ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 7, January 2013

Experimental Evaluation of Strength and Stiffness of Fibre Reinforced Composites under Flexural Loading

G.Rathnakar, H K Shivanan

Abstract- ***Many structures used in Automobile, Aerospace, Naval and other Transportation vehicle structural parts are subjected to various kinds of loads. These structures are further subjected to bending loads causing flexural stress in the structures. The structures subjected to bending loads are prone to catastrophic failure. Therefore the structural integrity of structures is a must to overcome bending. Structures subjected to pure bending load often experiences maximum flexural stress of the specimen either at the outer or the inner fibre leading to failure, the stress will be zero at the neutral axis or the middle axis. The present study aims at investigating the flexural parameters of epoxy glass & graphite fiber reinforced composites when subjected to static flexural loading using Flexural Test system. The flexural parameters are determined by conducting the three point bend test on composite specimen as per ASTMD790 standards. The composite laminate specimens are prepared using the vacuum baggage technique and the specimens are subjected to three point bending test. The load versus deflection graphs were plotted and Flexural properties like flexural strength and stiffness for glass laminated and graphite laminated composites are evaluated and the appropriate conclusions are drawn.***

Keywords: **Composite laminate, Flexural, E-glass, Graphite, Stiffness, deflection.**

I. INTRODUCTION

Composite materials are commonly used in structures that demand a high level of mechanical performance. Their high strength to weight and stiffness to weight ratios has facilitated the development of lighter structures, which often replace conventional metal structures. Composite structures combine materials which together result in a structure with properties not achievable with any of the constituents alone. Fibre-reinforced composites, specifically those based on fibre reinforced materials, combine the best of both materials inheriting the high stiffness and strength from the fibres. In addition, the fibre-reinforced material tends to be more resistant to damage and defects than the homogeneous material. Cracks in the matrix are either shortened by an encounter with a fibre or occur parallel to the fibre, which, presumably is in the loading direction, causing little effect on the tensile/flexural strength. The matrix keeps the fibres together and oriented, protects the fibres from the environment (e.g. moisture, surface abrasion) and each other (fibres rubbing against each other), and acts as a load-transfer medium between fibres. For uniaxial fibre-reinforced composites (all fibres are oriented in the same direction), the ability to bear a tensile load / flexural load is greatest in the direction of fibre orientation, and consequently the tensile strength in this direction is a key parameter when designing engineered materials of this type. Kertesis [1] has presented a comprehensive review on the properties of hybrid composites. The relative volume fraction of reinforcing fibers and their positioning in the hybrid layup act as the determining factors in the enhancement of flexural properties. Wu and Sun [2] applied a combination of second and third approaches to compute the laminated beam stiffness depending on the element slenderness and the presence of stiffening ribs. Li and Xian [3] showed that the incorporation of a moderate amount of carbon fibers into ultra-high-modulus polyethylene (UHMPE) fibers reinforced composites greatly improved the compressive strength, flexural modulus. Barcero et.al [4] adopted the above approach in order to develop a first order shear deformation theory for laminated beams and stiffness was characterized. Vinson and Sierakowski [5] applied the above approach to develop “an advanced theory” to obtain strength and stiffness of laminated beams under flexural load.

II. FABRICATION OF SPECIMENS

The composite specimen is fabricated as per standard procedure and tested.

A. Fabrication of Glass Fiber Laminates

The fibres chosen were bi-woven glass fibre with density of 360GSM. The laminate will be cut to the required size and bonded to the glass fibre cloth by using an adhesive made from a mixture of LY556 resin & HY 951 hardener in proportions of 100:10 by weight. The surfaces will be thoroughly cleaned in order to ensure that they were free from oil, dirt. etc., before bonding at room temperature and pressure. The models will be allowed to cure for about 24 hours. Thicknesses of the Specimens was be maintained at 2 mm & 4 mm throughout the experiments for all the specimens prepared.

B. Fabrication of Graphite Fiber Laminates

The material used in this work was plain weave graphite fiber with epoxy resin as matrix. The table on which laminate were stacked is cleaned with acetone. The ply stacks were compression molded in a hot plate press under a pressure of 2 bars until a temperature of 120°C reached at a heating rate of 9°C per minute, after which the pressure was increased to 8 bars and held at this temperature and pressure for 120 minutes. Finally, the laminate was cooled down to room temperature at a cooling rate of 25°C per minute. The specimens were cut from the laminates with a diamond disc cutter and dried in a vacuum oven for at least 24 hours. Fig. below depicts the vacuum bagging process. Details of the composite specimens fabricated are as shown in Fig 1 below.

