International Journal For Advanced Research In Science & Technology
A peer reviewed international journal
www.ijarst.in
ISSN: 2457-0362

CHARACTERIZATION OF HYBRID GLASS/CARBON FIBER REINFORCED EPOXY COMPOSITES

P. Ravikanth Raju
Dept of Mechanical Engineering, Malla Reddy College of Engineering & Technology, Secunderabad - 500100, India

Abstract: **Over the past three to four decades, the application of composite materials has been rising from traditional areas such as aircraft engineering to various fields (automobile industry, marines, civil engineering) because they have desired properties which cannot be achieved by other types of constituent materials. Fiber Reinforced Plastics (FRP) has significantly expanded their application in aerospace industry in recent years. Advantages like light weight, low cost, simple maintenance and superior corrosion resistance have been recognized although the design of fiber reinforced materials are typically not well understood as those for metallic counterpart. Long term degradation of FRP requires distinctive strength design methods, acceptance criteria, testing procedures, etc. Glass fibers alone have very less Young's modulus, shear modulus and Poisson's ratio and because of this disadvantage this material is not recommended for many works in aircrafts. On the other side, carbon fiber has very excellent mechanical properties but it's too costly and the orientation of the fibers plays a vital role. For conducting the tests like tensile and compressive test for the flat FRP in universal testing machine is unavailable. In this paper, we discuss the new setup and system to conduct the above mentioned test for the flat FRP material and also conducting the test for the hybrid fiber reinforced plastic with glass and carbon fibers in the universal testing machine. From the tensile and compressive tests, the value of Young's modulus, tensile strength and compressive strength and Poisson's ratio of the hybrid FRP composite materials has been achieved**.

Keywords: **Glass fiber; Carbon fiber; Composites; Young's modulus; Tensile; Compressive.**

I. INTRODUCTION

For years, composite materials have growing applications in different industries. Composite is a mixture of two or more constituents/materials (or phases) with different physical/chemical properties at the macroscopic or microscopic scale. In general composites have two or more constituents, fiber and matrix. Composites are classified by the geometry of the reinforcement: particulate, flake, and fibers or by the type of matrix: polymer, metal, ceramic, and carbon. The basic idea of the composite is to optimize material properties of the composite, i.e., the properties of the matrix are to be improved by incorporating the reinforcement phase. Fibers are the principal load-carrying constituents while the surrounding matrix helps to keep them in desired location and orientation and also act as a load transfer medium between them [1]. The effective properties of the fiber reinforced composites strongly depend upon the geometrical arrangement of the fibers within the matrix [2]. This arrangement is characterized by the volume fraction, the fiber aspect ratio, fiber spacing parameters and orientation angles of fibers**.** For Fiber Reinforced Polymeric (FRP) composites, the main Research and Development (R & D) challenges concern material characterization and the need to ensure that the properties assumed in the design are well-matched with those achieved by the real production processes [3]. For performing various tests on the FRP materials still requires more knowledge and technology therefore there is a lagging in the material's characterization. In this paper, we are introducing the new systems for carrying out the tensile test and compressive test in the universal testing machine to get the accurate results. Due to the poor mechanical properties of the glass fiber reinforced plastic material; there is a need to go for alternatives like carbon and other natural fibers. But the carbon fibers are too costly therefore a combination of glass fiber with carbon fiber is required to get the assured mechanical properties. Other topics requiring R&D which concern improved fire performance includes light weight fire protection systems and development of reliability based design codes that take proper account of the multiplicity of failure mechanisms that are possible with composites, proper characterization of non-linear structural behavior including buckling and recycling. In future, even the fuselage of the aircraft will come with the FRP material with better compositions and the molding methodology. As composites are light in weight compared to most metals and woods, their lightness is important in automobiles and aircraft as less weight means better fuel efficiency [4]. Most of the research and development is concerned with the replacement of the aluminum alloy; steel aircraft body to the FRP body so as to decrease the weight of it and eventually the cargo capacity will increase further. Engineers who blueprint aero planes are seriously concerned with weight since reducing a craft weight reduces the amount of fuel it needs and also increases the speed. Also, specific strength and dimensional stability holds an important property while building aero planes as they need a very high strength material at lowest possible weight and the latter states that composite materials retain their shape and size when they are hot or cold, dry or wet. The advancement of FRP composites in aerospace has resulted in the combination of two or more different fibers such as glass and carbon into a structure to improve its mechanical performance at little cost. In this paper, we are concerning craft‘s super structure but in future we will go with other parts like winglet, spoiler, rudder, cockpit, slats and further more we can go with the body which will make the complete replacement of the materials other than composites in the aerospace engineering.

