Polymer Laminated Composites Reinforced With Bi-Woven Glass Fibers: Subjected To Tensile And Compression Loading

Dr. P.V. Sanjeeva Kumar, Dr. A.Hemantha Kumar, Dr. G.Venkata Subbaiah

Abstract: The present engineering applications require new and better materials for the replacement of existing ones. In view of this demand, at present we focused on latest upcoming materials such as composite materials especially laminated composites. The composites are having the greatest strength to weight ratio compared to conventional materials. Fiber reinforced polymer composites have been used in a variety of application because of their many advantages such as relatively low cost of production, easy to fabricate and superior strength compare to neat polymer resins. Reinforcement in polymer is either synthetic or natural. Synthetic fibers such as glass, carbon etc. have high specific strength but their fields of application are limited due to higher cost of production. The present research focus on characterization and testing of Bi- woven Glass Fiber/Epoxy composite material. The different mechanical tests are performed on Bi-wove Glass Fiber/Epoxy composite and the mechanical properties such as, tensile strength, tensile modulus, compressive strength is determined as per ASTM standards. The mechanical properties were improved as the number of layers of Bi-woven glass fibers reinforcement content increased in the epoxy matrix material

Key words: Laminated Composites, Bi-woven Glass Fibers, Epoxy, Hand layup Technique, Tensile strength, Number of layers, Compressive strength.

1. INTRODUCTION

Fibre reinforced polymer composites has been used in a variety of application because of their many advantages such as relatively low cost of production, easy to fabricate and superior strength compare to neat polymer resins. Reinforcement in polymer is either synthetic or natural. Synthetic fibre such as glass, carbon etc. has high specific strength but their fields of application are limited due to higher cost of production. Glass fibers reinforced polymer composites have been prepared by various manufacturing technology and are widely used for various applications. Initially, ancient Egyptians made containers by glass fibers drawn from heat softened glass. Continues glass fibers were first manufactured in the 1930s for high-temperature electrical application. Nowadays, it has been used in electronics, aviation and automobile application etc. Glass fibers are having excellent properties like high strength, flexibility, stiffness and resistance to chemical harm. It may be in the form of roving's, chopped strand, yarns, fabrics and mats. Each type of glass fibers have unique properties and are used for various applications in the form of polymer composites. Hassan Abdolpour et.al, [1] have given in their paper the how to improve the flexural strength of hybrid sandwich plates with glass fiber reinforced polymer by using the strain hardening method. Francis L King [2] are performed the mechanical testing on the poly lactic acid reinforced hybrid fiber composite and proved that the mechanical properties are improved. M.K. Gupta and Rohit Singh [3] are investigated the static and dynamic mechanical properties for PLA coated sisal fibers reinforced with polyester and obtained the fair results.

P.V.Sanjeeva Kumar and Dr.B.Chandramohana Reddy [4] are fabricated and tested the laminated carbon bi-woven fibers Reinforced with vinyl ester composites and evaluate its tensile and flexural strength for different number of layers. In this the vinyl ester was used as a matrix to prepare composites by in situ polymerization technique. The various investigations [5-10] are given the best results on the improvement of mechanical properties such as tensile strength, compressive strength, flexural and impact strength of polymer based composites. Sanjeev R nandaragi et.al [11] is fabricated and tested the woven glass fiber composite materials and determined its mechanical properties. The obtained results are shown in enrichment of mechanical properties. Enrique .J et.al are fabricated the hybrid laminates reinforced with aligned carbon nanotubes with situ technique_and evaluated its mechanical properties. The obtained results are having the good agreement. Many investigators [12-15] are used natural fibers or bi-woven fibers as the reinforcement in polymer matrix and successfully evaluated their mechanical properties.

2. MATERIALS

2.1 Bi-woven Glass Fiber

In this project glass fibers are used for fabricating the composite specimen. The glass fibers were obtained from Dharmapuri District, Tamil Nadu, India. Polyester resin and the catalyst Methyl Ethyl Ketone Peroxide (MEKP) were purchased from M/s. Sakthi fiber glass Ltd., Chennai, India. 10% of catalyst is added with the resin for the quantity taken. The bi-woven glass fiber used for present work is shown in Fig2.1 and its closed view is shown in Fig2.2.

