RESEARCH ARTICLE OPEN ACCESS

Experimental Test of Stainless Steel Wire Mesh and Aluminium Alloy With Glass Fiber Reinforcement Hybrid Composite

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ABSTRACT
At present, composite materials are mostly used in aircraft structural components, because of their excellent properties like lightweight, high strength to weight ratio, high stiffness, and corrosion resistance and less expensive. In this experimental work, the mechanical properties of laminate, this is reinforced with stainless steel wire mesh, aluminum sheet metal, perforated aluminum sheet metal and glass fibers to be laminate and investigated. The stainless steel wire mesh and perforated aluminum metal were sequentially stacked to fabricate, hybrid composites. The aluminum metal sheet is also employed with that sequence to get maximum strength and less weight. The tensile, compressive and flexure tests carried out on the hybrid composite. To investigate the mechanical properties and elastic properties of the metal matrix composite laminate of a material we are using experimental test and theoretical calculation. The experimental work consists of Tensile, compressive and flexural test. The expectation of this project results in the tensile and compressive properties of this hybrid composite it is slightly lesser than carbon fibers but it could facilitate a weight reduction compared with CFRP panels. So this hybrid laminates composite material offering significant weight savings and maximum strength over some other GFRP conventional panels.
Keywords – sequentially stacked, fabricate, metal matrix composites, CFRP panels, GFRP panel.

I. INTRODUCTION

A composite material or a composite is a mixture of two or more distinct constituents all of which are present in reasonable proportions (> 5%) and have different properties so that the composite property is noticeably different from that of each of the constituents. Plastic is not a composite because it is a compound. An alloy is not a composite because it is a homogeneous mixture. Laminates are composite material where different layers of materials give them the specific character of a composite material having a specific function to perform. Fabrics have no matrix to fall back on, but in them, fibers of different compositions combine to give them a specific character. Reinforcing materials generally withstand maximum load and serve the desirable properties. In matrix-based structural composites, the matrix serves two paramount purposes viz., binding the reinforcement phases in place and deforming to distribute the stresses among the constituent reinforcement materials under an applied force. A hybrid composite material is which two or more high-performance reinforcements are Combined. Hybrid composites have been extensively uA composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. The reinforcing phase material may be in the form of fibers, particles, or flakes. The matrix phase materials are generally continuous. Examples of composite systems include concrete reinforced with steel and epoxy reinforced with graphite fibers, etc. Composite materials can be tailored for various properties by appropriately choosing their components, proportions, distributions, t morphologies, degrees of crystalline and their crystallographic textures, as well as the structure and composition of the interface between components. Due to this strong tailor ability, composite materials can be designed to satisfy the needs of technologies relating to the aerospace, automobile, electronics, construction, energy, biomedical and other industries. As a result, composite materials constitute most commercial engineering materials. An example of a composite material is a lightweight structural composite that is obtained by embedding continuous carbon fibers in one or more orientations in a polymer matrix. The fibers provide the strength and stiffness, while the polymer serves as the binder. The fibers can be long or short. Long, continuous fibers are easy to orient and process, but short fibers cannot be controlled fully for proper orientation. A strong, inert woven and nonwoven fibrous material incorporated into the matrix to improve its metal glass and physical properties. Laminar composites are found in as many combinations as the number of materials. They can be described as materials comprising of layers of materials bonded together. Microstructures of metal and ceramics composites, which show particles of one phase strewn in the other, are known as particle reinforced composites.

II. EXPERIMENTAL STUDY

2.1 Specimen preparation

In this experiment, aluminum 8011 alloy sheet, stainless steel wire mesh (SSW) is combined with E-Glass fiber. The properties of those materials are shown below. The epoxy based on LY556 resin and HY951hardener was used to manufacture the composite plate. The aluminum sheet present in the top and bottom layers with glass fibers which is present in between the each layer and stainless steel wire mesh,aluminum sheet with random perforated holes of 5mm radius is placed between the lamina arrangement is employed to fabricate nine ply hybrid composites as seen in Table 1.The nine ply of layered composite plates were produced by compression molding at the Composite technology Laboratory of Indian Institute of Technology Madras. The Compressive force acting on the laminate is 571.068 kg. The compression molding process takes about 120 minutes which is quite enough for compressing and curing of laminate. At the end of this process, the thickness of the laminate is 5.4mm.