II. GLASS FIBER MATERIAL

Glass fibers material is having a various combinations ofB_2O_3, SiO_2, Al_2O_3, Mg O, or Ca O in a powder form. Then the combinations are heated with heated through melting directly to temperatures around thousand three hundred degrees Celsius after that various dies are used to extrude glass fiber in filaments form in diameter in the ranging of 9to 17µm. Then the glass fiber filaments are made into larger threads thereby it made into spun onto bobbins, which is convenient for further transportation and further processing. Glass fiber material in past is the most popular in the world by means of using to reinforce plastic and thus it as a very good place in the production process. It is significantly cheap and easily available when compare to the other fiber materials like carbon fiber and aramid fiber. The only disadvantages of the glass fiber are it cannot withstand more temperature like carbon fiber.

Table 1: Mechanical properties of glass fiber FRP

S.No	Parameters	GFRP
1	Youngs Modulus in N/mm^2	24
2	Poisson‘s Ratio	0.1
3	Shear Modulus in N/mm^2	3.5
4	Fiber Volume Fraction in %	50

III. CARBON FIBER

Carbons fiber material is created by when the poly acryl nitrite fibers or Pitch resin or Rayon are carbonized at higher temperatures. Through further processes of graphitizing or stretching the fibers strength or elasticity can be enhanced respectively. Carbon fibers are manufactured in diameters analogous to glass fibers with the diameters ranging from 9 to 17µm.

Table 2: Mechanical properties of carbon fiber FRP

S.No	Parameters	GFRP
1	Youngs Modulus in N/mm^2	113
2	Poisson‘s Ratio	0.32
3	Shear Modulus in N/mm^2	3200
4	Fiber Volume Fraction in %	50

After that the carbon fiber material goes for further processes which include weaving or braiding which leads to carbon fabrics, cloths and mats as the same way of glass

Fiber material that will be used as actual reinforcements [5]

IV. WET LAYUP

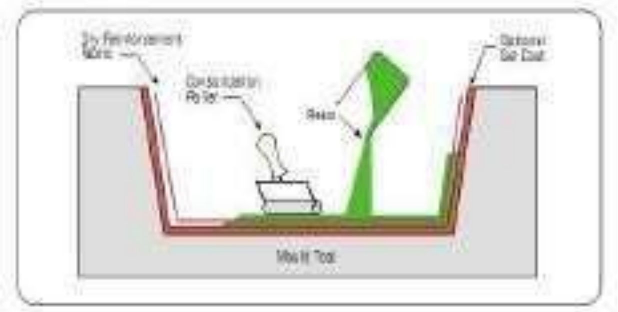


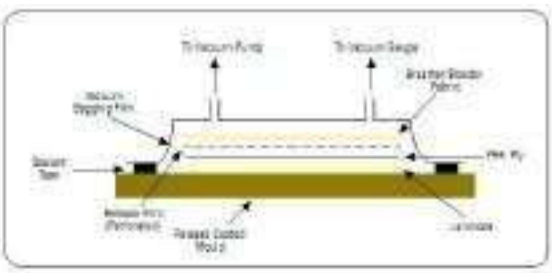
Fig1: Hand Lay process

Resins are impregnated by hand into fibers which are in the form of woven, knitted, stitched or bonded fabrics. This is usually accomplished by rollers or brushes, with an increasing use of nip-roller type impregnators for forcing resin into the fabrics by means of rotating rollers and a bath of resin [6]. Laminates are left to cure under standard atmospheric conditions. Usually the resin was taken 70 percentage of its volume and remaining 30 percentages of carbon fiber and glass fiber are taken in combinations. Then it is saturated with the epoxy wet resin by pouring on the reinforced fiber layer. Then the reinforced fiber layer mould is with the wet epoxy resin is allowed to cool in the normal room temperature and vacuum bags are used to compress the reinforced fiber layer for getting the better result. For getting the better result we can still keep the mould at different temperature level to get the best temperature level for getting the very good mechanical Properties.