Fig 1 Graphite Fiber Layers

III. EXPERIMENTAL METHOD

The flexural strength is the ability to resist deformation under load for a material. The material deforms significantly but does not break, the load at yield is typically measured at 5% deformation/strain of the outer surface, is reported as the flexural strength or flexural yield strength. The test beam specimen is under compressive stress at the concave (inner) surface and tensile stress (Outer) at the convex surface. ASTM D790 test gives the procedure to measure a material's flexural modulus (the ratio of stress to strain in flexural deformation).The flexural test measures the force required to bend a beam under three point loading conditions. The data is often used to select materials for parts that will support loads without flexing. Flexural modulus is used as an indication of a material’s stiffness when flexed [7].

C. Test procedure

The specimen with the given span is supported between two supports as a simply supported beam and the load is applied at the centre by the loading nose producing three point bending at a specified rate. The parameters for this test are the support span, the speed of the loading, and the maximum deflection for the test. These parameters are based on the test specimen thickness and are defined differently by ASTM. Under ASTM D790, the test is stopped when the specimen reaches 5% deflection or the specimen breaks.

D. Standard specimen size

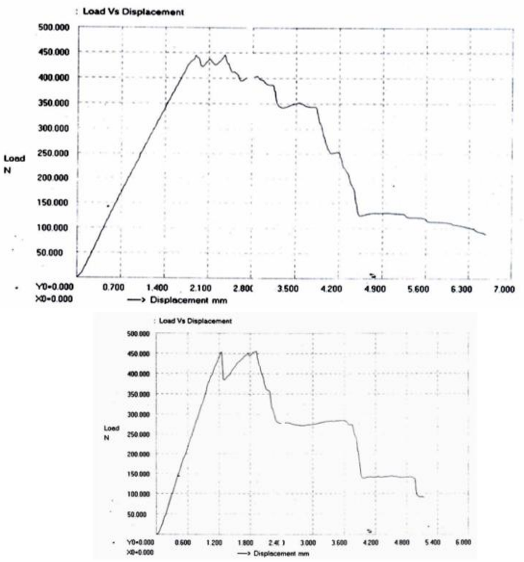
A varying specimen shapes and sizes can be used for this test, but the most commonly used specimen size for ASTM D790 is 3.2mm x 12.7mm x 125mm [8]. Three-point bending tests were performed in a servo controlled UTM machine having a load cell capacity of 5kN. At least 3 specimens were tested for each thickness of laminate. The crosshead speed was maintained at 2mm/min. The tested specimens were examined through visual inspection for failure of fibres and matrix.

Fig – 2 vacuum bagging process

Fig.-3 Three Point Bend Test

Fig – 4 Flexural Test Specimen - Epoxy Glass Laminate

Fig – 5 Flexural Test Specimen - Epoxy Graphite Laminate



Flexural test system

Specimen Details	Designation	Depth mm	Width mm	Span mm	Load N	Average Load, N
Glass Fiber 2mm thick	A1	2.02	12.46	32.0	445.3	430.9
	A2	2.02	12.67	32.0	418.8	
	A3	1.99	12.45	32.0	428.8	
Glass Fiber 4mm thick	A4	3.46	12.71	54.0	561.8	593.6
	A5	3.47	12.61	55.0	539.7	
	A6	3.46	12.68	55.0	679.3	
Graphite Fiber 2mm thick	A7	1.89	12.33	30.0	455.2	456.3
	A8	1.95	12.63	31.0	481.5	
	A9	1.93	12.7	31.0	432.2	
Graphite Fiber 4mm thick	A10	3.20	12.72	51.0	664.5	697.9
	A11	3.20	12.64	51.0	712.8	
	A12	3.20	12.61	51.0	716.5	

Table – 1 Specimen Designation, Dimensions and load

Material	Fiber (%)	Resin (%)
Glass (FRP)	52	48
Graphite (FRP)	54	46

Table – 2 Percentages of Fibre and Resin Content

Table 3 -Result of Flexural Parameters

Specimen designation	Deflection mm	Average Deflection	Maximum Flexural Strength MPa	Average Flexural Strength, MPa	Maximum Flexural Stiffness N/mm	Average Flexural Stiffness, N/mm
A1	2.36	2.13	421	409	188.66	204.82
A2	1.78		389		235.25	
A3	2.25		417		190.55	
A4	4.87	4.63	310	324	125.36	125.65
A5	4.69		293		125.07	
A6	4.34		369		126.52	
A7	1.92	1.97	465	452	237.08	238.67
A8	1.96		426		245.56	
A9	2.04		466		233.39	
A10	2.94	2.84	421	412	246.02	244.32
A11	2.71		390		240.81	
A12	2.87		424		246.13	

