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Evaluation of Mechanical Properties of Glass Fibre Reinforced Plastics

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***Abstract*—High strength-to-weight ratio, directional strength and stiffness are the significant factors, forcing polymer composites into the Aerospace, Marine and Automotive industries. Due to these major factors fuel efficiency and crashworthiness properties are the significant outcomes from use of these advanced materials. The work presented in this project investigates the experimental study of tensile properties and compressive properties of polymer matrix composite materials with respect to orientation of fibres to the test direction. Behaviour of Glass fiber-reinforced (GFRP). The test specimens are fabricated by simple hand lay-up technique and prepared according to ASTM standards. With a UTM TUE-600(C) high stroke rate test machine the related experiments are carried out to find out the mechanical properties of test specimens.**

***Index Terms*— Glass fibre, Epoxy resin, Hand layup, Quasi-isotropic, Unidirectional, Tensile strength , Compression strength.**

I. Introduction

Following the technological developments, industries are searching for lighter weight, higher strength and safer material to meet the demands of structural designs and for economic benefit. In order to extend the application area of plastics, plastic composites are developed by adding reinforcement materials to the polymer matrix. Some of the reinforcements used in structural and industrial applications are Carbon, Aramid and Glass fibers; the most commonly used is glass fiber. Plastic composite material has therefore become one of the new competitive materials in engineering.fibrereinforced plastic is a relatively new class of composite material manufactured from fibers and resins, and has proven efficient and economical for the development and repair of new and deteriorating structures. The mechanical properties of FRPs make them ideal for widespread applications in various industries worldwide. The enhancement of the mechanical and structural properties due to addition of fibers makes FRPs ideal materials for aircraft parts, aerospace structures, and railways, marine and other industrial applications.

II. Literature Review

W.Richards Thissels, Anna k. zurek and Frank addessio The mechanical behavior of quasi-isotropic and unidirectional epoxy-mttrix carbon-fiber laminated composites subjected to compressive loading are described. Failure in the studied composites was dominated by delamination which proceeded by brittle

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fracture of the epoxy-matrix. The IM6 fibers 3051/6 epoxy resin showed a 40% increased in stress –strain slope under compression loading at strain rate of 2000 L/S than 1×10^{-3} L/S when the applied load was parallel,45^0 and normal to thefibreaxis. The compression test showed that delamination significant failure component. The applicability of current hole in plate analytical methods to highly anisotropic material is there questionable. Both hole in a plate analytical methods indicates that G_I[12] is about 50% higher than G_1[13]
Jane Maria Faulstich de Paiva This paper shows a study involving mechanical (flexural, shear, tensile and compressive tests) and morphological characterizations of four different laminates based on 2 epoxy resin systems (8552^{TM} and F584^{TM}) and 2 carbonfibrefabric reinforcements (Plain Weave (PW) and Eight Harness Satin (8HS)). All laminates were obtained by handing lay-up of prepregs plies (0°/90°) and consolidation in an autoclave following an appropriate curing cycle with vacuum and pressure. The results show that the F584-epoxy matrix laminates present better mechanical properties in the tensile and compressive tests than 8552 composites. It is also observed that PW laminates for both matrices show better flexural and inter laminar shear properties.
Roberto J. Cano and Marvin B. Dow The use of toughened matrix composite materials offers an attractive solution to the problem of poor damage tolerance associated with advanced composite materials. In this study, the unidirectional laminate strengths and moduli, notched (open-hole) and unnotched tension and Compression properties of quasi-isotropic laminates, and compression after- impact strengths of five carbon fiber/toughened matrix composites,, have been evaluated. The compression-after-impact (CAI) strengths were determined primarily by impacting quasi-isotropic laminates with the NASA Langley air gun. A few CAI tests were also made with a drop-weight impact or. For a given impact energy, compression-after-impact strengths were determined to be dependent on impact or velocity. Properties and strengths for the five materials tested are compared with NASA data on other toughened matrix materials, This investigation found that all five materials were stronger and more impact damage tolerant than more brittle carbon/epoxy composite materials currently used in aircraft structures.
Jose Ricardo Tarpani, Quasi-static tensile properties of four aeronautical grade carbon-epoxy composite laminates, in both the as-received and pre-fatigued states, have been determined and compared. Quasi-static mechanical properties assessed were tensile strength and stiffness, tenacity (toughness) at the maximum load and for a 50% load drop-off. In general, as-molded unidirectional cross-ply carbonfibre(tape) reinforcements impregnated with either standard or rubber-toughened epoxy resin exhibited the maximum performance. The materials also displayed a significant tenacification (toughening) after exposed to cyclic loading, resulting from the increased stress (the so-called wear-in phenomenon) and/or strain at the maximum load capacity of the specimens. With no exceptions, two-dimensional woven textile (fabric) pre-forms fractured catastrophically under identical cyclic loading conditions imposed to thefibretape architecture, thus preventing their residual properties from being determined.

