can occur due to the increase in the external load.

Lassila J and Vallittu P [1] investigated the influence of the position of fiber rich on the flexural properties of fiber-reinforced composite construction. They found that the specimens with FRC positioned on the compression side showed flexural strength of approximately 250 MPa. While FRC positioned on the tension side showed strength ranging from 500 -600 MPa. Zsolt R'ACZ studied the analysis of the flexural strength of the unidirectional composite carbon fiber composites and estimated the magnitude of size effect in carbon fiber composite and the result revealed that a specimen with lower span – to thickness ratio exhibits a lower flexural strength [2]. Johnston,

C.D. and Zemp, R.W. examined the influence of fiber content (0.5-1.5 % of volume), fiber aspect ratio (47-100), and fiber type (4 types) on the flexural fatigue performance of steel fiber reinforced concrete [3]. T. Waki and T. Nakamura studied and compared the flexural strength of three types of Glass-fiber reinforced composite systems. They found that the BR-100 (686 MPa.) and vectris (634 MPa.) beams demonstrated significantly higher flexural strength than the fiber Kor (567 MPa.) beam and also found that (Estenia / BR-100) composite had a good mechanical strength for metal – free restorations [4]. Khashaba and Seif [5] investigated the mechanical behavior of woven FRP composites under tension, bending, and combined bending/tension loadings. Mauricio et al. [6] predicted the elastic behavior of hybrid plain weave fabric composites with different materials and undulations in the warp and weft directions by formulating a 3D analytical micromechanical model. Pu Xue et al. [7] presented an integrated micro macro model for woven fabric composites subjected to combine tensile and large shear deformation.J.Kosoric, et.al [8] has carried out research using E-glass fiberglass and epoxy resin with catalyst addition as matrix for the composite material. The modal test was carried out for the measurement of flexural properties and modulus elasticity on flexural testing machine the analysis showed that the glass fiber reinforcing the laboratory composite resins have greater effect on the flexural strength than modulus of elasticity. Mechanical properties of mono directional fiber reinforced composite have been extensively studied by Jones [9]

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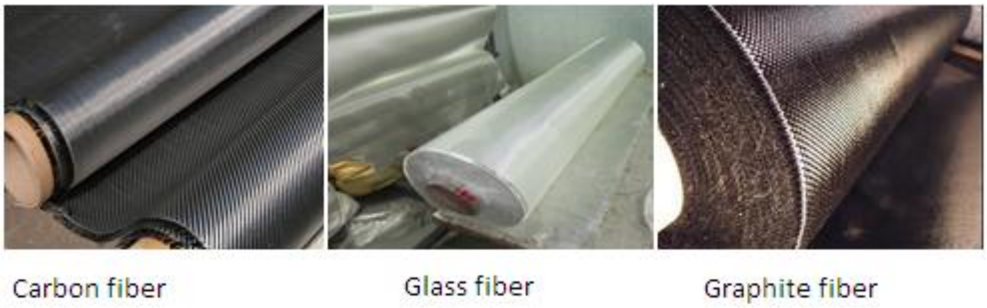
From the above literature, it is evident that there is no single source of literature available on experimental evaluation of flexural properties of bi-woven composite laminates under varying thickness and Resin. Hence, in this work it is proposed to address the flexural behavior of composite laminates with varying thickness under flexural loading conditions.

II. EXPERIMENTAL INVESTIGATION

Materials:

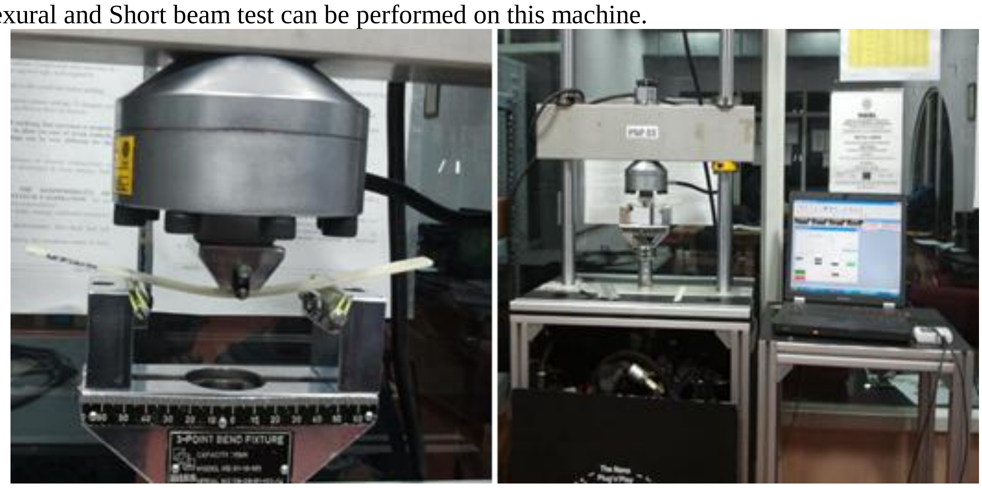


Bi woven Carbon fiber, Glass fiber & Graphite fiber are used as reinforcement materials in the form of bi directional, Epoxy & Polyester resins are used as Matrix materials for the laminate preparations with the hardeners HY140 & MEPK respectively for epoxy resin and Polyester resin respectively.

Instrumental: Machine specifications:

Machine Specifications	**Fixture Details**
Actuator capacity: 10 KN	3-Point Bending Fixture
Stroke:+/-30mm	Capacity:15 KN
Vertical daylight:570mm	MODEL: BI-10-101
Horizontal day light:40mm	
Supply 6 kHz digital servo control	
Rate of Loading: 1mm/min	

Testing Machine: The universal testing machine used in the above test was manufactured by BISS Bangalore. It is a versatile and comprehensive testing machine which can be used as a standalone machine or it can be linked to a remote computer and data analysis software. This machine is designated as PNP-01 and is shown in the below fig.1.5 Flexural and Short beam test can be performed on this machine.



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Sample preparation:

Preparation of the Laminate: Two types of Resins Epoxy resin and Polyester Resins are used to prepare the Glass fiber, Graphite and Carbon fiber laminates as shown in the table 1 & 2.

Case 1: Epoxy resin as matrix material.

Composite laminates were fabricated at room temperature (24 -26ºC) in a clean and net environment. Composite laminates were fabricated by hand lay-up process, proper care was taken during the preparation of laminates to maintain the uniform thickness and to prevent the voids. The first layer of Bi-woven glass fiber cloth (ranging from 0.25 mm to 0.35 mm) is laid and resin is spread uniformly over the cloth by means of brush. The second layer of the cloth is laid and resin is spread uniformly over the cloth by means of brush. After second layer, to enhance wetting and impregnation, a teethed steel roller is used to roll over the fabric before applying resin. Also resin is tapped and dabbed with spatula before spreading resin over fabric layer. This process is repeated till all the 10 layers (2 mm thickness) and 16 layers (4 mm thickness) are placed. No external pressure is applied while casting and curing because uncured matrix material can squeeze out under high pressure. This results in surface waviness (non-uniformed thickness) in the model material. The casting is cured at oven temperature of about 100º C up to 2 hrs & finally removed from the mould to get a fine finished composite plate. The below picture shows the clear view of the fabrication process. This process is repeated to prepare the Graphite and carbon based epoxy resin laminates.

Fig – 1 Cutting of Graphite Cloth

Fig – 2 Hand Lay up

Fig – 3 Applicatoin of Resin

Fig – 4 Stacking sequence

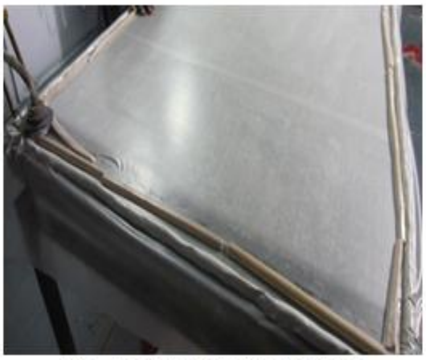

Fig – 5 Vacuum Bagging Technique

Preparation of test specimens:

After the cure process, the test specimens are cut from the sheet to the following size as per ASTM standards (ASTM D-790) by using diamond impregnated wheel, cooled by running water. All the specimens are finished by abrading the edges on a fine carborundum paper.

Fig 6 Flexural specimen

This completes the preparation of the testing samples as shown in the table 1

Case 2- Polyester resin as matrix material: the laminates were fabricated by placing the one layer of bi woven fabric over the other Polyester resin as a matrix material in between each layer, tools were used to distribute resin uniformly as explained earlier and a teethed steel roller is used to roll over the fabric before applying resin. Also resin is tapped and dabbed with spatula before spreading resin over fabric layer. This process is repeated till all the 10 layers (for 2mm thickness) and 16 layers (4mm thickness) are placed without applying any kind of external pressure. The surfaces of the laminates were covered MILA film to prevent lay up from external disturbance. After proper curing about 2 days at room temperature the specimens were cut in required sizes per ASTM (ASTM D-790) standards. This completes the preparation of the testing samples as shown in the table 2.