Notation	Number of laminates	Structure	Sequence
Al_2 G_4 SSW	9	Al 8011 + Glass Fiber + Stainless Steel Wire Mesh	Al/G/ SSW/ G/ Al/G/ SSW/ G/Al

Table 2.1 Stacking sequence of hybrid composite

Specific gravity	Young's modulus	Ultimate tensile strength	Coefficient of thermal expansion
2.54	10.5	500	2.8

Table 2.2 Properties of Glass fiber

Properties	Value
Grade	304
Mesh Configuration	64 meshes/inch
Tensile Strength	620.550138 Mpa
Yield Strength	275.80062 Mpa
Density	8.0 g/cm^3
Melting Point	1420^{0}C
Coefficient Of Thermal Expansion	17.6micro meter/m^{0}C
Modulus of Rigidity	70.3 KN/mm^2
Modulus of Elasticity	187.5 KN/mm^2

Table 2.3 Properties of Wire Meshes

Properties	Values
Young's Modulus 0^0	135 Gpa
In Plane Shear modulus	5
Major Poisson's ratio	0.3
Ultimate Tensile Strength 0^0	1500 Mpa
Ultimate Compressive Strength 0^0	1200 Mpa
Ultimate Tensile Strength 90^0	50Mpa
Ultimate Compressive Strength 90^0	250 Mpa
Ult. In plane shear Strength	70 Mpa
Ultimate tensile strain 0^0	1.05 %
Ultimate Compressive strain 0^0	0.85%
Ultimate tensile strain 90^0	0.5 %
Ultimate Compressive strain 90^0	2.5 %
Ult. In plane shear Strain	1.4 %
Thermal Expansion Coeff. 0^0	-0.3 Strain/K
Thermal Expansion Coeff. 90^0	28 Strain/K
Moisture Expansion Coeff. 0^0	0.01 Strain/K
Moisture Expansion Coeff. 90^0	0.3 Strain/K
Density	1.6 g/cc

Table 2.4 Properties of aluminum 8011 alloy

III. TESTING

3.1 Tensile Test

The tensile tests were carried out in accordance with IS10192_1982 standard specimen, using a minimum of three specimens (dimensions: 230 mm of length x 20 mm of width x 5 mm of thickness) for each laminate. This procedure resulted in available area of 1800 mm2 of the specimen for the tensile test. Figure 5.4.1 shows, the specimens T1, T2, T3 respectively.

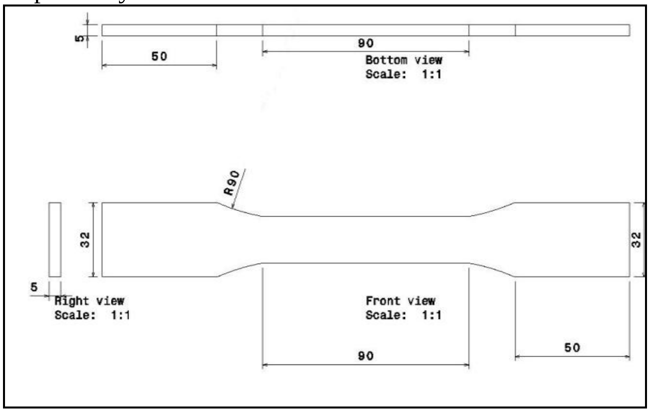


***Fig 3.1 IS** 10192-1982 Standard Specimen Diagram For Tensile Test.*

EQUIPMENT

The most common testing machine used in tensile testing is the universal testing machine. This type of machine has two crossheads; one is adjusted for the length of the specimen and the other is driven to apply tension to the test specimen. There are two types: hydraulic powered and electromagnetically powered machines.

There are three main parameters: force capacity, speed, and precision and accuracy. Force capacity refers to the fact that the machine must be able to generate enough force to fracture the specimen. The machine must be able to apply the force quickly or slowly enough to properly mimic the actual application. Finally, the machine must be able to accurately and precisely measure the gauge length and forces applied; for instance, a large machine that is designed to measure long elongations may not work with a brittle material that experiences short elongations prior to fracturing.

Alignment of the test specimen in the testing machine is critical, because if the specimen is misaligned, either at an angle or offset to one side, the machine will exert a bending force on the specimen. This is especially bad for brittle materials, because it will dramatically skew the results. This situation can be minimized by using spherical seats or U-joints between the grips and the test machine. A misalignment is indicated when running the test if the initial portion of the stress-strain curve is curved and not linear.

