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Effect of Carbon Nanotube Layers on Change in Mechanical Characteristic of E-Glass Fiber Reinforced Epoxy Composite

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Abstract**: *Polymer composite reinforced with fiber materials have always proven its superior significant enactment over numerous traditional materials, considering their incomparable strength to weight ratio and stiffness. The Carbon nanotubes (CNTs) usage in glass-fiber reinforced polymer (GFRP) has high potential in changing the characteristics of composite laminates. Carbon nanotubes (CNT) because of their outstanding mechanical, electrical and thermal properties have engrossed composite fraternity in exploring the opportunity of utilizing them as a supplementary reinforcement in fiber reinforced polymer composites. Reports of the fabrication of GFRP with and without CNT are discussed in this paper. The target in this study is to examine the mechanical characters of GFRP with and without Multi-walled carbon nanotubes (MWCNT). GFRP laminated composite are fabricated by hand lay-up technique. Composite laminated layers are fabricated using epoxy resin without CNT and with 0.5% and 1.5% MWCNT. The materials were tested to determine tensile, flexural and compression properties. It is observed that carbon nanotubes can enhance the mechanical properties in the composite laminates. Composite laminate with 1.5wt% MWCNT exhibited good mechanical properties compared to that with 0.5wt% MWCNT and without MWCNT.***

Index Terms**: *CFRP Composites, Carbon nanotubes, Mechanical Characteristics, Bending moment***

I. INTRODUCTION

From the past few years, composite materials are extensively used various engineering field like civil constructions, aerospace applications and automotive industries due to their high-quality characteristics of light weight, corrosion resistance, improved strength, controllable anisotropic properties, less manufacturing cost and maintenance cost. However, there is a rising demand to produce more improved composite materials within the reasonable cost of construction [1, 2]. The use of fillers, metals and fibers in the thermoplastics and thermosets for spans to form composites. In compassion with neat resins, these composites illustrate a number of enhanced mechanical properties which includes distortion, tensile strength and modulus. Therefore, for structural applications, composites are extensively used have turn out to be highly popular [3]. Advanced composite materials are preferred to use while manufacturing spacecraft components in the present demanding environments. Engineered composite materials must be formed to desired shape and size. This involves advantageously arranging the reinforcements while covering the matrix material to achieve the intended property which is at or near the being of expected component life [4]. The different available methods are used in accordance to obtain the desired design requirements. Chunk et al hearsays the fabrication method of CNTs/GFRP composite laminates use ultra sonication process and the hand lay-up technique [5]. When CNT content is 0.75 percent hundred resin, the mechanical properties are the best. The ILSS was significantly improved 15.7% and flexural strength upgraded 9.2%. Ramanan et al Discussed the characterization of Epoxy based Composite materials for the applications where strength to weight ratio is the primary design parameter weight and high strength application [6]. He also analyzed the fiber volume fraction of the composites with operative consolidation (low thickness) of layers by applying vacuum and pressure throughout laminate curing. Maciel et al studied the characterization of carbon fiber reinforced epoxy composites modified by the introduction of Nanoclay and CNTs [7, 8]. In this study, 2 wt. % Montmorillonite nanoclay and 0.3 wt. % multi-walled carbon nanotubes (MWCNTs) were used with carbon fiber reinforced epoxy composites. Sivasaravanan et al studied the inter-laminar shear strength of multi-walled carbon nanotubes and carbon fiber reinforced, epoxy - matrix hybrid composite. The results illustrate the substantial escalation in inter-laminar shear strength of the hybrid composite with orientation that is longitudinal as connected to transverse orientation; and more significantly highlights that such anisotropy is of an order of higher magnitude [9]. Objective of the current research is to examine the mechanical properties of Glass fiber reinforced epoxy polymer with and without the carbon nanotube filler material. In view of the above, the main objective of this work is to fabrication of Glass Fiber reinforced Epoxy resin composites and bidirectional glass fiber reinforced epoxy resin composite with and without carbon nanotube filler content are fabricated by Hand lay-up Process [10]. To evaluate the mechanical properties of glass fiber reinforced epoxy composite with and without carbon nanotubes filler and Mechanical properties like flexural strength, compressive strength and tensile strength are evaluated using graphical interpretation.