***Fig 2.1**: Bi-woven glass fiber*

- *Dr.P.V.Sanjeeva kumar is the author and is currently working as Associate Professor in Annamacharya Institute of Technology and Sciences, Rajampet,-516216.A.P. INDIA. E.Mail: sanjeevpalagiri@gmail.com.*
- *Dr.A.Hemantha kumar is the co-author and currently working as Professor in Annamacharya Institute of Technology and Sciences, Rajampet,-516126,A.P. INDIA. E.Mail: ahkaits@gmail.com*
- *Dr.G.venkata Subbaiah is the co-author and is currently working as Senior lecturer in S.V.Govt.Polytechnique, Tirupati-517501,A.P.INDIA . ganganapallivenkat@gmail.com*

***Fig 2.**2: Close view of bi-woven fibers*

2.2 EPOXY

Epoxy is the thermosetting matrix or resin materials, having at least one or more epoxide groups in the molecule. The epoxide also termed as oxirane or ethoxyline group and is regarded as representative unit of epoxy polymer. Most of the commercially available epoxy resins are oligomers of diglycidyl ether of biphenyl A (DGEBA). These oligomers when react with the hardener, the epoxy resin get cured and becomes a thermosetting polymer. There are mainly two families of epoxies non-glycidyl and glycidyl epoxies. Glycidyl epoxy resins can be further defined as either glycidylamine, glycidyl-ester, or glycidyl-ether. Non-gylcidyl epoxy resins are also called cyloaliphatic or aliphatic resins. The most common glycidyl epoxy resins are synthesized by reacting bisphenol A (BPA) with epichlorohydrin molecules. Novolac-based epoxy resin is the other type of epoxy that is also frequently used in certain industries. Nowadays, epoxies are combined with a large range of co-reactants/curing agents/hardener, such as anhydrides, amines, and amides; perhaps the amine-based hardener is quite common. Epoxy resins usually require the higher amount of curing agent in the ratio of resin to hardener (1:1 or 2:1), compared with polyester or vinyl ester resins, where the resin is catalyzed with a small (1–3%) addition of a catalyst. Like other thermosetting resin, cured epoxy systems indicates low fracture toughness, inherently low impact resistance, unaltered shaped after curing/ polymerization, and reduced resistance to crack initiation and propagation.

3. METHODOLOGY

The composite samples used for the present investigation consist of five layers, and fabricated by the hand layup method. In the five layers, the glass fiber layers are mounted on the top, middle and bottom of the specimen. Add 10% catalyst by weight with resin for quick setting, immediate mixing, and reduce the heat generated due to exothermic reaction. Before fabricating the composite specimen the glass fibers are dried in the hot air oven at 80ºC for 8 hours to remove the moisture completely. Initially, the releasing agent is coated over the plain horizontal table for easy removal of the specimen, and the first layer of the specimen, i.e., the glass fiber mat is placed over the coated surface after the releasing agent gets dried. Then the resin is applied over the glass fiber mat and the resin is evenly distributed on the entire surface by using a roller. The resin is allowed 10-20 minutes for getting completely mixed; after that, the second layer of the specimen. The air gaps formed between the layers during processing are gently squeezed out. Then these samples are taken to the hydraulic press to remove the air gap between the layers, and any excess air present in the resin, by applying a force of about 70 to 100N for 48 hours, to get perfect samples. After the samples get hardened completely, they are taken out from the mould, and the rough edges are neatly cut as per the required dimensions. The glass mould with resin distribution while fabricating the first layer plate is shown in Fig.3.1 and also the ejected plate after solidification is shown in Fig.3.2.

