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EXPERIMENTAL STUDY ON EFFECT OF FIBER ORIENTATION ON THE TENSILE PROPERTIES OF FABRICATED PLATE USING CARBON FIBER

BISWAJIT JENA[1], S .Z KHAN[2], BIPIN BIHARI MOHANTY[3] & SWATI SURABHI[4]

[1]Assistant Professor, Department of Civil Engineering, DRIEMS Cuttack, India

[2,3]Professor, Department of Civil Engineering, DRIEMS Cuttack, India

[4]B.Tech Student, Department of Civil Engineering, DRIEMS Cuttack, India

ABSTRACT

Advantageous application of corrosion resistant fiber reinforced polymer (FRP) reinforcement is in structures especially susceptible to deicing salts, and/or located in extremely pungent environment. As low density, high thermal conductivity, good chemical stability and exceptional abrasion resistance, and can be used to decrease or reduce cracking and shrinkage. These afibers increase some structural properties like tensile and flexural strengths, flexural toughness and impact resistance. This experimental program determines the fibre content and fiber orientation of carbon fibre on tensile properties of the fabricated composites. In this research different fiber orientations are examined and the fabrication is done by hand lay-up process. The variation in the properties corresponding to the different layers in increasing number of fiberplate thickness is also considered. Tensile strength of specimens upto failure is tested by means of INSTRON universal testing Machine. The result of tensile strength and from that the modulus of elasticity is calculated.

KEYWORDS: Carbonfiber, Carbon Fabric Plate, Fabrication, Fiber Reinforced Polymer (FRP), Strengthening

INTRODUCTION

Filaments such as carbon fibers, glass fibers and ceramic fibers which are high performance in nature are used repeatedly. Fibres in the composites are known to confer strength and rigidity to the weak matrix .Reinforcement filaments bear most of the external loads during the service period of material. Carbonfiber is a fresh fibre shown up in recent years. It has high strength, excellent fiber/resin adhesion and ability to be easily processed using conventional processes and equipment. In addition, the carbon fibers do not contain any other additives in a single producing process which makes them have an additional advantage in cost. As low density, high thermal conductivity, good chemical stability and exceptional abrasion resistance, and can be used to decrease or reduce cracking and shrinkage. These fibers increase some structural properties like tensile and flexural strengths, flexural toughness and impact. In comparison to traditional glass and basalt fibres carbon fibre of mineral origin has gathered significant attention. Significance of basalt fibre as a practicable new reinforcing material is mentioned by several articles dealing with glass fibre reinforced polymer composites. With use of such low density and tough composites instead of metal raw materials e.g. in manufacturing of rotating fluid machinery mechanical problems e.g. related to swept rotor blades can be surmounted. There are only a few researchers who managed to create a composite to embed carbon fibers in a polymer matri. The main reason is the problem of fibre-matrix interfacial interaction and the high sensitivity to fracture in carbon fibers. Most of the former examination on the declination of the reinforcement fibers in chemical environments are focused on the fabricated materials in which the fibers are covered by the matrix. According to ref[9-11], the resistance of the filament to corrosion is mainly dependant on the resin's corrosion-resistance, and the crack propagation is also affiliated to the resin toughness.

The works on carbonfiber fabricated composites are very poor according to subsisting literatures. Based on the critical observations made from the subsisting literatures, the objectives of the present study are defined as follows.

- To study the effect of fiber orientation on the mechanical properties of carbonfiber fabricated composites.
- To study the effect of number of layers of fiber on the mechanical properties of carbonfiber fabricated composites.

EXPERIMENTAL WORK

2.1. The Factors Selected for the Experimental Study are as Follows

- Different variation in thickness of CFRP layer
- ($0^0/90^0$fiber direction) taken as fiber orientation

2.2. MATERIALS

2.2.1. Carbonfiber

Carbon fibers have low density, high thermal conductivity, good chemical stability and exceptional abrasion resistance, and can be used to decrease or reduce cracking and shrinkage. These fibers increase some structural properties like tensile and flexural strengths, flexural toughness and impact resistance. Carbon fibers also help to improve freeze-thaw durability and dry shrinkage. The adding of carbon fibers decreases the electrical resistance.

2.2.2. Epoxy Resin

The success of the strengthening technique primarily depends on the performance of the epoxy resin used for bonding of FRP to concrete surface. Epoxy, which is also considered as binding material is used between fibre layers. Epoxy resins with a broad range of mechanical properties are commercially available in the market in multiple types. Epoxy resins can be divided into two parts and they are, a resin and a hardener. The resin and hardener used in this study are Araldite LY 556 and hardener HY 951 respectively.

