Tensile, Compression and Flexural Behavior of Hybrid Fiber (Hemp, Glass, Carbon) Reinforced Composites

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***Abstract*— in recent years, there has been an increasing environmental consciousness and awareness of the need for sustainable development, which has raised interest in using natural fibers as reinforcements in polymer composites to replace synthetic fibers such as glass. Natural hybrid fiber, which consist of two relatively thin and stiff faces bonded to a low density core, offer many benefits such as high bending stiffness, good thermal and acoustic insulation properties, and high specific energy absorption. In this study, natural hybrid reinforced composites panels are made with Hemp fabric/glass fabric/Epoxy and Hemp fabric/carbon fabric/Epoxy 3mm thickness and composites are fabricated using Simple hand layup technique. Appropriate test methods as per standards and guidelines are followed to analyze mechanical behaviour of the composites. The physical and mechanical characteristics of the natural hybrid reinforced composites used for the fabrication of the sandwich panels are tested as per the ASTM standards. To characterize the tensile, compression and flexural properties of the natural composites, a series of tensile test, compression test and 3-point bending tests were conducted on the sandwich panels. A quantitative relationship between the Hemp fabric/glass fabric/Epoxy and Hemp fabric/carbon fabric/Epoxy has been established with varying thickness.**

***Key words*—Hand layup, hemp fabric, carbon fabric, glass fabric, epoxy resin.**

I. INTRODUCTION

Natural fibers, as reinforcement, have recently attracted the attention of researchers because of their advantages over other established materials. They are environmentally friendly, fully biodegradable, abundantly available, renewable, cheap and have low density. Plant fibers are light compared to glass, carbon and aramid fibers. The biodegradability of plant fibers can contribute to a healthy ecosystem while their low cost and high performance fulfills the economic interest of industry. Polymeric materials reinforced with synthetic fibers such as glass, carbon and agamid provide advantages of high stiffness and strength to weight ratio as compared to conventional construction materials, i.e. wood, concrete and steel. In spite of these advantages, the widespread use of synthetic fiber-reinforced polymer composite has a tendency to decline because of their high-initial costs and also production of synthetic composites requires a large quantum of energy and quality of environment suffered because of the pollution generated during the production and recycling of these synthetic materials.

II. RELATED WORK

T. Madhusudhan [1] conducted a research based on hybrid composites with the combination of Glass-Hemp and Sisal with epoxy resin as binder Epoxy resin in the hybrid composite will result in the strong bond for the materials. Hybrid composites are usually used when a combination of properties of different types of fibers have to be achieved, or when longitudinal as well as lateral mechanical performances are required. By adding the filler to the composite material we can further improve the performance of composites. In this study the filler was Tungsten Carbide (WC), it improves erosion resistance and increase the strength

C. Velmurugan[2] In this study, the properties of Hemp fiber is improved by combining it with glass fiber with the help of epoxy resin and its mechanical properties tensile, compression, impact strength and flexural strength is found out and compared. Due to their eco-friendly nature and sustainability, natural fiber reinforced composite are more popular nowadays. Artificial fiber reinforced composite are becoming more valuable due to their better properties. In order to improve the properties of natural fiber, it can be combined with artificial fiber to form hybrid composite.

M. Muthuvel[3] The aim of the present work was to investigate the hybridization of glass fibers with natural fibers for applications in the aerospace and naval industry. Mechanical properties such as tensile, impact and flexural test of hybrid glass/Hemp fiber reinforced epoxy composites in the forms of lamina and laminates were determined.The lamina prepared with natural fiber mat showed lower mechanical properties compared to laminas with glass mat. For this reason we proposed to use a hybrid design for the various applications which makes use of glass woven fabrics and Hemp fiber mats. The adoption of this design allowed for a cost reduction of 20% and a weight saving of 23% compared to the current commercial solution.