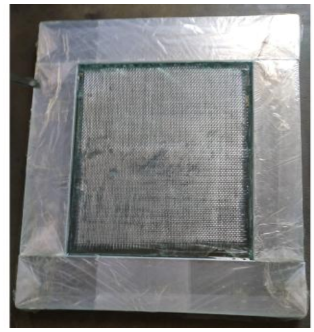


***Fig 3.1** Resin distribution*

***Fig 3.**2 Fabricated composite laminates*

A mould was prepared on par with ASTM dimensions, and it was coated with a mould releasing agent (poly-vinyl-alcohol) for easy removal of casting. Predetermined dimensions of 200 x 200 mm glass woven fiber were cut with appropriate scissors and made sure to ensure flat surfaces of mats. Mats were mercerized for about 2h under tensile loading to obtain the flat surfaces. Vinyl epoxy was stirred gently at 50^0 C to decrease its density as it facilitates easily flowing properties to the end destiny. Then the accelerator/catalyst/promoter (1:10) parts by weight was added to the modified vinyl ester mixture. The mat should be placed in the mould cavity before modified solution is to be poured, on par with the orientations mentioned in the above for different layers. Laminated mixture was poured into the mould cavity in such a way that mat should be completely drowned with laminated solution and yet it has to be in the approximately centre place if it is asked to be single layer-1. Air was removed with the help of vacuum machine. Brush and roller were used to impregnate fiber. The closed mould was kept under pressure for 24 h at room temperature. To ensure complete curing, the composite samples were post-cured at 80˚C for 1 hour. Now the single layered laminated polymer composites are ready. In order to get two layered laminated composites, it is made sure to keep two mats in the mould cavity one upon the other in the orientations mentioned above and then same modified solution has to be poured into the mould. Similarly three and four layered laminated composites were prepared. Specimens of required size were cut out from the post cured laminated composites for further characterizations as per ASTM standards. Fabrication of polymer based composites begins with preparation of fillers or reinforcements and then followed with resin impregnation

4. TESTING

4.1 TENSILE TEST

After the fibre reinforced composite was dried, it was cut using a saw cutter to get the dimension of specimen for mechanical testing. The tensile test specimen was prepared according to ASTM D3039, the most common specimen for ASTM D3039 has a constant rectangular cross section, 25 mm (1 in) wide and 250 mm (10 in) long. The prepared specimens are shown in Fig4.1 and the testing machine in the Fig.4.2.The specimen was mounted in the grips of the Instron universal tester with 10 mm gauge length. The stress strain curve was plotted during the test for the determination of ultimate tensile strength and elastic modulus. All the test results were taken from the average of two tests. For the tensile tests, due to the smooth surface finish on the specimens, the metal grips for the MTS machine sometimes slip when tension is applied. To solve this problem, emery cloth is placed in the grips which provide enough friction to stop the slipping. Initially, before a specimen in loaded in the MTS machine the load cell channel is zeroed because it has a tendency to drift. The MTS machine is set to a home position that is a good distance for specimen testing. A test specimen is carefully measured and the width and thickness of the neck region are recorded in a file along with the specimen and panel number and any observations made during the experiment run. The specimen is then placed in the grips; care is taken to ensure good alignment of the specimen. The biaxial extensometer is then placed on the specimen using the conical point grips. The conical points are placed in the center of the specimen, either on the edge or on the face depending on the data to be obtained. Alignment pins are used to ensure the axial extension gauge length will be exactly one inch. The transverse channel must be zeroed using the signal conditioning software. Since the alignment pins are used for the axial direction the axial channel is automatically zeroed the grips separate at a displacement rate of 12.7 mm/min. After complete fracture of the sample the test is stopped and no more data is collected. The specimen is then removed and kept for observation purposes.

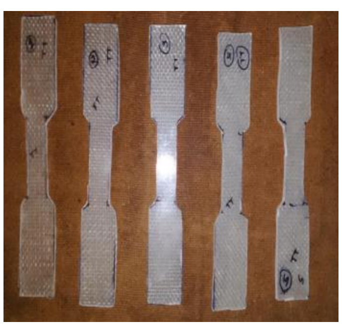


Fig 4.1*: Tensile test specimens*

Fig 4.2*: Universal Testing Machine*

4.2 COMPRESSION TEST

After the fibre reinforced composite was dried, it was cut using a saw cutter to get the dimension of specimen for mechanical testing. The compression test specimen was prepared according to ASTM D3039; the most common specimen for ASTM D3039 has a constant rectangular cross section, 4.90 mm wide and 7.14 mm long. The testing samples are shown in Fig.4.3 and the testing machine is shown in Fig. 4.4 the specimen is mounted on the grips of the Instron universal tester and the test is performed.