Table 1- Designation of glass, carbon &Graphite specimens reinforced with epoxy resin.

Sl. No.	Specimen Designation (EPOXY RESIN)	Description
1	CAFE/02/01	Carbon Fiber /2 mm thickness/Sample 01
2	CAFE/02/02	Carbon Fiber/2 mm thickness/Sample 02
3	CAFE/04/01	Carbon Fiber/4 mm thickness/Sample 01
4	CAFE/04/02	Carbon Fiber/4 mm thickness/Sample 02
5	GRFE/02/01	Graphite Fiber/2 mm thickness/Sample 01
6	GRFE/02/02	Graphite fiber/2 mm thickness/Sample 02
7	GRFE/04/01	Graphite Fiber/4 mm thickness/Sample 01
8	GRFE/04/02	Graphite Fiber/4 mm thickness/Sample 02
9	GLFE/02/01	Glass Fiber/2 mm thickness/Sample 01
10	GLFE/02/02	Glass Fiber/2 mm thickness/Sample 02
11	GLFE/04/01	Glass Fiber/4 mm thickness/Sample 01
12	GLFE/04/02	Glass Fiber/4 mm thickness/Sample 02

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Table 2- Designation of glass, carbon &Graphite specimens reinforced with Polyester resin.

Sl. No.	Specimen Designation (POLYESTER RESIN)	Description
1	CAFP/02/01	Carbon Fiber /2 mm thickness/Sample 01
2	CAFP/02/02	Carbon Fiber/2 mm thickness/Sample 02
3	CAFP/04/01	Carbon Fiber/4 mm thickness/Sample 01
4	CAFP/04/02	Carbon Fiber/4 mm thickness/Sample 02
5	GRFP/02/01	Graphite Fiber/2 mm thickness/Sample 01
6	GRFP/02/02	Graphite fiber/2 mm thickness/Sample 02
7	GRFP/04/01	Graphite Fiber/4 mm thickness/Sample 01
8	GRFP/04/02	Graphite Fiber/4 mm thickness/Sample 02
9	GLFP/02/01	Glass Fiber/2 mm thickness/Sample 01
10	GLFP/02/02	Glass Fiber/2 mm thickness/Sample 02
11	GLFP/04/01	Glass Fiber/4 mm thickness/Sample 01
12	GLFP/04/02	Glass Fiber/4 mm thickness/Sample 02

Table 3- Designation and Measured Dimensions of Glass, Graphite and carbon specimens reinforced with Epoxy Resin.

Sl. No.	Specimen Designation (Epoxy Resin)	length (mm)	Width (mm)	Thickness (mm)
1	CAFE/02/01	200.1	12.05	2.1
2	CAFE/02/02	200	12.02	2.2
3	CAFE/04/01	201	12	4.01
4	CAFE/04/02	200	12.04	4.05
5	GRFE/02/01	200.3	12.01	2.2
6	GRFE/02/02	200.5	12.09	2.1
7	GRFE/04/01	201	12.1	4.06
8	GRFE/04/02	200.4	12.08	4.03
9	GLFE/02/01	201.2	12.05	2.2
10	GLFE/02/02	200	12.08	2.1
11	GLFE/04/01	200.1	12.06	4.3
12	GLFE/04/02	200	12	4.1

Table 4- Designation and Measured Dimensions of Glass, Graphite and carbon specimens reinforced with Polyester Resin.