Table – 4 Results of Flexural Tests

Details	Glass composite		Graphite composite	
	2mm	4mm	2mm	4mm
Max. Load at break (N)	430.9	593.6	456.3	697.9
Flexural Strength(N/mm^2)	204.8	125.6	238.6	244.3
Max. Deflection, mm	2.13	4.63	1.97	2.84
Max. Stiffness, N/mm	202.3	128.1	231.6	245.7

IV. RESULTS & DISCUSSIONS

Table 1 and Table 2 provides the specimen designation and specimen dimensions for each specimen the fabrication details of laminated Composite specimens with two different thicknesses such as 2 mm & 4 mm using bi-woven glass and graphite cloth is carried out successfully. Simple Digital Flexural test System is utilized to determine Flexural parameters such as Flexural stiffness, & Strength for composite specimens. Flexural parameters of laminated Composites were tested and results tabulated for various combinations of fiber system as per tests recommended by ASTM standards. The values obtained have been analyzed from available literature & an excellent agreement between test results has been observed. Graph 1 and 2 describes typical flexural load vs.

deflection of glass and graphite specimens (only 2 sample graphs have been indicated). Curves for both specimens show linear behavior until failure. Curves show inflection at the point of yielding in both cases; however the deflection is more in case of glass when compared to graphite. Table 3 depicts the flexural behavior of both glass and graphite fibers for two different thicknesses. Flexural strength and Flexural stiffness have been recorded. It can be observed from table 3, that increase in the thickness of specimen for both glass and graphite specimens there is significant increase in the strength as well as stiffness values. However, the increase in strength and stiffness in case of graphite seems to be more significant as compared to glass fibers. An increase of 10 % in strength and 22% in stiffness can be observed in case of graphite specimens compared with glass specimens. Finally, the application of graphite fibers seems to manifest in terms of flexural properties as compared to glass fibers.

V. CONCLUSION

Three point bending tests were performed on 0°/90° lay-up composite specimens. The load-deflection curve was evaluated. Two types of laminates were tested with two different thicknesses. The main findings of the present investigation are as follows:

- Effect of thickness on flexural strength and stiffness seems to play a vital role in assessing material behaviour under flexural loading conditions.
- Three point bending method probably provides a better estimate of the actual material behaviour under flexural loading.
- There is a significant improvement in strength and stiffness of graphite laminates as compared to glass for same thicknesses under test. This may be due to good adhesion between graphite fibre and matrix.

ACKNOWLEDGEMENT

Authors thankfully acknowledge the Management, Principal and Head of the Department of Mechanical Engineering of their respective institutions for their constant encouragement and support in carrying out this work.

REFERENCES

[1] G.Kertsis, “A review of the tensile, compressive, flexural, and shear properties of hybrid reinforced plastics”, Composites vol.18, No.1, 1987.

[2] Wu and Sun, “A Review of laminated composite plate buckling”, Applied mechanics review, 40(5), 575-591, 1987.

[3] Y.Li, K.J.Xian, et.al, Compressive and flexural behavior of ultra-high-modulus polyethylene fiber and carbon fiber hybrid composites, Comp. Sci. & Tech, vol.59,pp. 13-18,1999.

[4] Barcero et.al, “A new Theory of laminated plates”, Composite science and technology, Vol. 26, page 225-239, 1986.

[5] Vinson and Sierakowski , “A review of redefined theories of laminated composite plates”, Shock and Vibration Digest 22(7)3-17, 1990.

[6] Di Sciuva, M, Bending, Vibration and Buckling of Simply Supported Thick Multilayered orthotropic plates: “journal of sound and vibration”, 105,425-442, 1986.

[7] P T Curtis, CRAG Test Methods for the Measurement of the Engineering Properties of Fibre-reinforced Plastics, “Royal Aircraft Establishment, Technical Report 88012”, 1988 edition.

[8] ASTM D790M-93, “Standard test methods for flexural properties of unreinforced and reinforced plastics and electrical insulating materials”, American Society for Testing and Materials, Annual Book of ASTM Standards, Vol. 08.01.1993.