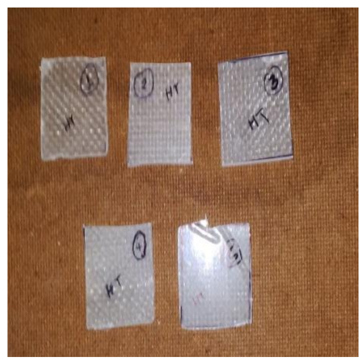


Fig 4.*3: Compression test specimens*

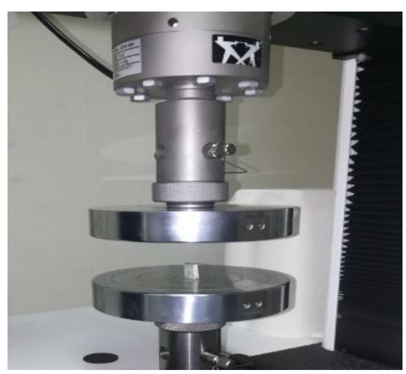


Fig 4.4: *Universal Testing Machine*

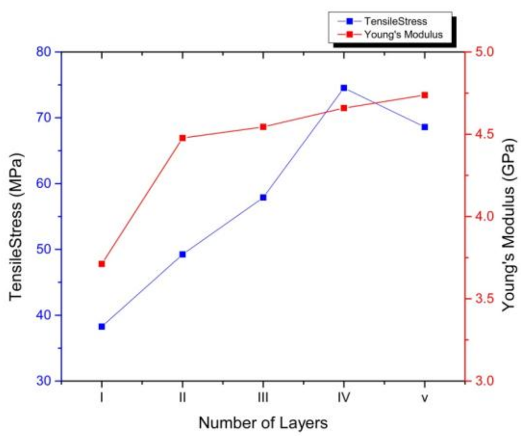
5. RESULTS & DISCUSSIONS

5.1 TensonTest

The tenson test is performed on the universal testing machine and the results are tabulated in the following table 5.1.The variation of tensile stress with increasing the number of layers is plotted on graph 5.1. As we can see that the stress bearing capacity of Bi-woven glass fibre reinforced composites under tension has been constantly increased from layer 1 to layer 4 i.e. from 38.26 MPa to 74.55 MPa and decreased for layer 5 up to 68.59 MPa, as the reinforcement weight percent is increased over epoxy and composite strength is decreased with more than 4 layers of reinforcement.

TENSION TEST	I Layer	II Layer	III Layer	IV Layer	V Layer
Maximum Load (N)	3257.60	3798.51	4341.08	5591.26	4956.84
Tensile Stress (MPa)	38.26	49.24	57.88	74.55	68.59
Young's Modulus (MPa)	3712.21	4476.53	4545.11	4659.67	4738.25

***Table 5.1**: Readings of Tenson Test*



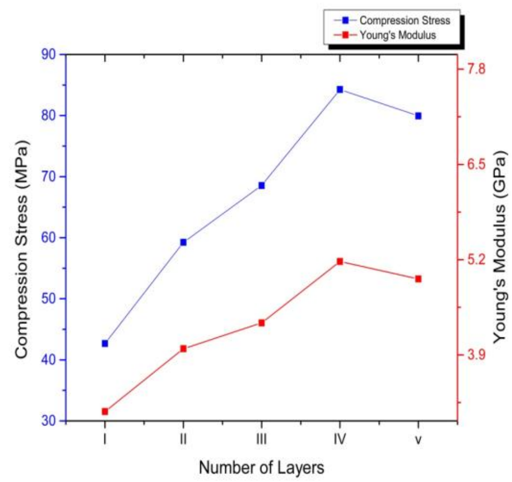
***Graph 5.1**: Tensile Stress Vs Number of Layers*

5.2. Compression Test

The compression test is performed on the universal testing machine and the results are tabulated in the following table5.2. The variation of compressive stress with increasing the number of layers is plotted on graph 5.2. As we can see that the stress bearing capacity of Bi-woven glass fiber reinforced composites under compression has been constantly increased from layer 1 to layer 4 i.e. from 42.68 MPa to 84.27 MPa and decreased for layer 5 up to 79.94 MPa, as the reinforcement weight percent is increased over epoxy and composite strength is decreased with more than 4 layers of reinforcement

***Table 5.2**: Readings of Compression Test*

COMPRESSIO N TEST	I Layer	II Layer	III Layer	IV Layer	V Layer
Maximum Load (KN)	5862.54	6324.89	7993.26	857694	8125.42
Compression Stress (MPa)	42.68	59.26	68.56	84.27	79.94
Young's Modulus (MPa)	3128.94	3984.72	4337.39	5176.263	4936.58



***Graph 5.2**: Compression Stress Vs Number of Layers*

6. CONCLUSIONS

Experimental evaluation of mechanical properties like tensile, compressive, impact & flexural strength of Bi-woven glass fibre reinforced polymer laminates as per ASTM standards has been successfully completed. The tensile properties have been studied and the breaking load has been measured. The inclusion of Bi-woven glass fibre mat reinforced polymeric composite significantly enhanced the ultimate tensile strength, yield strength and peak load of the composite. The tensile test is performed and the stress bearing capacity of GFRP composites under tension has been constantly increased from layer 1 to layer 4 i.e. from 38.26 MPa to 74.55 MPa and decreased for layer 5 up to 68.59 MPa as the reinforcement weight percent is increased over epoxy and composite strength is decreased with more than 4 layers of reinforcement. The compression test is performed and the stress bearing capacity of GFRP composites under compression has been constantly increased from layer 1 to layer 4 i.e. from 42.68 MPa to 84.27 MPa and decreased for layer 5 up to 79.94 MPa as the reinforcement weight percent is increased over epoxy.