Sl. No.	Specimen Designation (Polyester Resin)	length (mm)	Width (mm)	Thickness (mm)
1	CAFP/02/01	200.03	12.33	2.2
2	CAFP/02/02	200.75	12.02	2
3	CAFP/04/01	200.24	12.04	4.02
4	CAFP/04/02	200.32	12.08	4.04
5	GRFP/02/01	200.73	12.1	2.1
6	GRFP/02/02	200.22	12.06	2
7	GRFP/04/01	200.98	12.12	4.08

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8	GRFP/04/02	199.72	12.08	4
9	GLFP/02/01	200.12	12.05	1.98
10	GLFP/02/02	200.02	12	2
11	GLFP/04/01	200.16	12.1	4.2
12	GLFP/04/02	200.02	12.03	4

III. RESULTS

Table-5: Flexural Properties Glass, Carbon and Graphite composites with 2mm & 4mm thickness Reinforced with Epoxy Resin

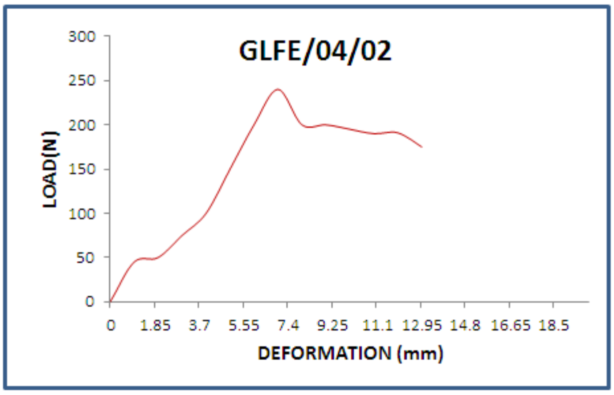
Sl. No.	Specimen (Epoxy Resin)	Max. Load (N)	Deflection at max load (mm)	Flexural Modulus (MPa)	Flexural Strength (MPa)
1.	CAFE/02/01	772.0	11.78	46.43	213.1
2.	CAFE/02/02	767.6	11.12	47.47	205.3
3.	CAFE/04/01	974.9	6.56	50.95	117.0
4.	CAFE/04/02	933.3	6.35	50.73	112.0
5.	GRFE/02/01	105.3	14.94	11.79	131.6
6.	GRFE/02/02	104.9	15.31	11.54	131.2
7.	GRFE/04/01	317.0	10.88	28.10	99.0
8.	GRFE/04/02	615.9	10.29	28.81	95.4
9.	GLFE/02/01	93.22	10.81	15.95	116.5
10.	GLFE/02/02	115.4	10.38	14.44	114.3
11.	GLFE/04/01	263.3	8.26	45.91	82.3
12.	GLFE/04/02	234.5	8.12	42.19	83.2

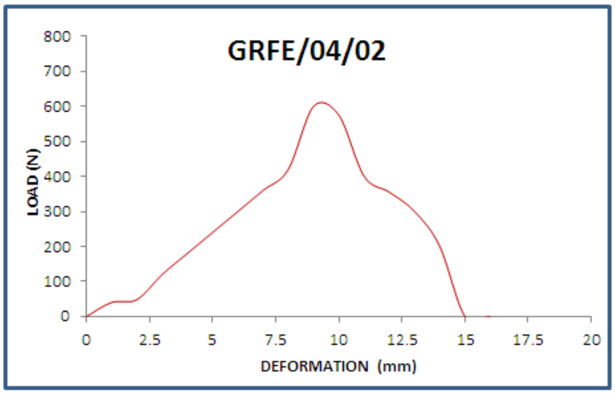
Table-6: Flexural Properties Glass, Carbon and Graphite composites with 2mm & 4mm thickness Reinforced with Polyester Resin.

Sl. No.	Specimen (POLYESTER RESIN)	Max. Load (N)	Deflection at max load (mm)	Flexural Modulus (MPa)	Flexural Strength (MPa)
1	CAFP/02/01	602	10.12	42.13	200.18
2	CAFP/02/02	610.6	10.18	41.11	200.16
3	CAFP/04/01	799.9	5.45	51.12	95
4	CAFP/04/02	813.3	5.12	49.18	94
5	GRFP/02/01	108.4	12.92	10.19	124.6
6	GRFP/02/02	116	13.13	10.02	122
7	GRFP/04/01	550.2	9.66	26.2	86
8	GRFP/04/02	585.8	8.96	25.6	84.6
9	GLFP/02/01	87.55	10.14	13.22	110.2
10	GLFP/02/02	109.4	10.59	13.12	110
11	GLFP/04/01	255.6	9.26	43.22	78.6