Materials Options: Resins: Any, e.g. epoxy, polyester, vinyl ester, phenolic

Fibers: Any, although heavy aramid fabrics can be hard to wet-out by hand & Cores: Any.

VACUUM BAGGING



This is basically an extension of the wet lay-up process described above where pressure is applied to the laminate once laid-up in order to improve its consolidation. This is achieved by sealing a plastic film over the wet laid-up laminate and onto the tool. The air under the bag is extracted by a vacuum pump and thus up to one atmosphere of pressure can be applied to the laminate to consolidate it.

Materials Options:

Resins: Primarily epoxy and phenolic. Polyesters and vinyl esters may have problems due to excessive extraction of styrene from the resin by the vacuum pump.

Fibers: The consolidation pressures mean that a variety of heavy fabrics can be wet-out.

Cores: Any.

V. TENSILE TEST FOR HYBRID FRP

The hybrid FRP specimens used in this study is cut from the rectangular sheet of thickness 14 mm manufactured by using vacuum bags assisted wet layup process. Table 3 shows the percentage of glass fiber and carbon fiber by volume in the hybrid fiber reinforced plastic sheet [7]. The mechanical properties of each glass fiber and carbon fiber are tabulated in Table 1 and Table 2 respectively. For the test purpose, we are cutting the specimens in two ways. The specimen cut along longitudinal axis of the sheet is labeled 01 and the one along transverse axis is labeled 02. The dimensions of the specimen are taken as per the Table 4.

Specimen	No. Of specimen	Total length	Gauge Length	Width	Thick	Length of pipe
01	10	1100	100	10	14	500
02	10	1100	100	10	14	500

Table 4: Dimensions of the specimen for tensile test

The hybrid FRP plastic material length is taken based on the maximum clearance of the universal testing machine and on the recommendation of the ASTMD 3039 code the gauge length is taken for composite specimen tension test. To make the tension test in the existing machine, special type of holding system is made as per Figure 1. It consists of a steel pipe filled with low viscosity epoxy with high strength in between the steel pipe and the flat FRP

International Journal For Advanced Research In Science & Technology
A peer reviewed international journal
IJARST
www.ijarst.in
ISSN: 2457-0362

specimen to perform the tensile test under tensile loading. The holding system is the modification of standard tensile tests for the fiber reinforced bars based of ACI440.3 R.

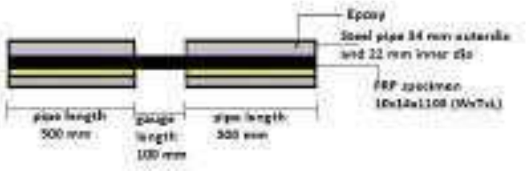


Figure 1: Details of the tensile test specimen with steel holder

The steel pipe is taken which is having the stipulated dimensions with internal thread to get better grip. It is cleaned with acetone and adhesive is provided in the contact area [8]. Then the specimen is kept in the centre and epoxy is poured. It was kept for 24 hours to get fixed in the steel pipe and hardened. Strain gauge with metallic foil type is attached on both the sides along the centre line of the material. Leakage of epoxy resin is prevented by duct tapes.