III. METHODOLOGY

A. Materials and experimental procedure

Materials ReinforcingfibreE-glassfibre200gsm , Matrix System Epoxy Resin & Hardener K-6, Moulding Process.Hand lay-up followed by Room temperature moulding.

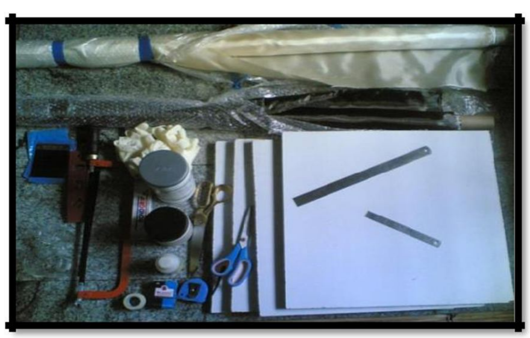


Fig.1.Materials used for fabrication of laminates

B. Fabrication of the test laminates

Test laminates of 300mm X 300 mm were initially fabricated to prepare mechanical test specimens by Hand lay-up followed by Room temperature.

C. Preparation of the Resin Hardener System

The resin and hardener were to be mixed in a ratio of 100:10 by weight, as follows
An empty bowl and brush were taken and weighed. Resin was added to the bowl and the brush setup and was placed on the electronic balance, till it registered the constant weight. The hardener was added to the bowl and bowl was removed from the balance. The resin and hardener were mixed thoroughly using the brush and is used immediately in the preparation of the laminate, From now on this mixture will be referred to as a "resin system".

D. Preparation of the reinforcing material

The fabric used was E-glass fibre of 200gsm. The fabric roll is spread on the flat surface and required dimension of 300mm x 300mm is marked using the marker pen on the fabric spread and cut using a scissor manually. Required such layers of fabric were cut to get the required thickness of laminate in this study.

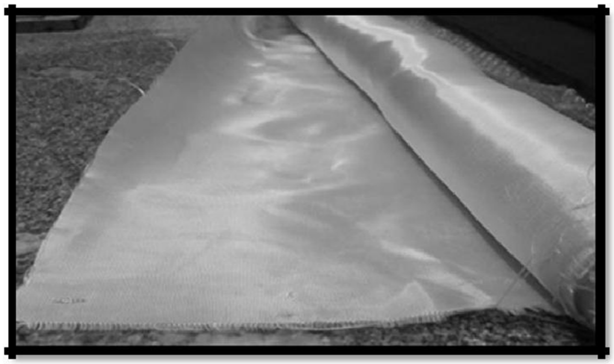


Fig.2.E-glass fabric 200gsm

E. Calculation of number of fibre layers for the laminates

TABLE I. MECHANICAL PROPERTIES

Sl No.	Material	Density(g/cm^3)	Volume fraction (%)	Ultimate Tensile Strength (Mpa)	Modulus(Gpa)
1	Glass Fiber	2.5	0.65	2000	80
2	Epoxy	1.18	0.35	60	4.4