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II. MATERIALS

Epoxy LY556 and hardener HY951 were used as matrix material for reinforced composites in this investigational work. The main reason epoxy resin was used as polymer matrix since it is known that CNTs gets dispersed in a better way in the epoxy resin when judged against other polymer resins.

2.1. E-Glass Fiber (300GSM)

Woven bidirectional E-glass fiber of mass 300GSM was used as reinforcing material. Each ply thickness was 0.28mm. The fibers in a bidirectional arrangement are in two directions – habitually at 90^0 to each other in the idea of providing the greatest strength in those directions. The identical number of fibers need not unavoidably be utilized in both directions [11]. High fiber loading could be obtained in woven bidirectional reinforcements. E-glass is the standard form and is also recognized as electrical grade which possess alkali content at low level and good mechanical, chemical and electrical properties. E-Glass is a low alkali glass with a typical nominal composition of SiO_2 (54%), Al_2O_3 (14%), CaO+MgO (22%), B_2O_3 (10%) and Na_2O+K_2O less than 2%. Some other materials also exist as impurities are shown in Table 1.

Table 1: Composition of E-glass fibre

$Si0_2$	AI_2O_3	CaO	MgO	B_2O_3	K_2O	Na_20	$Ti0_2$
52	12	16	2	9	1	1	0.8

2.2. Multi walled carbon nanotube (MWCNT)

MWCNT is a filler material which acts as an additional reinforcing component. Accumulation of Nano particle to GFRP laminate raises the mechanical properties not only tensile strength but also the tensile modulus without substantial weight addition. Carbon Nanotubes (CNT) because of their admirable mechanical, thermal and electrical properties to have fascinated composite fraternity in exploring the possibility of utilizing them as an added reinforcement in fiber reinforced polymer composites [12]. Raw materials used in this work are Resin-Epoxy LY556, Hardner-HY951, E-Glass fabric woven sheet, Filler-Carbon nanotube and acetone.

III. METHODS

The base plate was cleaned with acetone. Epoxy- LY556 (resin) was heated for a certain period of time to reduce the viscosity. After attaining particular viscosity carbon nanotube was added continuously and the mixture was stirred mechanically at 450 rpm until it reached room temperature. Hardner-HY951 was then added in the ratio of 100:10. A mixture of epoxy resin, hardener and carbon nanotube filler forming a matrix was thus prepared in the prescribed ratio and required wt% [13]. The glass fabric sheet was placed and the matrix mixture was spread uniformly using brush. The wetting of the glass fabric by applying the matrix mixture on each ply was continued until the required thickness was obtained. Total 10 layers of glass ply were used. Vacuum bagging was carried out by applying one atmospheric pressure onto the system. The laminate was cured at room temperature for 24 hours. Post curing was then carried out for 2 hours at 100ºC in an oven.

A. *Process of Fabrication*

Glass woven fabric sheet

Mixture of resin hardener & filler

Wetting of E-glass fabric

Vacuum bagging

Post curing of the laminate

Laminate without CNT

Laminate with 0.5 CNT

Laminate with 1.5 CNT

Fig.1: Fabrication process of nanotubes filled carbon composites

By following the same procedure as said above, composite material with and without filler material was prepared. A polythene sheet which is a non-perforated release film is used to hold the resin and for the easy removal of the laminate. For vacuum bagging a Teflon paper which is a perforated release film or peel-ply material is used in removing excess of resin from the laminate. A Teflon paper which is a perforated release film or peel- ply material is used in removing excess of resin from the laminate. The next layer added is the bleeder/breather material. As its name implies, this material offers two significant functions. First, it engrosses surplus resin from the laminate. Succeeding, it insures that the vacuum is dispersed evenly within the bag.

Now surface bagging is carried out. Around the laminate's perimeter, sealant tape is attached to the base structure with an inch overlap at all four corners. Succeeding the vacuum coupling is inserted. On removing the paper strip from one line of the sealant tape and the bag gets closed to the exposed sealant. Vacuum is applied when the bag find its place.