REFERENCES

[1].Hassan Abdolpour et.al, " Increasing flexural performance of hybrid sandwich panels by using strain hardening cementations base composites and glass fiber –reinforced polymer ". Journal of composite materials, 2018, 53(1); 19-31.

[2].Francis L King, A.A.J. Kumar, S.Vijayaraghavan, "Mechanical characterization of polylactic acid reinforced bagasse/basalt hybrid fiber composites" ". Journal of composite materials, 2018, 53(1); 33-43.

[3].M.K. Gupta, Rohit Singh," PLA-coated sisal fibre-reinforced polyester composite: water absorption, static and dynamic mechanical properties". Journal of composite materials, 2018, 53(1); 65-72.

[4].P.V.Sanjeeva kumar, Dr.B.Chandramohana Reddy, "Fabrication and characterization of Polymer laminate composites reinforced with bi-woven carbon fibers, International Journal of Engineering Research and Applications, 2015,5(4-VII);11-17.

[5].Ahmad Rafiq, Necar Merah, "Nanoclay enhancement of flexural properties and water uptake resistance of glass fiber-reinforced epoxy composites at different

temperatures", Journal of composite materials, 2018, 53(2); 143-154.

[6].Abba Alhaji Hammajam et.al, "The Green Composites: Millet Husk Fiber (MHF) Filled Poly Lactic Acid (PLA) and Degradability Effects on Environment". Open journal of composites, scientific research, 2019, 9(3); 300-311.

[7].P.V.sanjeev kumar, M. Ashok kumar, Dr.B.Chandramohana reddy, G. Ramachandra reddy, "Compression and Impact Properties of Clay /Epoxy Nanocomposites Reinforced with Short Weave Glass Fiber Reel", International Journal of Nanomaterials and Biostructures, 2012, 2(3); 50-54.

[8].Maryam Jahan et.al," Enhancing the Mechanical Strength for a Microwave Absorption Composite Based on Graphene Nanoplatelet/Epoxy with Carbon Fibers". Open journal of composites, scientific research, 2019, 9(2); 230-248.

[9].S.Z.H.ShahS.KaruppananP.S.M.Megat-YusoffZ.Sajid," Impact resistance and damage tolerance of fiber reinforced composites: A review". Open journal of composites, scientific research, 2019, 217, 100-121.

[10].Garret.W.Melenka et.al " evaluation and Prediction of the tensile properties of continuous fiber reinforced 3D printed structures", Journal of Composite Structures, 2016,153;866-875.2018,5(1) part-3;

[11].Sanjeev R.Nandaragi, et.al,"Fabrication ,Testing and Evaluation of mechanical Properties of wovwn glass fiber composite material". Journal of Composite Structures, 2018,5(1) part-3;2529-2434.

[12].Enrique J.GarciaBrian L.WardleA.John HartNamikoYamamoto," Fabrication and multifunctional properties of a hybrid laminate with aligned carbon nanotubes grown In Situ". Journal of Composites Science and Technology, 68 (9), 2008; 2034-2041.

[13]P.Veera Sanjeeva Kumar, Dr.B.Chandramohana Reddy, Dr.K.Vijaya Kumar Reddy, "Transient Analysis of Smart Composite Laminated Plates Using Higher Order Theory", International Journal of Mechanical Engineering and Technology, 2016, 7(6); 166-174.

[14].M.V.Hosur, M, Abdhulla, S.Jeelani," Studies on the low-velocity impact response of woven hybrid composites". Journal of Composite Structures ,67 (3), 2005; 253-262.

[15].K.Muralimohan Rao, K.Mohan Rao, A.V.ratna Prasad, "Fabrication and testing of natural fiber composites: vakka, sisal, bamboo and banana. Journal of Materials & Design, 31(1), 2010; 508-513.