Table 5: Mechanical properties of Hybrid FRP material in tension

Sr. No.	Parameters	Specimen 01	Specimen 02
1	Young's modulus	51	13.5
2	Poisson's ratio	0.236	0.0823
3	Tensile strength	890	172

The procedure and the test setup are made based on the ACI440.3R and ASTMD 3039 specifications. The universal testing machine having a capacity of 500 KN is used for the test. The specimen end with steel pipe is loaded in the wedge friction metal grips of the machine. Strain rate of 100 micro strains is made by applying load until the final failure. Data logger is used to record the load and strain [9]. All the other specimens are tested in the same format.
The final average values of the Young's modulus, tensile strength and Poisson's ratio is calculated (Table 5). The Young's modulus is calculated with the help of stress and strain created in the specimen, tensile strength from the average thickness and width of specimen and maximum tensile load whereas Poisson's ratio is calculated from lateral and liner strain [10]. The specimen 01 is having the maximum stiffness and maximum strength while the specimen 02 is having low strength and stiffness as compared to specimen 01. The difference of modulus value is less than the difference of tensile strength values. This can be due to the imperfections created during the manufacturing process.

VI .COMPRESSIVE TEST FOR HYBRID FRP COMPOSITE

For the compressive test, the dimension of the specimens is taken as per the Table 6. All the specimens are taken in similar compositions for the compressive test as that taken for tensile test. The specimen A1 denotes that the specimen is tabbed with glass fiber reinforced plastic laminated at both ends with 30 mm length while the A2 specimen denotes that it was inserted in the steel pipe as same done for the tensile test filled with epoxy with adhesives. Both the A1 specimen and the A2 specimen will have a gauge length of 80 mm after tabbed with either steel pipe or glass fiber reinforced plastic. These kinds of arrangement are done on the specimens for performing the strength test without end crushing.

Table 6: Dimensions of the specimen compression.

Specimen	No. of specimen	Length	Width	Thick
A1 [0°]	5	140	15	14
A1 [90° 0°]	10	100	10	14
A2 [0°]	5	140	15	14
A2 [90° 0°]	10	100	10	14
B1 [0°]	5	140	15	14
B1 [90° 0°]	10	100	10	14
B2 [0°]	5	140	15	14
B2 [90° 0°]	10	100	10	14

For the compressive modulus the specimens used for the test are similar to strength test but the ends are not tabbed. For performing the compressive modulus test, two specimens are taken namely B1 and B2. Both the specimens are un-tabbed and have the dimensions of 140 mm and 80 mm. The test set up and the procedure for performing the strength test and compressive modulus test are done under compressive load with the help of developed test fixture. These developed test fixture are designed and fabricated based on the ASTM 3410 code. The compressive load is introduced to the hybrid FRP specimens through the end loading to get accurate results [11]. For measuring the strain occurred in each hybrid FRP specimen is done by using foil resistance strain gauges. The amount of bending of

International Journal For Advanced Research In Science & Technology
A peer reviewed international journal
IJARST
ISSN: 2457-0362
www.ijarst.in

the hybrid FRP specimens while conducting the test is done by using back to back strain gauges. To fix the hybrid FRP test specimen in the fixture, at first, the specimen is inserted in the cap heads with the bolts and placed with the test fixture. The cap head along with the specimen is placed on the top loading platen in the circular groove. While fixing the in the platen, the fixing bolts is loosen slightly to make the specimen top surface pressing on the top platen. After that, the fixing bolts in the test fixture are then again slim down with hand tight. The test fixture is turned over slowly for inserting the lower end cap head in the bottom loading platen in the circular groove. Then the lower head cap fixing bolts is loosened slightly to make the test specimen pressing the lower loading pattern. After that the lower head cap fixing bolts is tighten with fingers tight [12]. The load guide steel is passed through the bored hole precisely made in the loading platen bottom side for maintaining the alignment of test specimen during the loading. Finally, the test specimens is inspected to ensure the hybrid FRP material of both ends are perfectly even with the bottom and top side of the loading platens. After that, the hybrid FRP specimen is accurately mounted on the test fixture.