F. Specimen Calculations

Glass / Epoxy:

i. Density of laminate = × + ×

$$= (0.65 \times 2.5) + (0.35 \times 1.18)$$
$$= 2.038 \text{ g/cc.}$$

ii. Mass of laminate = Density × Volume of sample

$$= 2.038 \times (30 \times 30 \times 0.2)$$

$= 366.84$ g.

iii. Mass of resin and hardener used (35%) = 366.84 × .35
$= 128.39$ g.

iv. Ratio of mass of resin to mass of hardener = 100:10

v. Mass of resin $= 128.39 \times \left(\frac{100}{110}\right)$
$= 116.71$ g.

vi. Mass of hardener $= 128.39 \times \left(\frac{10}{110}\right)$
$= 11.67$ g.

vii. Mass of glassfibreused = 366.84 × 0.65
= 238.44 g.

viii. Mass of each glassfibre= 18 g.

ix. Number of glassfibreplies used to prepare one laminate of 2mm thickness = ( )

$= 238.44 / 18$
$= 14$ plies.

G. Number offibrelayers for the each laminates:

i. Glassfibreunidirectional laminate G1 (0, 0, 0, 0, 0…) = 14 layers
ii. Glassfibrequasi isotropic laminate G2 (0, 45, 90,-45, 0...) = 14 layers

H. Lay up process for laminate preparation

The resin and the hardener of required quantities are taken in a previously weighed empty bowl. They are mixed properly in the bowl using a paintbrush. The mixture is used immediately in the preparation of the laminate which otherwise would start gelation.A highly polished flat mould was cleaned and wiped dry with acetone. PVA wax was applied and was left for 20 minutes to dry. The wax was then applied in order to form a thin realizing film.

Fig.3.PVA applied mould

A small quantity of resin system was coated on the mould surface and then a layer of the fabric (300 x 300mm) already cut was placed on that.The resin system was applied on the fabric to wet it and then the next layer of fabric was placed. The same procedure was followed till the required layers were placed ensuring adequate impregnation. The mylar sheet was sticked on the topmost ply and specimen war rolled using roller. Finally the specimen was allowed to cure for 48hrs.After RT curing, the specimens were hardened. The laminates were properly labelled and kept aside for further processing.

Quasi-isotropic (a) Unidirectional (b) (c)

Fig.4(a,b).Specimen orientation & (c)Experimental Setup of Room Temperature simple hand lay-up process

TABLE II. DETAILS OF THE DIFFERENT FWF LAMINATES FABRICATED

Laminates (65:35)	Wt. of dry fabric (grams)	Wt. of Resin (grams)	Wt. of Hardener (grams)	Wt. of laminate before trimming (grams)	Wt. of laminate after trimming (grams)	Global Weight Fraction	thickness of the laminate (mm)
Laminate C1 & C2	175	88.77	8.77	265	225	0.66	2.1

Preparation of specimens as per ASTM standards

A. Preparation of tensile specimens as per ASTM-D3039 standards for unidirectional laminates.

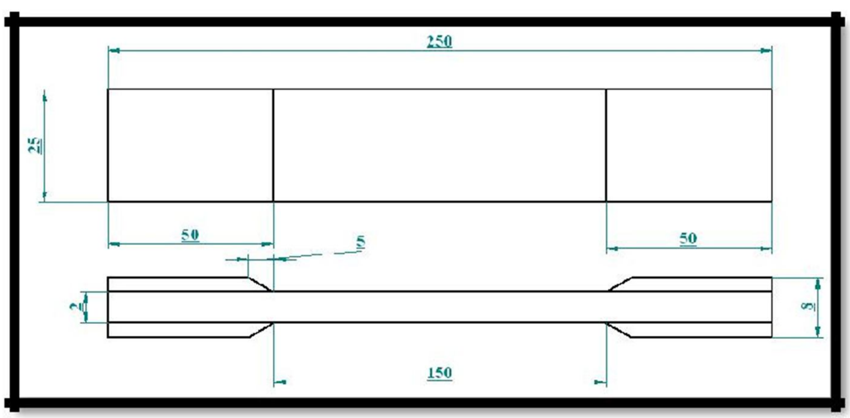


Fig.5.Geometry and dimensions of composite specimens for tensile

test B. Preparation of tensile specimens as per SACMA SRM9 standards for quasi-isotropic laminates.