The strain measurements are most commonly measured with an extensometer, but strain gauges are also frequently used on small test specimen or when Poisson's ratio is being measured. Newer test machines have digital time, force, and elongation measurement systems consisting of electronic sensors connected to a data collection device (often a computer) and software to manipulate and output the data. However, analogue machines continue to meet and exceed ASTM, NIST, and ASM metal tensile testing accuracy requirements, continuing to be used today.

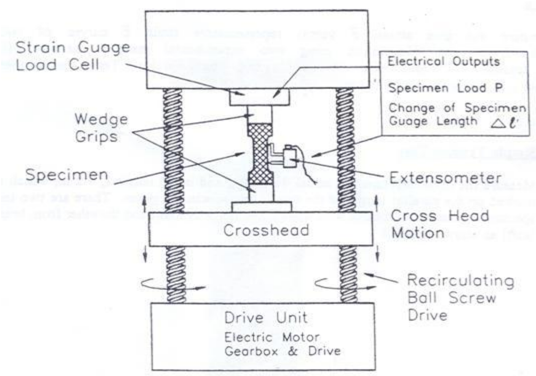


Fig 3.2 Schematic diagram of tensile universal testing machine

PROCESS

The test process involves placing the test specimen in the testing machine and applying tension to it until it fractures. During the application of tension, the elongation of the gauge section is recorded against the applied force. The data is manipulated so that it is not specific to the geometry of the test sample. The elongation measurement is used to calculate the engineering strain, ε, using the following equation

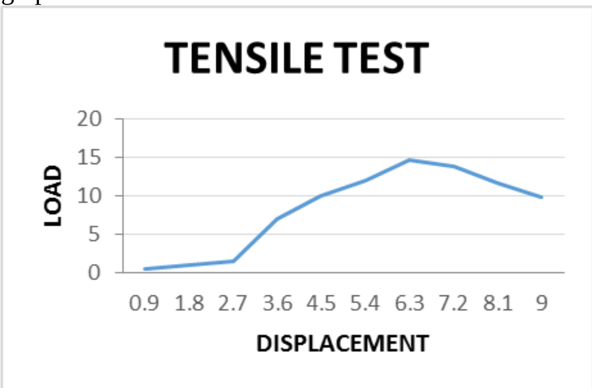
$$\varepsilon=\Delta L/L_0 = (L-L_0)/L_0$$

Where ΔL is the change in gauge length, L0 is the initial gauge length, and L is the final length. The force measurement is used to calculate the engineering stress, σ, using the following equation

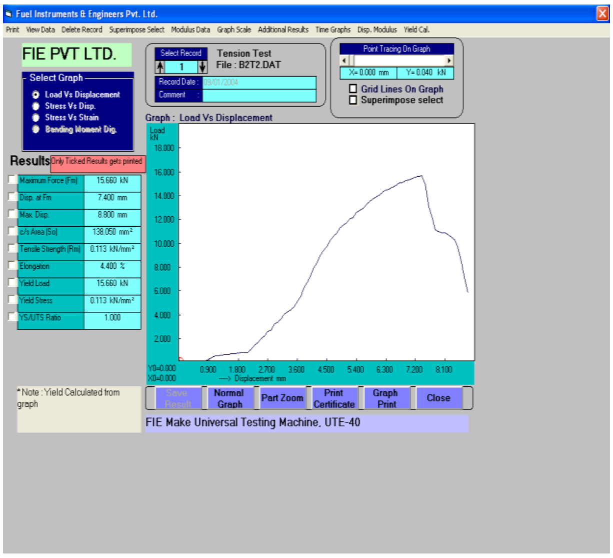
$$\sigma = F_n/A$$

Where,

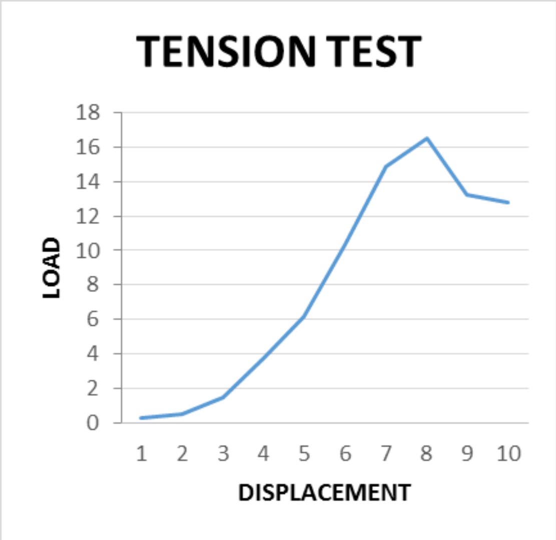
F is the force and A is the cross-section of the gauge section. The machine does these calculations as the force increases, so that the data points can be graphed into a stress-strain curve.