Table 7: Mechanical properties of Hybrid FRP in compression

Table 7: Mechanical properties of Hybrid FRP in compression

Specimen	Young's modulus	Compressive strength	Poisson's ratio
A1 [0°]	49.22	216	0.27
A1 [90°/0°]	16.34	172	0.098
A2 [0°]	49.34	847	0.277
A2 [90°/0°]	16.12	177	0.091
B1 [0°]	48.7	191	0.27
B1 [90°/0°]	15.5	176	0.085
B2 [0°]	48.1	198	0.285
B2 [90°/0°]	15.9	177	0.109

The test fixture is placed on the universal testing machine and the tests are carried out. By using the machine, the hybrid FRP test specimens are compressed and the corresponding deformations at the various load conditions are recorded as recommended by the ASTM 3410 code. The compressive load is given at the rate of 1.27 mm/ min in displacement control and the load is measured with the help of 300 KN load cell at the bottom of the test fixture. The effective compressive modulus and compressive strength of all the hybrid FRP composites (A1, A2, B1, B2) laminates with 0^o orientation and 90^o orientation are reported in the below Table 7. The mechanical properties of compressive modulus are calculated based on the stress- strain value of each specimen and the compressive strength from the maximum compressive load, average thickness and width of the specimen.

As per the tabulated value in Table 7, the specimen 01 has the highest strength and stiffness while the specimen 02 show less strength and stiffness when subjected to the compressive loading which is quite similar to the tensile test report. The variations in between the values of Young‘s modulus, compressive strength and Poisson‘s ratio are less than 10% which therefore proves that the test fixture provides consistent results. This less than 10 % difference is acceptable in conducting fiber composite materials pointed out by Weiner and Wolfe. The difference on compressive modulus of each specimen is lower that the difference of compressive strength value. It also shows that the Young‘s modulus is less sensitive to defects when compared to the strength of the materials. When compared to the tensile strength values, the compressive strength values is low. This is due to the existence of manufacturing defects in the hybrid FRP composites such as voids and internal micro cracks which tends to open in conducting the tensile test.

VII. CONCLUSIONS

The system used for holding the flat FRP specimen for performing the tensile test and compressive test was given accurate result. In the tensile test the failure was occurred in the gauge length of the specimen this proves that the holding mechanism was worked out correctly. The young‘s modulus of the specimens both in tensile test and compressive tests were found out. When compare with the glass fiber reinforced plastic material, the hybrid composites with glass

Fiber and carbon fiber was having the very good mechanical properties. So this hybrid fiber reinforced composites was used for the replacement of glass fiber reinforced plastic

Material where there is a need of very good mechanical properties. The test set up also easy to use and it is economical when compared with unconventional test and it will give reliable data for the composite materials. The variations in the results are less than ten percentages which proves that the experimental test was conducted between the margins of error. To get the precision result it is

International Journal For Advanced Research In Science & Technology
A peer reviewed international journal
www.ijarst.in
ISSN: 2457-0362

recommended to have more number of samples, thereby the coefficient of variation of the measured value will be reduced. The fiber reinforced plastic with mixture of carbon fiber and plastic fiber will increase the strength and stability of the material. Less amount of carbon fiber will reduce the cost of the material and thereby we can get the best material at the less cost. The methodology for determining the structural properties and critical temperature at which anFRP structure fails has significant merits.

REFERENCES

Kaw A.K.; Mechanics of composite materials, Chapter 1, CRC Press: Taylor & Francis Group, USA, 2006, 2nd ed. ISBN: 0-8493- 1343-0

Ghassemieh, E.; Nassehi, V. Polymer Composites. 2001, 22, 528. DOI: 10.1002/pc.10557

G. Caprino, L. Carrino, M. Durante, A. Langella, V. Lopresto , Composite Structures 133 (2014) 892–901

M Aniber Benin, B. S. Jones Retnam, M. Ramachandran, International Journal of Applied Engineering Research. 10(11) (2014) 10109-13.

ASTM D2105 Standard Test Method for Longitudinal TensileProperties of Fiberglass (Glass-Fiber-Reinforced Thermosetting- Resin) Pipe and Tube, American Society for Testing and Materials, 2001

Malvika Sharma, M. Ramachandran, International Journal of Applied Engineering Research. 10(11) (2014) 10324-27.

P. Pradeep, J. Edwin Raja Dhas, M. Ramachandran, International Journal of Applied Engineering Research. 10(11) (2014) 10392-96.

Tara Sen, H.N., Jagannatha Reddy; T. Sen, H.N. Jagannatha Reddy, International Journal of Sustainable Built Environment 2 (2012) 41–55.