2.3. METHODOLOGY

2.3.1. Fabrication Process

Moulding follows two basic processes that is, hand lay-up and spray-up. The oldest, simplest, and most labour intense fabrication method is hand lay-up process. This process is the most common in FRP marine construction. In hand lay-up method liquid resin is placed along with reinforcement (unidirectional carbonfiber) against finished surface of an open mould. Chemical reactions which takes place in the resin harden the material to a strong, light weight product. The resin serves as the matrix for the reinforcing carbon fibers, much as concrete acts as the matrix for steel reinforcing rods. The percentage of fiber and matrix was 45:55 in weight.

The following constituent materials are used for fabricating the CFRP plate:

- Unidirectional carbon FRP (CFRP)
- Epoxy as resin
- Hardener as diamine (catalyst)

- Polyvinyl alcohol as a releasing agent

Contact moulding in an open mould by hand lay-up and was used to combine plies of unidirectional fibre in the prescribed sequence. A flat plywood rigid platform was selected. A thin film of polyvinyl alcohol was applied as a releasing agent by use of spray gun after placing plastic sheet on the plywood platform. Lamination is done with the application of a gel coat (epoxy and hardener) deposited on the mould by brush. The main purpose of gel coat was to provide a smooth external surface and to protect the fibers from direct exposure to the environment. Ply was generally cut from roll of unidirectional roving. Reinforcement layers were placed at the top of the gel coat on the mould and again the gel coat was applied by brush. Each and every air bubble which may be caught up was removed using serrated steel rollers. The process of hand lay-up was the continuation of the above process before the gel coat had fully hardened. Again, the top of the plate was covered with the help of plastic sheet by applying polyvinyl alcohol inside the sheet as releasing agent. After that for compressing purpose a heavy flat metal rigid platform was kept at the top of plate. Last but not the least, the plates were left for a minimum of 48 hours before being transported and cut to exact shape for testing. Plates of 2 layers, 4 layers, 6 layers and 8 layers of $0^0 and\ 90^0$fiber direction were casted and three specimens from each thickness were tested.

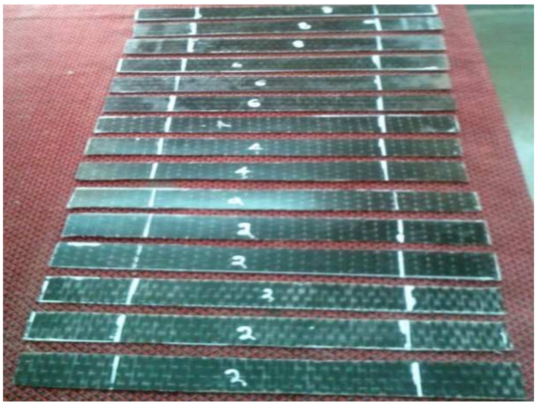

Figure 1: Specimen

Figure 2: UTM

Figure 3: Testing of Specimen

2.3.2. Results of Ultimate Stress, Ultimate Load & Young's Modulus of CFRP

With the help of unidirectional tensile tests on specimens cut in longitudinal and transverse directions, the ultimate stress, ultimate load and young's modulus was determined experimentally. By using diamond cutter or by hex saw the specimens were cut from the plates. After cutting by hex saw, it was polished with the help of polishing machine. At least three repeated sample specimens were tested and mean values adopted. The dimensions of the specimens are shown in below Table 1.

Table 1: Dimension of Specimens for Tensile Test

Orientation	0^0 Orientation				90^0 Orientation			
No. of Layers	2 Layer	4 Layer	6 Layer	8 Layer	2 Layer	4 Layer	6 Layer	8 Layer
Length of specimen (cm)	25	25	25	25	25	25	25	25
Width of specimen (cm)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Thickness of specimen (cm)	0.52	1.05	1.54	2.01	0.58	1.1	1.58	2.1

For measuring the tensile strength and young's modulus, the specimen is loaded in INSTRON 100 kN in Production Engineering Lab, NIT, Rourkela. Specimens were gripped in the fixed upper jaw first and then gripped in the movable lower jaw. The specimen should be gripped properly to prevent the slippage. Here, it is taken as 50 mm from the each side. Initially, the strain is kept zero. Load cell and an extensometer were used to record the load, as well as the extension digitally. From these data, stress versus strain graph was plotted, the initial slope of which gives the young's modulus. With the help of the graph the ultimate stress and ultimate load were obtained at the failure of the specimen.