Graph 3.3 *Load vs. Displacement for Specimen 1*



Graph 3.4 *Load vs. Displacement for Specimen 2*



Graph 3.5 *Load vs. Displacement for Specimen 3*

The graph 3.3 shows the plot between the loads versus displacement for the specimen 1. The result indicates that the displacement of maximum load of 16.7 KN is 10.9mm which is within the limit. Graph 3.4 shows the plot between the loads versus displacement for the specimen 2. Similarly the graph 3.5 in order. The result indicates the load of 17.8 kN is 14.3mm which significantly more than the previous one. From the experiment of hybrid tensile specimens, the tensile behavior is developed for the maximum load is very much suitable for alternate hybrid MMC.

Fig 3.6 *Specimens after Tensile Testing*

RESULTS:

Table 3.2 Experimental values for Tensile Test

Sample	**Max. breaking load KN**	**σ N/mm²**	**Extension mm**	**Δ %**	**E N/mm²**
1	14.7	107.13	8.20	4.20	147.163
2	15.6	113.43	8.80	4.40	160.211
3	16.5	119.88	9.60	4.80	177.863

The above table notifies the Ultimate Tensile Strength, Percentage of Elongation and Young's modulus values for the three test specimens. The average values for the specimens is Ultimate Tensile Strength - 113.48 N/mm^{2}Percentage of Elongation - 4.46 Young's Modulus - 161.745 N/mm^2

IV. COMPRESSIVE TEST

A compression test determines behavior of materials under crushing loads. The specimen is compressed and deformation at various loads is recorded. Compressive stress and strain are calculated and plotted as a stress-strain diagram which is used to determine elastic limit, proportional limit, yield point, yield strength and, for some materials, compressive strength.

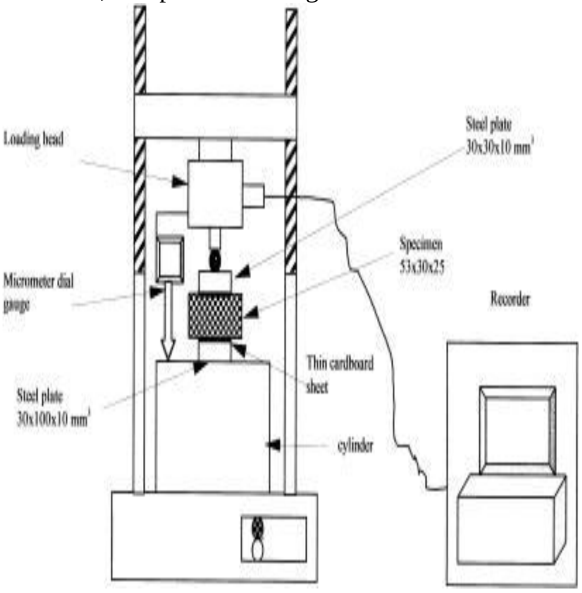


Fig 4.1 Schematic diagram of unconfined compression testing machine

The compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. It can be measured by plotting applied force against deformation in a testing machine. Some material fracture at their compressive strength limit; others deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load. Compressive strength is a key value design of structures.

ASTM TEST FOR COMPOSITES

ASTM E9-09, Standard Test Methods of Compression Testing of Metallic Materials at Room Temperature.

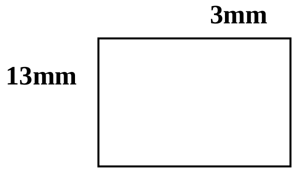


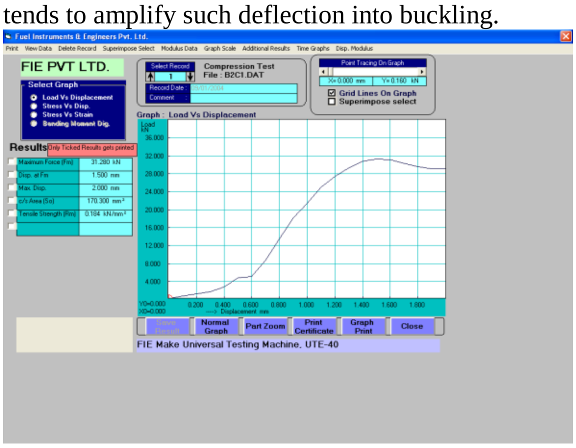
Fig 4.2 *Standard Specimen Diagram for compression Test*