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IV. TESTING OF COMPOSITE MATERIALS

Tensile testing was carried out for the micro tensile test specimens with dimension of 250×25×3 as per the ASTM-D3039. The test specimen is positioned vertically in the grips of the testing machine.

4.1. Flexural Testing

A point is reached before the breaking point, by the material in order to withstand the bending. Predictably a three point bend test is performed to determine this material property. Flexural test has been done with ASTM-D3029 standard with dimensions of 125×12.7×3.2.

4.2. Compression Testing

Compression testing was carried out for ASTM-6641 standard test specimens. Compressive properties pronounce the material behavior when it is exposed to a compressive load. At uniform rate, the specimen with 150×12.25×3.2 specification is compressed. The maximum load is documented along with stress-strain data. An extensometer attached to the front of the fixture is used in determining modulus.

V. RESULTS AND DISCUSSION

Experiments were performed in characterizing the candidate composite material under varying loading conditions along with numerous specimen configurations. Beside those properties, the interfacial bonds nature and the load transfer mechanisms at the inter phase too perform a significant role. Result analysis and the influence of numerous parameters on the properties are shortened in the succeeding sections. After carrying out the above mechanical experiments it was seen that the tensile, flexural and compression strength increased with the addition of MWCNT. The enhancements in mechanical properties attribute to the dispersion of MWCNT and the interfacial adhesion between epoxy matrix and MWCNT so that the chain matrix mobility is controlled under loading. The strong interfacial interaction that exist in the composites may also limit the matrix mobility in the interface among the fiber and the matrix and the matrix permitting improved stress transfer to the glass fibers within the composite.

5.1. Tensile behavior of composite

Three specimens from each variation of the composite have been tested. Dimensions of the test coupons were 250 mm in length, 25 mm in width and 3 mm in thickness correspondingly. Average modulus for the glass-carbon epoxy composite with and without fillers has been determined to be 2.44MPa, 3.03 and 2.16MPa respectively. The tensile test results with carbon nanotubes are given in Table 2. From the obtained results, it is concluded that the average modulus of elasticity will be increased by 19.44% between the hybrid composite samples made from without MWCNT and with MWCNT [13]. Tensile strength stress versus strain plots are depicted in figure 2-10 illustrates the effect of nano particles on the ultimate stress-strain properties of composites.

Table.2: Tensile results of Composites with nanotubes

Specimen/Load	**Ultimate stress (KN/sq.mm)**		
Specimen	No CNT	0.5	1.5
Specimen 1	0.396	0.441	0.452
Specimen 2	0.399	0.426	0.510
Specimen 3	0.463	0.507	0.445
Avg. Results	**0.419**	**0.458**	**0.469**