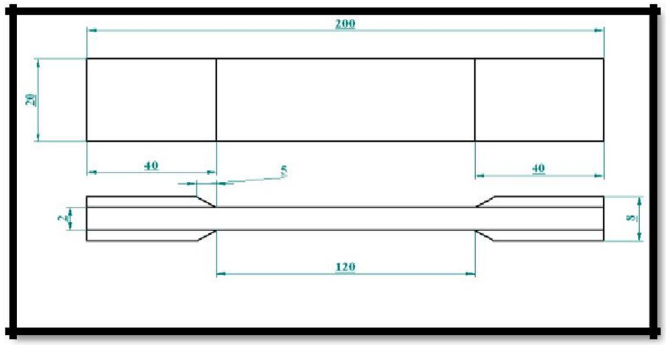


Fig.6.Geometry and dimensions of composite specimens for tensile test

C. Preparation of compression specimens as per ASTM D3410 standards for unidirectional laminates.

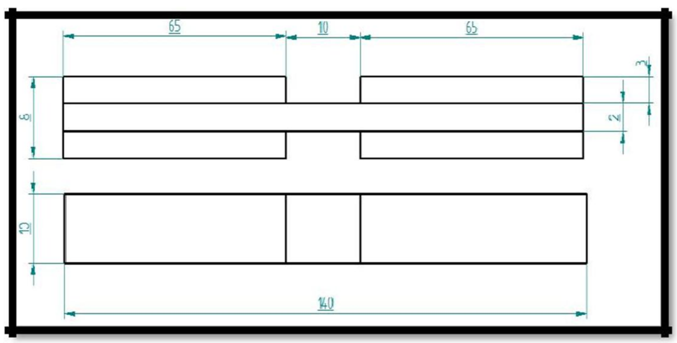


Fig..7. Geometry and dimensions of composite specimens for compression test

D. Preparation of compression test specimens as per SACMA SRM6 standards for quasi-isotropic laminates.

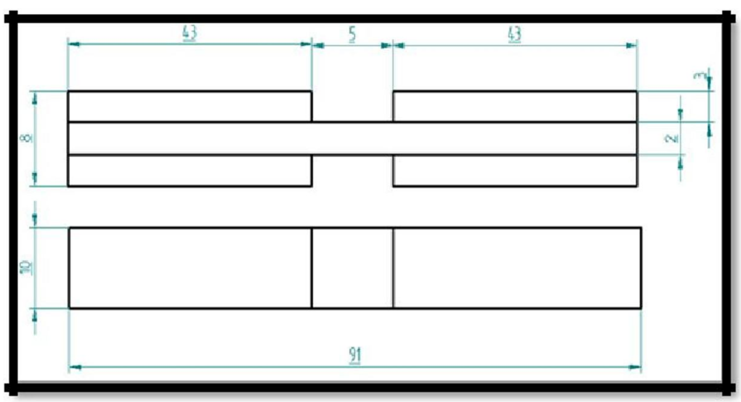


Fig.8.Geometry and dimensions of composite specimens for compression test

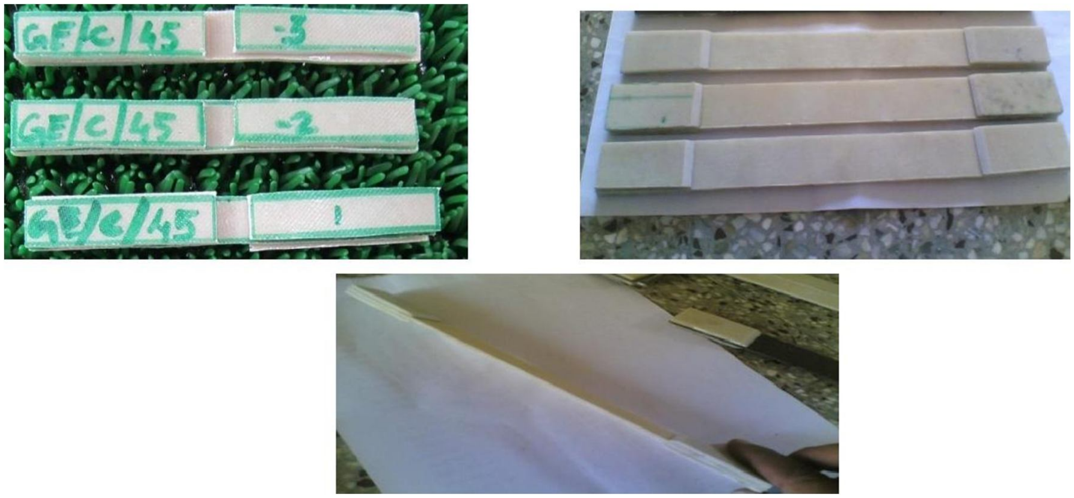


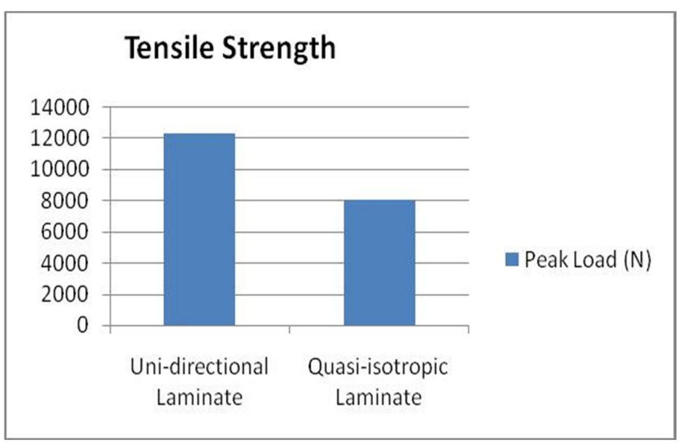
Fig.9. ASTM standard compression and tensile specimen after fabrication

IV. RESULTS & DISCUSSION

A. Tensile test result for GFRP composites

TABLE.III. TENSILE TEST RESULT FOR GFRP COMPOSITES

Material	**Breaking load(KN)**	**Maximum displacement (mm) Average**	**Tensile Strength (MPA)**
Glassfibrewith 2.5mm thick unidirectional laminate	12.30	2.29	190.11
Glassfibrewith 2.5mm thick quasi-isotropic laminates	8.04	1.93	166.12



B. Tensile test result of Glass fibre reinforced plastic unidirectional specimen:

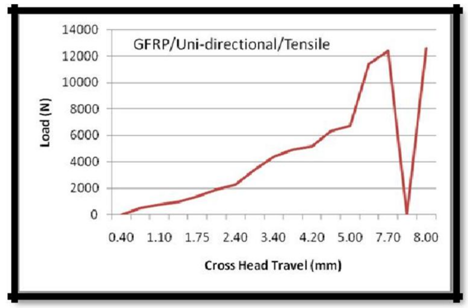


Fig.10.Tensile test graph of GFRP (unidirectional)