PROCESS

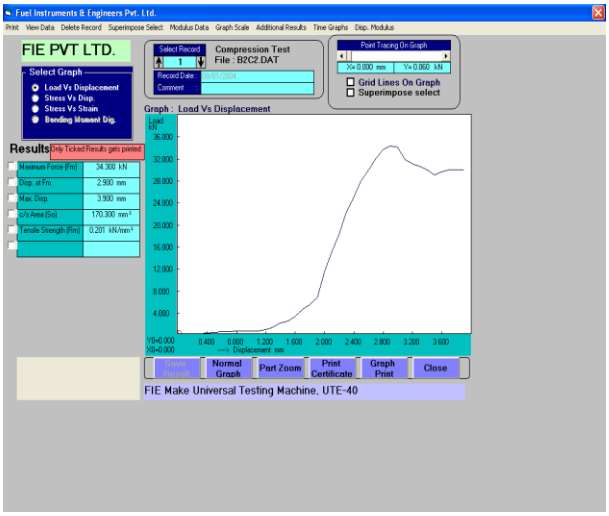
Compressive strength is often measured on a universal testing machine; these range from very small table-top systems to ones with over 53 MN capacity. Measurements of compressive strength are affected by the specific test method and conditions of measurement. Compressive strengths are usually reported in relationship to a specific technical standard. When a specimen of material is loaded in such a way that it extends it is said to be in tension. On the other hand if the material compresses and shortens it is said to be in compression.

On an atomic level, the molecules or atoms are forced apart when in tension whereas in compression they are forced together. Since atoms in solids always try to find an equilibrium position, and distance between other atoms, forces arise throughout the entire material which oppose both tension and compression. The phenomena prevailing on an atomic level are therefore similar.

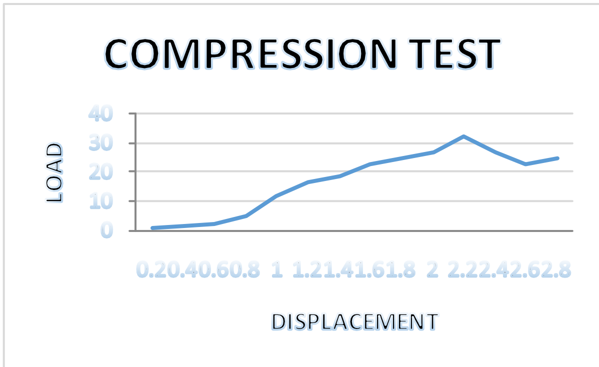
The "strain" is the relative change in length under applied stress; positive strain characters an object under tension load which tends to lengthen it, and a compressive stress that shortens an object gives negative strain. Tension tends to pull small sideways deflections back into alignment, while compression tends to amplify such deflection into buckling.



Graph 4.3 *Load vs. Displacement for Specimen 1*



Graph 4.4 *Load vs. Displacement for Specimen 2*



Graph 4.5 *Load vs. Displacement for Specimen 3*

Table 4.6 shows the obtained values of the compressive specimens which is observed from the plotted graph 4.3 and 4.4 It shows the plot between the loads versus displacement for the specimen 1. The results indicates that the maximum force acting at 31.28 kN gives the 1.5 mm displacement and similarly the graph 4.5 shows the same order. The value indicates that the maximum force acting at 34.3 kN gives the 2.9 mm displacement. It shows that the development of displacement is influenced by the maximum load applied is not rapid but it is gradually increasing due to the nature property of these laminates.

Width mm	Thickness mm	Breaking Load KN	Compressive strength N/mm^2	E N/mm^2
13	13.1	13.2	184	208.71
13	13.1	13.4	201	261.55
13	13.1	13.3	192	231.33

Table 4.6 Experimental values for compression Test

RESULT

Table 4.6 Experimental values for compression Test The average values for the specimens is

Ultimate compressive Strength - 192.33 N/mm^2

Young's Modulus - 233.86 N/mm^2

V. FLEXURE TEST

The determination of young modulus for fml using three point bending tests:

The aim of this work was to determine the value of Young's modulus for three specimens in order to have a more accurate value. The specimens are in ASTM D790 dimension. The modulus of elasticity is calculated by steepest initial straight-line portion of the load-deflection curve.