12	GLFP/04/02	222.5	8.97	42.36	76

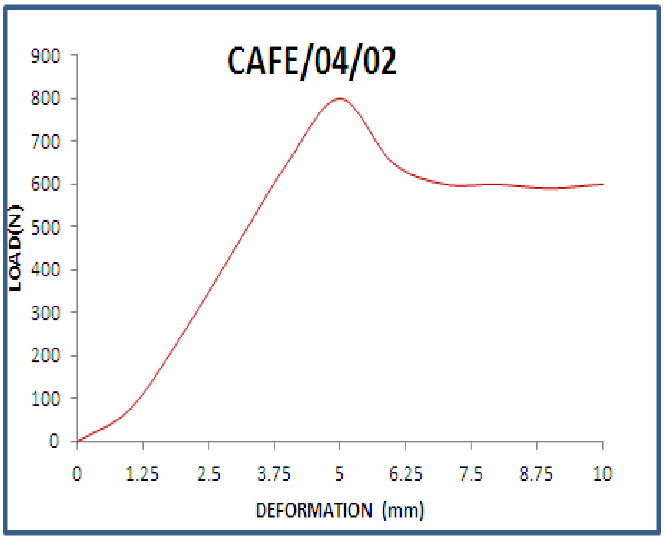
Graphs:



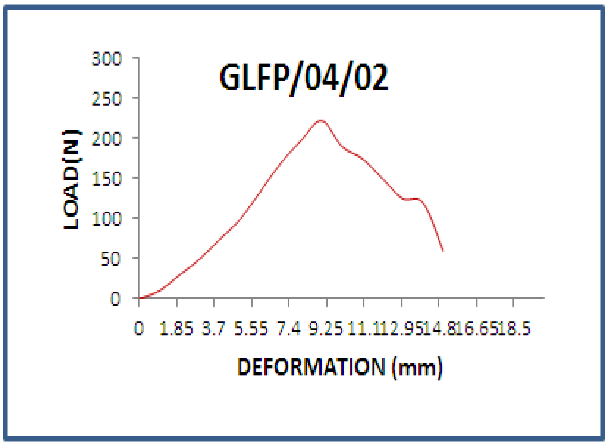


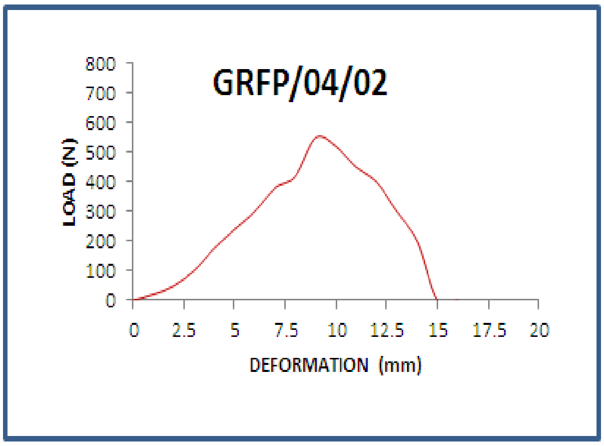
Graph 01: Glass fiber with Epoxy

Graph 02: Graphite fiber with Epoxy



Graph 03: Carbon fiber with Epoxy





Graph 04: Glass fiber with Polyester Resin

Graph 05: Graphite fiber with Polyester Resin

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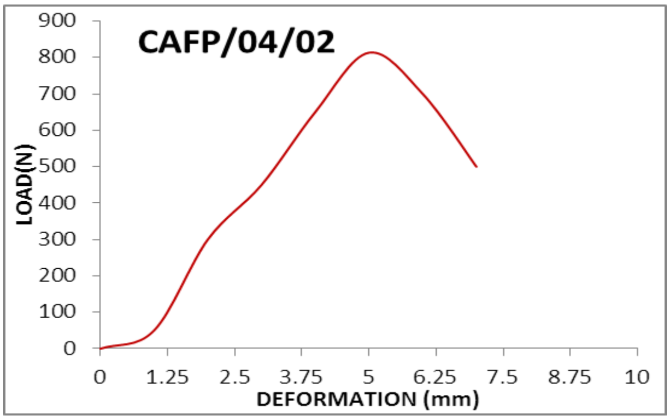

Graph 06: Carbon fiber with Polyester Resin

IV.DISCUSSIONS

The results obtained from experimental work on the flexural testing of different fibers of laminated composites are illustrated in Table-5 & 6, which represents deflection of beam, flexural stress, flexural modulus and maximum flexural load. Results are obtained for two different thicknesses of 2mm & 4mm respectively with two different resins. The results show that there is a variation of deflection and stresses from linear to nonlinear analysis beyond certain load. The values of deflection decreases as the thickness FRP laminated composite plate increase because of increase in stiffness of the plate. Similar trend is observed in the bending stress values indicated in table 5 & 6. Also, it is clear from the table 5 & 6 that the maximum value of the flexural strength (213.1 MPa) for Carbon with epoxy resin and, while the minimum value of flexural strength (76 MPa.) for Glass fiber with Polyester resin.