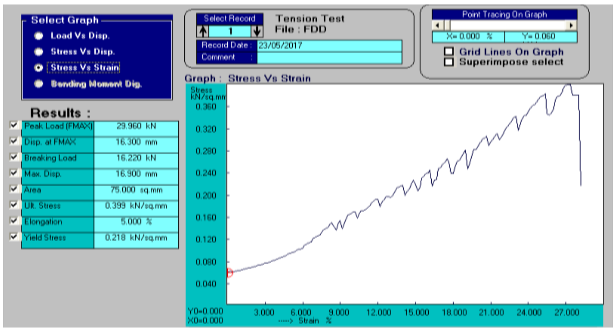

Fig. 2: Stress–strain curves of composites for 0% carbon nanotubes

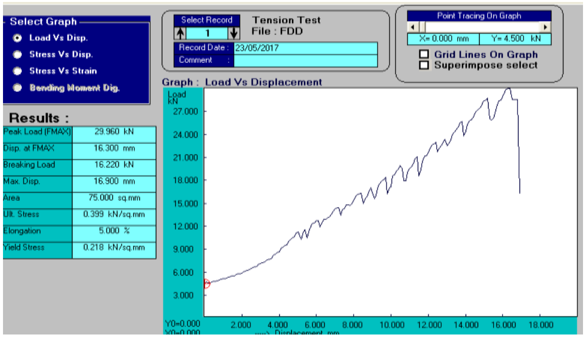

Fig. 3: Load–Displacement curves of composites for 0% carbon nanotubes

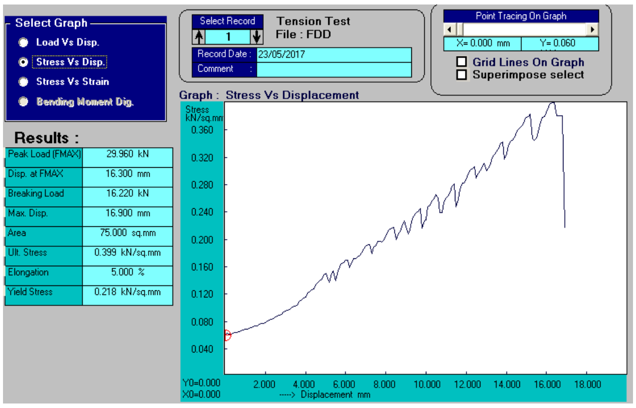

Fig. 4: Stress–Displacement curves of composites for 0% carbon nanotubes

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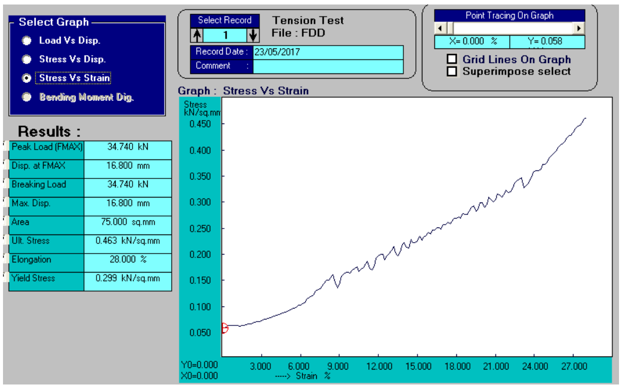