Figure 4: Failure Specimens of 90^0 Orientation

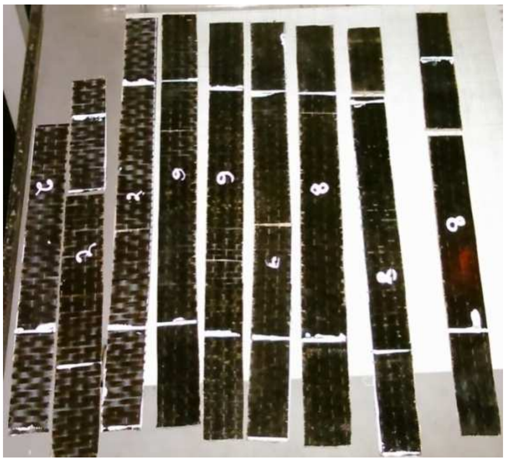

Figure 5: Failure Specimens of 0^0 Orientation

RESULTS AND DISCUSSIONS

The result of Ultimate Stress, Ultimate Load & Young's Modulus for each layer of the specimens of different orientations is given in the Table 2.

Table 2: Experimental Results

Orientation	0^0 Orientation				90^0 Orientation			
No. of Layers	2 Layer	4 Layer	6 Layer	8 Layer	2 Layer	4 Layer	6 Layer	8 Layer
Ultimate stress (Mpa)	14.58	17.15	23.48	25.81	421	489	532	608
Ultimate load (kN)	0.212	0.703	1.06	1.105	6.21	12.9	23.4	25.9
Young's modulus (Mpa)	4896	5978	6102	6845	12201	13321	13817	14310

From Table 2, it is observed that the specimens for 90^0 orientation give traditional result as compared to the specimens for 0^0 orientation for each layer.

The ultimate stresses for0^0orientation with different layersof CFRP are represented in Figure.6.

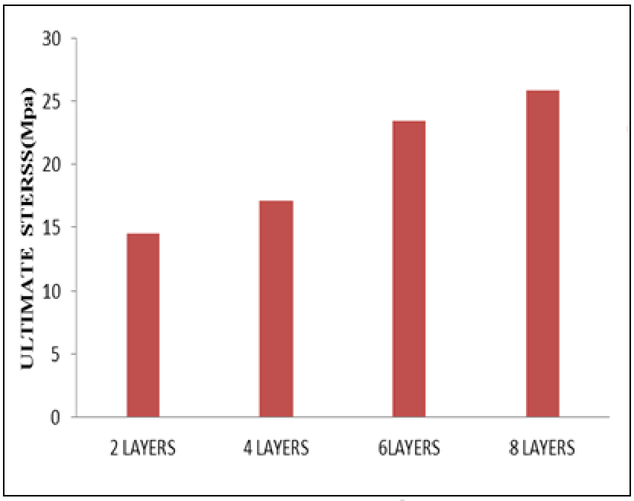

Figure 6: Results of Ultimate Stress for 0 DEG Orientation

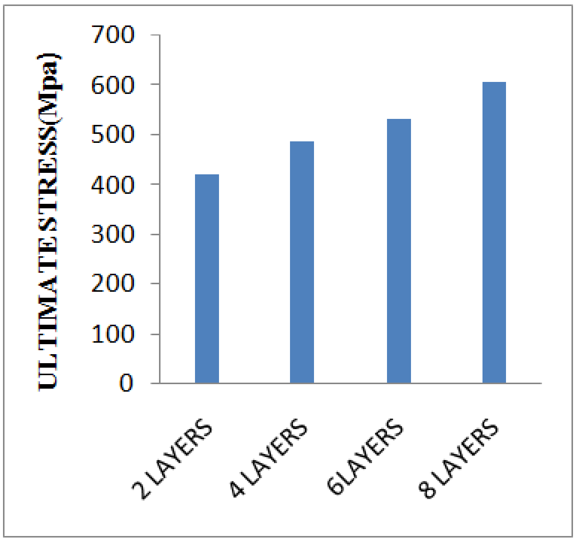

Figure 7: Results of Ultimate Stress for 90 DEG Orientation

The ultimate stresses for 90^0orientation with different layersof CFRP are represented in Figure 7.

From Figures 6 and 7, it is observed that there is marginal increase in the ultimate stress at failure with the increase of number of layers of CFRP.