This study is carried out in order to investigate the flexural properties of three types of laminated composites namely Glass fiber, Graphite fiber and Carbon fiber with epoxy and polyester resins as matrix materials. This test had given the basic concept of the effect of thickness and different resin system onto the tensile properties of the laminated composites. The results of experiments show that the flexural properties of the specimens were increased when epoxy resin was used as matrix system.

V. CONCLUSIONS

The main conclusions of the experimental investigation of flexural analysis of laminated composite material are as follows:

- In this work, flexural test on two different thicknesses with two different resins of bi-woven glass epoxy, graphite epoxy and carbon epoxy specimens were compared with glass polyester, graphite polyester and carbon polyester resin tested and results recorded. The influence of specimen thickness and influence of resin on the flexural properties were evaluated and it is found that the increase in thickness decreases the flexural properties such as flexural strength & flexural modulus and as the thickness increases the load carry capacity increase on the specimen.
- Flexural properties of Epoxy Glass, Graphite and Carbon Laminates of 2mm and 4 mm thicknesses with Epoxy Resin and Polyester Resin were successfully conducted and results are recorded.
- The Maximum value of deflection (15.31 mm) is at Graphite fiber with epoxy resin, while the minimum value of deflection (5.12 mm) is at Carbon fiber with polyester resin.
- The effects of specimen thickness & Resin on the flexural properties were evaluated and it is found that the specimen's reinforced with epoxy resin shows better Flexural properties as compared to the specimen reinforced with polyester resin.

Finally, it can be concluded that for same thickness and orientation, carbon fiber reinforced with epoxy resin provides better flexural properties as compared to glass and graphite resin forced with both epoxy resin and polyester resin under flexural loading conditions.

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REFERENCES

[1] Lassila L.J. and Vallittu P.K., "The Effect of Fiber Position and Polymerization Condition on the Flexural Properties of Fiber –Reinforced Composite", Journal of Contemp Dent, Vol.5, No.2, May (2004).

[2] Zsolt R'ACZ, "Analyzing the Flexural Strength Properties of Unidirectional Carbon / Epoxy Composites", Hungarian Scientific Research Fund, (2002).

[3] Johnston, C.D. and Zemp, R.W.,"Flexural Fatigue Performance of Steel Fiber Reinforced Concrete-Influence of Fiber Content, Aspect Ratio, and Type," ACI Materials Journal, Vol.88, No.4, Jul-Aug, (1991).

[4] T. Waki and T. Nakamura," Flexural Strength and Bending Elasticity of Fiber Reinforced Composite Systems", IADR/AADR/CADR 80th General Session, (San Dieg.), (2002).

[5] Khashaba U.A. and Seif M.A., 2006, Effect of different loading conditions on the mechanical behavior of [0/±45/90] s woven composites, Composite Structures, 74, pp 440–448.

[6] Mauricio V. Donadon, and John M., A 3D micromechanical model for predicting the elastic behaviour of woven laminates, Composites Science and Technology, 67, pp, 2007, 2467–2477.

[7] Pu Xue, Jian Cao and Julie Chen, "Integrated micro/macro mechanical model of woven fabric composites under large deformation", Composite Structures, 70, 2005, pp 69–80.

[8] Kosoric J., M.Cattani, S.Bouill, CH Godin and J.Meyer," reinforcement of composite resins with unidirectional glass fibers", European cells and materials, vol.3, suppl.1 (2002).

[9] Robert M. Jones, (1999), Mechanics of composite materials, Taylor & Francis. New York.

[10] Jordan, W. M.; Bradley, W. L.; Moulton, R. J.,Re lating Resin Mechanical Properties of Composite Delamination Fracture Toughness, Journal of Composite Materials, 23, (1989), 923-943.

[11] Russell A. J.; Street, K. N., Moisture and Temperature Effects on the Mixed Mode Delamination of Unidirectional Graphite/Epoxy in, Delamination and De bonding of Materials, Johnson S (Ed), ASTM-STP-876, (1985), 275-293.

[12] Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulation, Annual Book of ASTM Standard, ASTM D-790-03, (2005).