Fig. 5: Stress–strain curves of composites for 0.5% carbon nanotubes

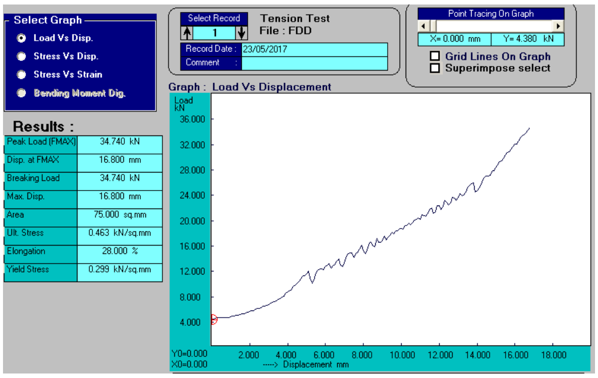

Fig. 6: Load–Displacement curves of composites for 0.5% carbon nanotubes

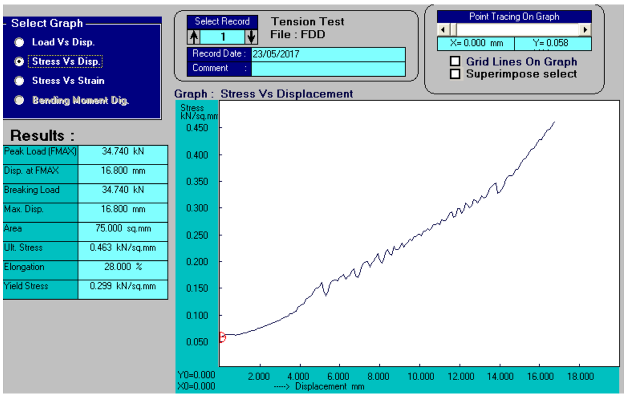

Fig. 7: Stress–displacement curves of composites for 0.5% carbon nanotubes

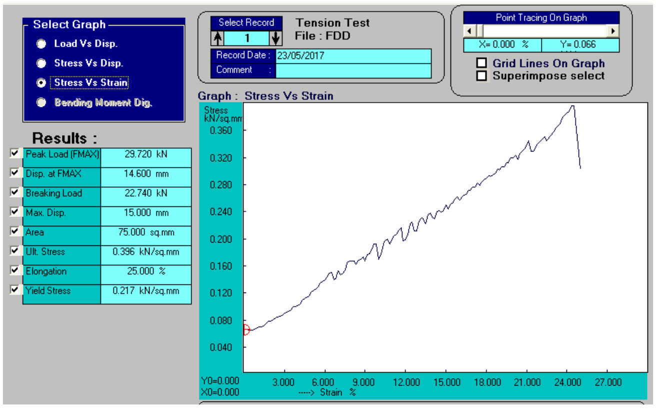

Fig. 8: Stress–strain curves of composites for 1.5% carbon nanotubes

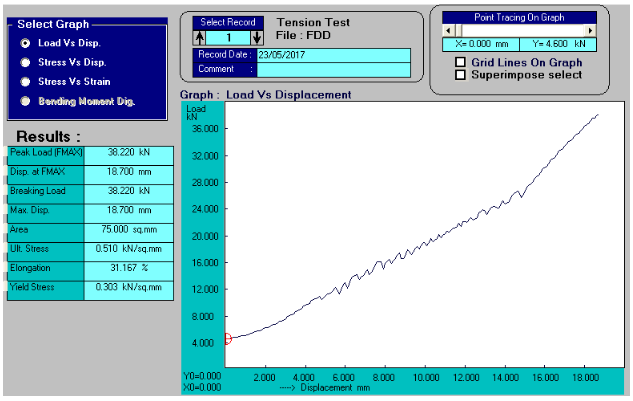

Fig. 9: Load–Displacement curves of composites for 1.5% carbon nanotubes

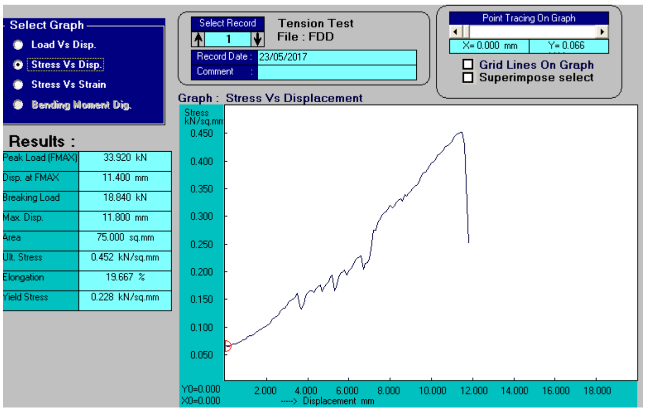

Fig. 10: Stress–displacement curves of composites for 0% carbon nanotubes

5.2. Flexural properties

Carbon fiber reinforced composites altered with nano particles are made to undertake three point bending load in the idea of comparing the flexural properties of nano particles modified ones to control one. Flexural stress versus strain plots are depicted in figure 11-13 illustrates the effect of nano particles on the flexural properties of composites. Related data accumulated is charted in Table 3.

Table.3: Bending test results for composites with nanotubes

Specimen	**Max. Bend. Moment (KN.mm)**		
Specimen	No CNT	0.5	1.5
Specimen 1	39.78	40.68	41.04
Specimen 2	41.22	41.22	41.94
Specimen 3	38.69	39.69	42.68
Avg. Results	**39.89**	**40.53**	**41.88**

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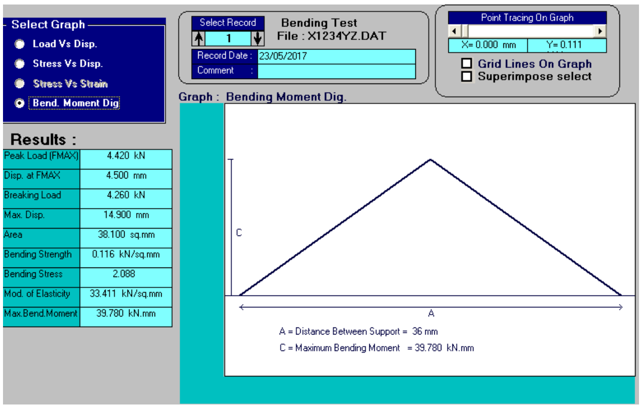