Glass fiber reinforced plastics (GFRP) are used on a large scale in aeronautical industry due to their advantages. In the same time, GFRP can present degradations during their use, as delimitation due to some impact even with low energies, accompanied or not by fibers breaking, local overheating, water adsorption, and the last two causes leading to the deterioration of the matrix. In a composite material, the metal matrix is designed to protect the dispersed phase in the environment action (corrosion and oxidation), transfer stresses and redistribute the efforts between fibers.

For transfer load to be optimized and limited movements, the matrix must adhere sufficiently to the reinforcement element. In most cases, the matrix stiffness and mechanical strength are lower than the reinforcement material those of. Young's modulus is one of the important characteristic specific to solid materials.

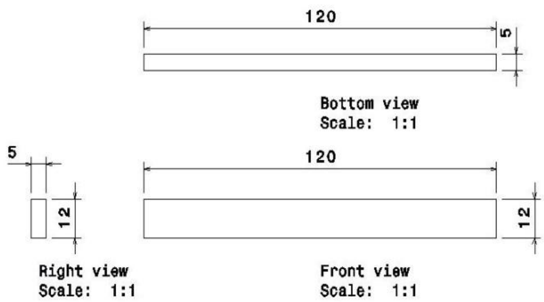
For polymer composites, the factors affecting the Young's modulus are complicated, such as the nature of the matrix and filler, the compatibility between them, materials processing technology and conditions, the dispersion or distribution of the filler in the matrix, as well as the interfacial structure and morphology, and so on. Prediction of the Young's modulus of composite materials has been the subject of extensive research over the last 40 years.

For more detailed information about the available theories and approaches the reader is referred to review articles which treat the theme comprehensively, notably the review by, which contains a discussion of the most relevant approaches and theories. Bending tests are used for determining mechanical properties of unidirectional composite materials. Due to the important influence of shear effects in the displacements, great span-to-depth ratios are used in order to eliminate these effects.

Three-point and four-point test configurations are used in order to obtain flexural strength and flexural modulus. Grim berg R. et al. propose a non-destructive control method with ultrasound Lamb wave spectroscopy. The Lamb waves are generated using Hertzian contact which presents the two important advantages: the coupling fluid between the transducer and the surface to be controlled is not required and the Hertzian contact behaves practically like a Lamb wave's punctual transducer, fact that assures a relatively simple modeling of the phenomena

ASTM TESTING STANDARD

Numerous investigations have been made in finding suitable methods for measuring test flexural properties. Standardization institutions such as the American Society for Testing and Materials (ASTM), European Structural Integrity Society (ESIS) and Japanese Industry Standards (JIS) have proposed the three point bending test as method used in the current study. The tests described in this article try to be consistent with the requirements of standards, in terms of sampling and test specimens, procedure and post-processing.



(All the dimensions in mm)

***Fig 5.1** Specimen Size for Flexural Test under ASTM-D790 Standard*

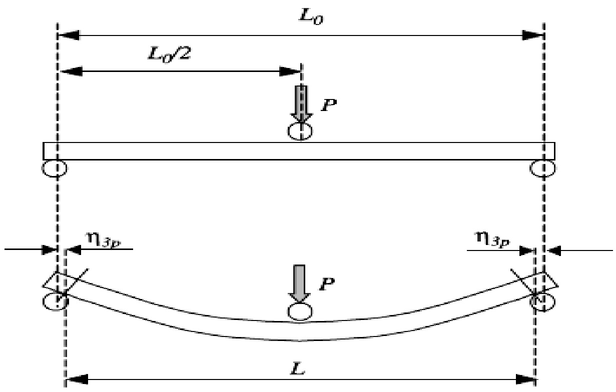


***Fig 5.2** Un-deformed and deformed three-point bending test configuration*

These test methods cover the determination of flexural properties of reinforced polymer, including high- modulus composites in the form of rectangular bars molded directly or cut from sheets, plates, or molded shapes. These test methods are generally applicable to both rigid and semi rigid materials. However, flexural strength cannot be determined for those materials that do not break or that do not fail in the outer surface of the test specimen within the 5.0 % strain limit of these test methods. These test methods utilize a three-point loading system applied to a simply supported beam. In Fig.5.2 Un-deformed and deformed three-point bending test configuration. Flexural properties can only be used for engineering design purposes for materials with linear stress/strain behavior. For non-linear behavior, the flexural properties are only nominal.