C. Tensile test result of Glass fibre re-in forced plastic Quasi-isotropic specimen:

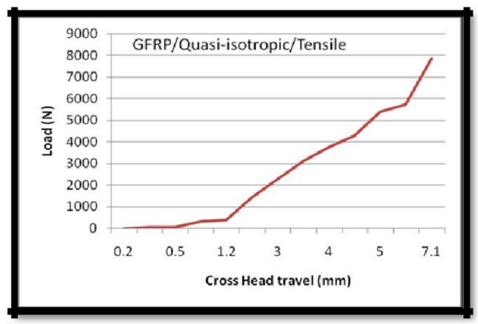
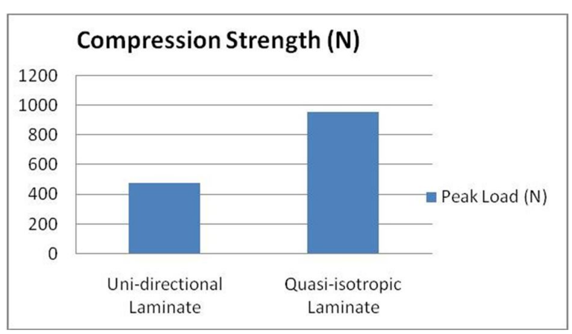


Fig.11.Tensile test graph of GFRP (Quasi-isotropic)

D. Compression test result for GFRP composites

TABLE.IV. COMPRESSION TEST RESULT FOR GFRP COMPOSITES

Material	Breaking load(KN)	Maximum displacement (mm) Average	Compression Strength (MPA)
Glass fibre with 2.5mm thick unidirectional laminate	480	1.2	24
Glass fibre with 2.5mm thick quasi-isotropic laminates	960	1.1	48



E. Compression test result of Glass fibre re-in forced plastic unidirectional specimen:

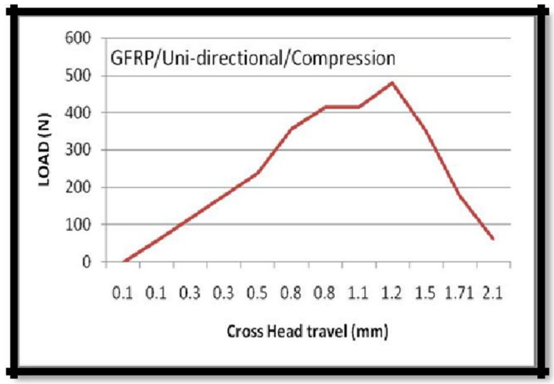


Fig.12.Compression test graph of GFRP (unidirectional)

F. Compression test result of Glass fibre re-in forced plastic Quasi-isotropic specimen:

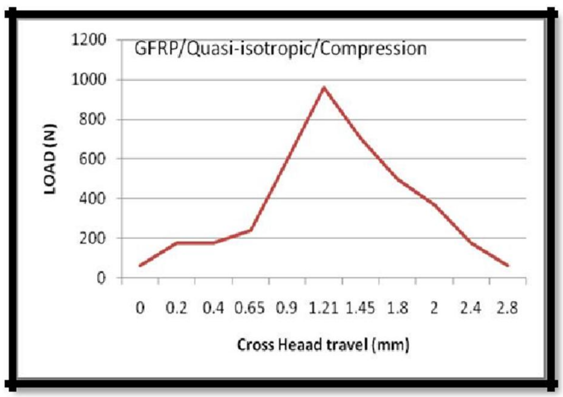


Fig.13.Compression test graph of GFRP (Quasi-isotropic)

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VI. CONCLUSIONS

By using a simple hand lay-up process, E-glass epoxy have been successfully fabricated. Specimens with varying orientation of fibre layers are fabricated and they are:Unidirectional laminate (0,0,0,0,0…………...) and Quasi-isotropic laminate (0,45,90,-45,0……..). E-glass epoxy polymer matrix composites, the tensile strength of unidirectional plies was found to be 15% greater than quasi-isotropic plies. In case of E-glass epoxy polymer matrix composites, the compressive strength of unidirectional plies was found to be 20% greater than quasi-isotropic plies.

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