Fig 11. Bending moment curve of composites for 0% carbon nanotubes

Table.4: Compression Test Results

Specimen	Peak Load (KN)		
	No CNT	0.5	1.5
Specimen 1	7.560	7.340	7.760
Specimen 2	7.480	7.680	7.810
Specimen 3	7.610	7.780	7.710
Avg Results	**7.550**	**7.600**	**7.760**

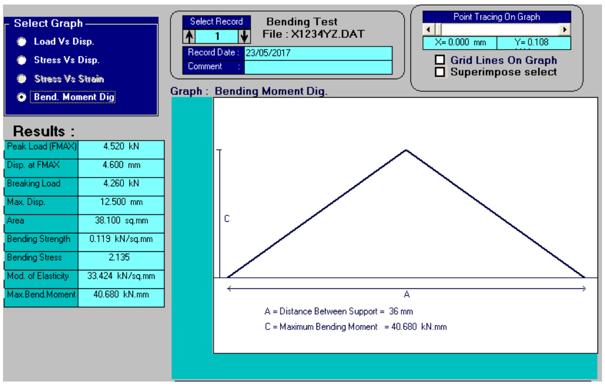

Fig 12. Bending moment curve of composites for 0.5% carbon nanotubes

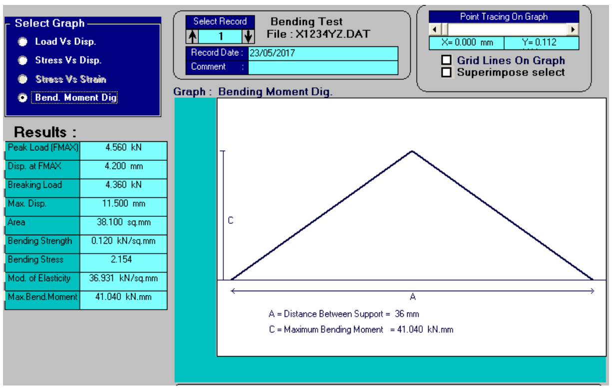

Fig 13. Bending moment curve of composites for 1.5% carbon nanotubes

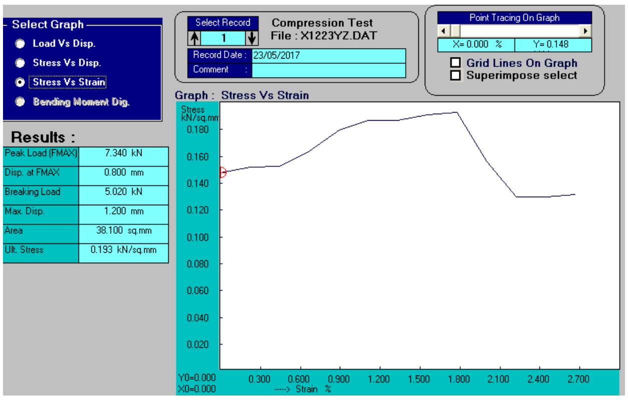

Fig 14. Stress–strain curves of composites for 0% carbon nanotubes after compression test

Flexural strength and all the samples modulus values goes up with adding of nano particles and the enhancement were practically similar. Compression test stress versus strain plots, stress and load displacements are depicted in Fig. 14-18 illustrates the effect of nano particles on the compression properties of composites.