Figure 5.1 shows the dimensions of three specimens named I_1, I_2 and I_3. The samples width and thickness are equal. For each of the three samples three measurements were performed in order to emphasize the repeatability of results.

Fig 5.3 *Test bench used in the three-point bending tests.*

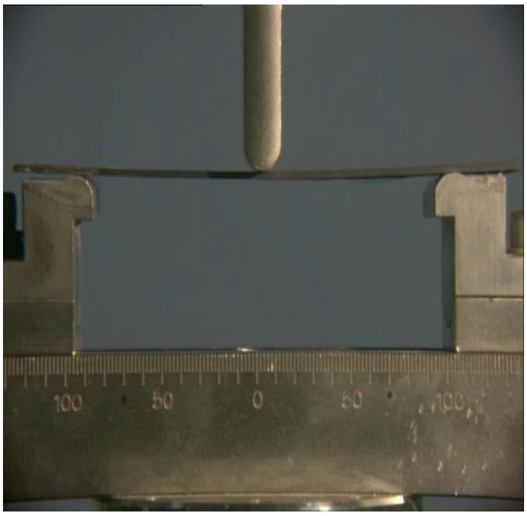
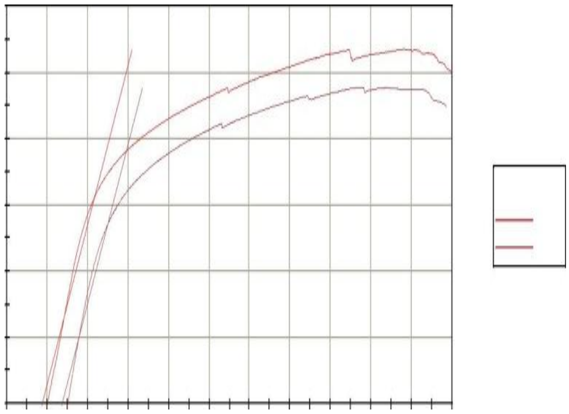
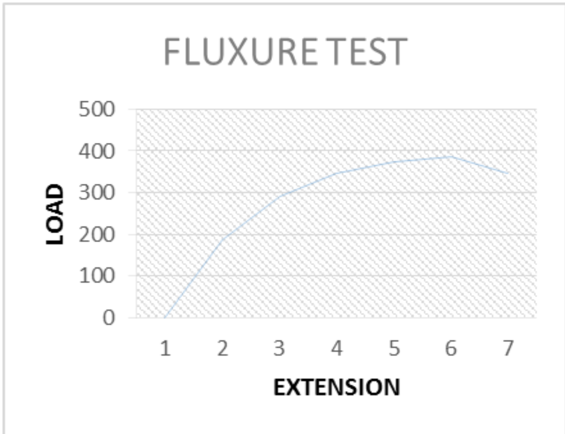


Fig5.4 *The specimen position on the test machine.*



Extension (mm)



5.6 Load vs Extension for specimen 3

The flexure test behavior of the three specimens is defined by Graph 5.5 and 5.6. It shows the response between load and deflection. The results indicates that the maximum load applied for the specimen 1 and 2 are 534 kN and 478 kN respectively and gives the maximum extension 8.79mm and 7.30mm for each. The result shows that the extension is increased with the load. Similarly the specimen 3 behaves in order. This may be due to the good bonding with the perforated sheet by the epoxy property. According to the publishers effect of perforated sheet in the center has reduced the circumferential stress and also increasing the flexure and impact behavior.

The proportionality between the load and the displacement is expressed by a stiffness term which is a function of the flexural stiffness Δf and the Young's modulus in compression.

From the slope of a graph of load versus displacement, and using the equation (4) a value for Young's modulus is obtained. In table 2 is shown the average of Young's modulus values for each specimen considering different span length.

A more complete three point bending mid-span displacement equation can be written as;

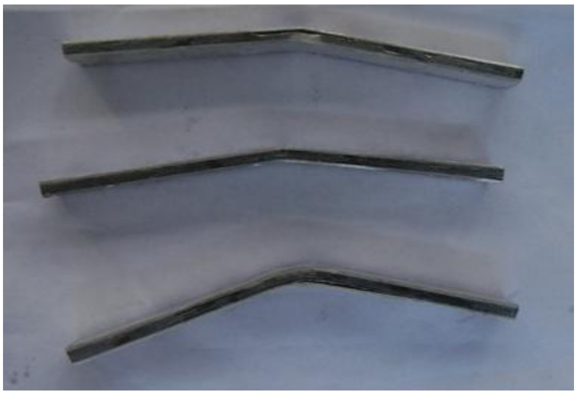


Fig5.5 *Specimens after Flexure Test*

EXPERIMENTAL RESULTS OF YOUNG'S MODULUS VALUES FOR THE THREE SPECIMENS:

SPECIMEN	I_1	I_2	I_3
E(MPa)	8263.88	6914.23	7748.17

Table5.1 *Experimental results of Test Specimens*

The above table notifies the Young's modulus values for the three test specimens. The average young's modulus for the specimen is **7642.093 MPa.**

VI. CONCLUSION

This paper presents an experimental investigation of stainless steel wire mesh/aluminum alloy hybrid composite materials based on glass/epoxy under the tension, compression, and three point bending. The concluding remarks can be summarized as follows:

- In this experimental test results consist of tensile, compressive and flexural test, an experiment test results, graph and calculations are noted above.
- The experimental result clearly show that stainless steel wire mesh-reinforced epoxy composite constitutes a new technique to extensively enhance the flexural strength over the simple GFRP panels.
- The perforated aluminum offer more load bearing capacity and reducing the circumferential stress. It was found that the tensile and compressive properties of this hybrid composite are notable, however its strength slightly lesser than carbon fibers but it could facilitate a light weight compared with CFRP panels.
- Further studies are necessary to develop this reinforcement method by the way such as the mechanical behavior of this composite is to compare with the CFRP hybrid combination either by placing the glass/fiber reinforcement or by placing different sequence fiber types alternatively.

REFERENCE

[1] Chung DDL. Composite material science and applications.2nd ed. Springer 2010.
[2] Aladdin Aktas ,Mehmet Aktas , Fatih Turan ,The effect of stacking sequence on the impact and post-impact behavior of woven/knit fabric glass/epoxy hybrid composites" 24 February 2013.
[3] Pedrop. Martin Ana Gonzalez Garcia, Nieveslapena, Sergio, Martinez-sanz, Marti ferror Green aircraft interior panels in sandwich construction,June 14 2012.
[4] R.Muñoz a, V. Martínez a, F. Sket a, C. González a,b, J.LLorcaa,b, Mechanical behavior and failure micromechanics of hybrid 3D woven composites in tension 11 January 2014.
[5] D.P.Graham a,b,1, A. Rezai a,⇑, D. Baker a, P.A. Smith b, J.F. Watts b,The development and scalability of a high strength, damage tolerant,hybrid joining scheme for composite–metal structures 5 may 2014,.
[6] Chensong Dong ⇑, Ian J. Davies, Optimal design for the flexural behavior of glass and carbon fibre reinforced polymer hybrid composites, 25 January 2012
[7] Kedar S. Pandya, Ch. Veerraju, N.K. Naik ⇑Hybrid composites made of carbon and glass woven fabrics under quasi-static loading5 March 2011.
[8] Jin Zhang, KhunlavitChaisombat, Shuai He, Chun H. Wang⇑Hybrid composite laminates reinforced with glass/carbon woven fabrics for lightweight load bearing structures, 12 November 2011.
[9] C.Soutis Fiber reinforced composites in aircraft construction.
[10] Sudarisman, Davies IJ. Flexural failure of unidirectional hybrid fiber-reinforced polymer (FRP) composites containing different grades of glass fiber.
[11] An experimental investigation on the impact behaviour ofhybrid composite plates(comp. Structures) ELSEVIES 2009.
[12] The effect of stacking sequence on the impact and post impart behaviour of Woven/Knit Fabric glass/epoxy hybrid composite. [Composite structures] ELSEVIER 2013.
[13] Hybrid Composite laminates reinforced with glass/carbon woven fabrics for light weight load behaving structures.[Materials and design, ELSEVIER 2011]
[14] Progressive failure analysis of perforated Aluminum (FRP fiber metal laminates using

a combined elastoplastic damage model and including delaminating effects. [comp. strut 2014]

[15] The development and scalability of a high strength, damage tolerant, hybrid joining scheme for composite metal structure. (composites, ELSEVIER 2014

[16] Optimal design for the flexural behaviour of glass and carbon fiber reinforced polymer hybrid composites. (materials and design ELSEVIER 2011).

[17] Hybrid composite laminates reinforced with glass/carbon woven fabrics for lightweight load bearing structures.

[18] Effect of fiber surface on flexural strength in carbon fabric reinforced epoxy composites.(Applied surface science 2012)