The ultimate loads for 0^0orientation with different layersof CFRP are represented in Figure 8& 9

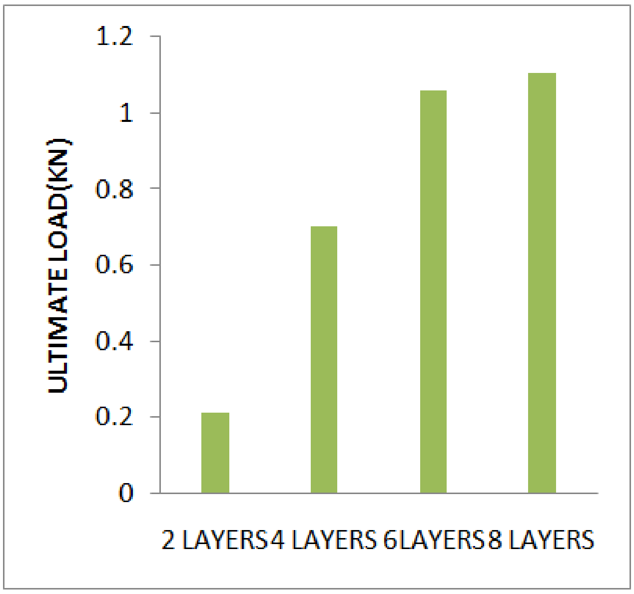

Figure 8: Ultimate Load for 0 Deg Orientation

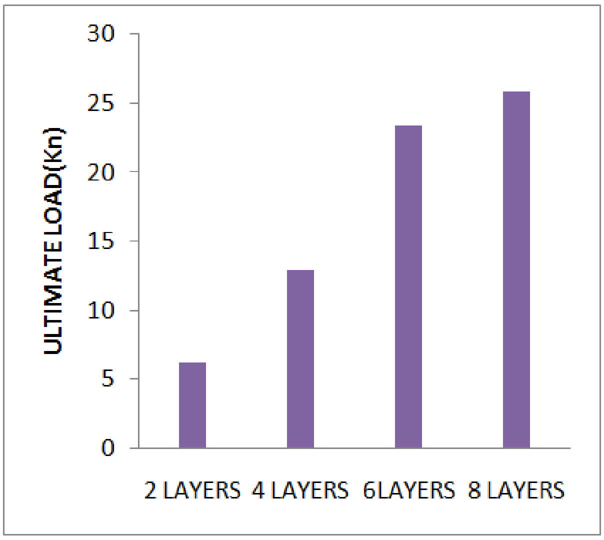

Figure 9: Ultimate Load for 90 Deg Orientation

From Figures 8 and 9, it is observed that there is significant increase in the ultimate loads at failure with the increasing layers of CFRP.

The young's moduli for $0^0 and\ 90^0$orientations with different layersof CFRP are shown in Figure 10.

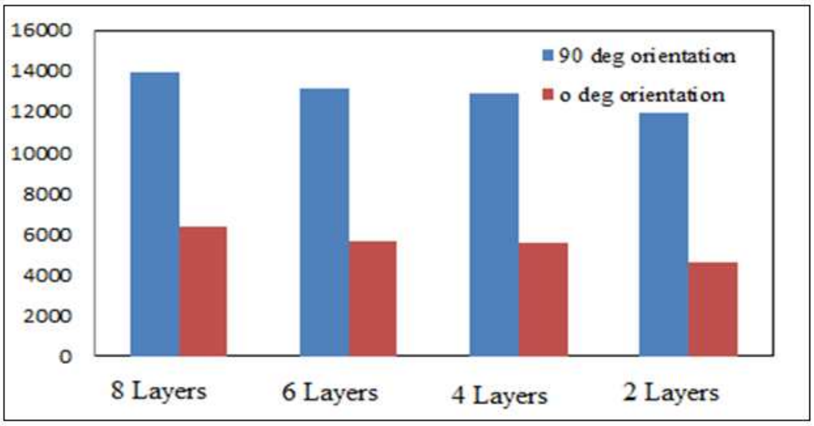

Figure 10

From Figure 10, it is shown that there is significant increase in the elastic moduli for 90^0orientation as compared to 0^0orientation.

CONCLUSIONS

In this study we investigated about the tensile strength of carbon fibre fabricated plates with different orientations and different thickness .The following observations came out from this investigation:

- The specimens for 90^0orientation give conservative results as compared to the 0^0orientation for Ultimate Stress, Ultimate Load & Young's Modulus.
- Unidirectional carbon fibre can be used in longitudinal direction to get better tensile strength.
- The tensile strength of the fabricated plate increases with the increasing number of layers of CFRP (i.e. increasing thickness of fabricated plate).

Carbon fibre can be an alternative for fibreglass since their average density and average tensile

Elasticmoduli are almost the same, and the production cost of carbonfibers is only one half of that of the fiberglass due to the simplicity of the Junkers production technology.

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