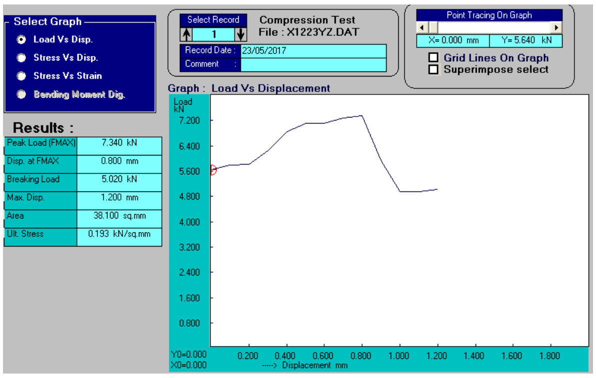

Fig 15. Stress–strain curves of composites for 0.5% carbon nanotubes after compression test

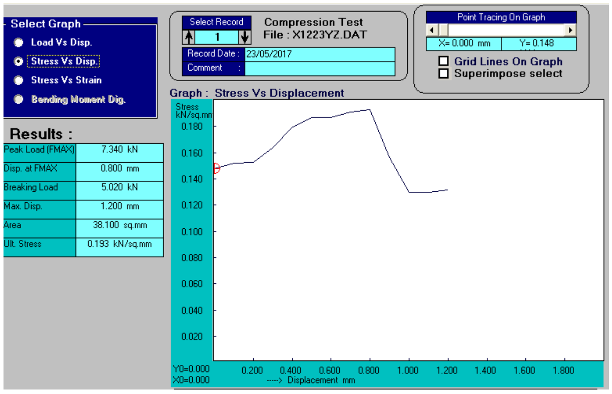

Fig 16. Stress–Displacement curves of composites for 1.5% carbon nanotubes after compression test

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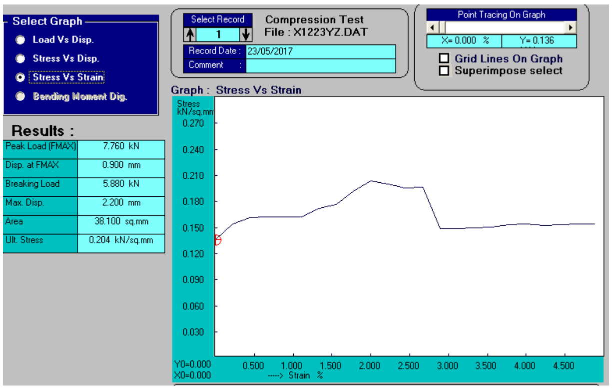

Fig 17. Stress–strain curves of composites for 1.5% carbon nanotubes after compression test

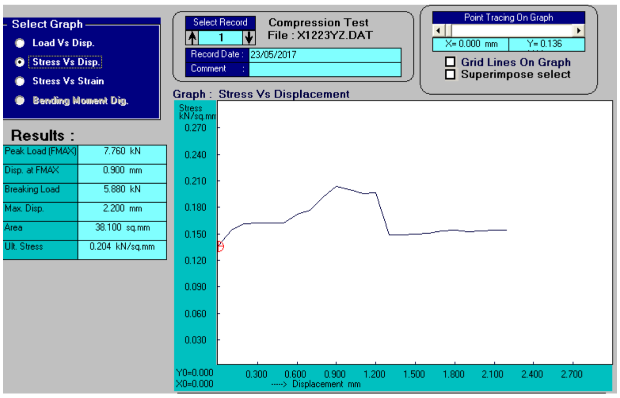

Fig 18. Stress–displacement curves of composites for 1.5% carbon nanotubes after compression test

VI. CONCLUSIONS

Based on the test outcomes achieved from the numerous tests performed, the succeeding inferences were made:

Out of the tensile tests carried out on the test specimens, it was noted that the elastic strength of the material increases with the addition of MWCNT fibres. Also the Ultimate stress for the glass fiber epoxy with and without MWCNT was found to be 0.419 KN/sq.mm, 0.458 KN/sq.mm and 0.469 KN/sq.mm respectively and thus the strength increases with the increase in percentage of MWCNT present in the material.

(i) From the flexural tests carried out on the specimens, it was noted that the Maximum bending moment increases with the addition of MWCNT and it increases with the percentage increase of MWCNT in the material.

(ii) From the compression tests carried out, it was seen that the compressive strength of the material increases with the addition of MWCNT to the material and increases with the increase in the percentage of MWCNT in the material. The overall mechanical properties of the material are noted to be improved by the addition of MWCNT to the material.

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