III. MATERIAL AND METHODS

❖ **Materials**

Reinforcing Fibre : Hemp fiber 500gsm, E-glass fibre 200gsm &Carbon fibre200gsm.
Matrix System : Epoxy Resin (lapox L-12 Atul ltd) & Hardener K-6.
Molding Process : Hand lay-up followed by Room temperature moulding.
Reinforcements: matrix ratio: 65:35

❖ **Fabrication of the test laminates**

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

❖ **Preparation of the Resin Hardener System**

The resin and hardener were to be mixed in a ratio of 100:10 by weight, as follows

1. An empty bowl and brush were taken and weighed.
2. Resin was added to the bowl and the brush setup and was placed on the electronic balance, till it registered the constant weight.
3. The hardener was added to the bowl and bowl was removed from the balance.
4. 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".

❖ **Preparation of the reinforcing material**

The fabric used wasHempfibre of 500gsm E-glass fibre of 200 gsm and Carbon fibre in the form of rolls. The fabric roll is spread on the flat surface and required dimension of 300 mm x 300 mm 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 1: Hemp fabric 500gsm

Fig 2: Carbon fabric plain view 200gsm

Fig 3: E-glass fabric 200gsm

❖ **Calculation of number of fiber layers for the laminates**

Table 1: Material Properties:

Sl No.	Material	Density (g/cm^3)	Volume fraction (%)	Ultimate Tensile strength (Mpa)	Modulus (Gpa)
1	HempFiber	1.4	0.325	550	13
2	Glass Fiber	2.5	0.325	2000	80
3	Carbon Fiber	1.76	0.325	4500	250
4	Epoxy	1.18	0.35	60	4.4

❖ **Number of fiber layers for the each laminates:**

1) Hemp/Carbon / Epoxy laminate 3mm thickness = 11 layers
2) Hemp/Carbon / Epoxylaminate3mm thickness = 11 layers

❖ **Layup process for laminate preparation**

1. 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 gelatin.
2. A highly polished flat mould was cleaned and wiped dry with acetone
3. 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.
4. 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.
5. 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.
6. The mylar sheet was sticked on the topmost ply and specimen war rolled using roller. Repeat the same procedure for other two composites.
7. Finally the specimen was allowed to cure for 48hrs.
8. After RT curing, the specimens were hardened. The hardened specimens are ejected from the mould.
9. The laminates were properly labeled and kept aside for further processing

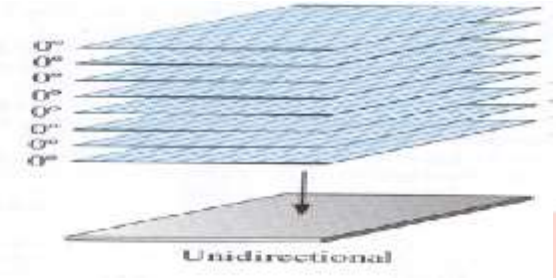


Fig 4: Unidirectional Specimen orientation

Fig. 5 Applying resin over Hemp and carbon fiber

❖ **Post curing**

Post curing is a technique used to take to completion in the process of curing as well as to ensure the enhancement of the service temperature limits. The post curing, in essence, increases the glass transition temperature (Tg) of the cured composite laminate.

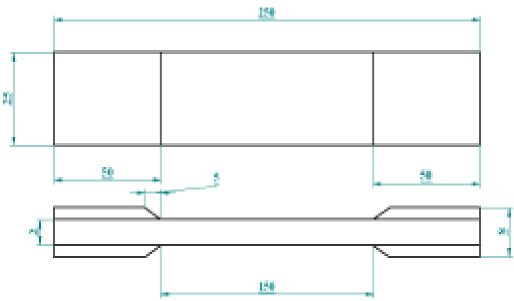
A step post curing cycle has been followed as outlined below

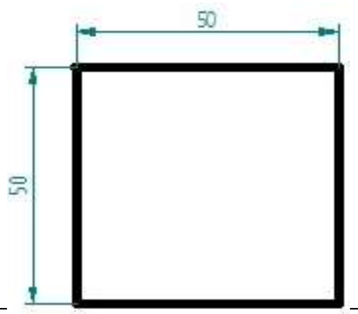
- The RT-cured specimens were placed in a hot air circulated oven.
- First specimens were heated to 50ºC and maintained at this temperaturefor 15 minutes
- Then the ILSS specimens were heated to 70ºC for 30min.
- Finally the ILSS specimens were further heated to 85ºC for 1 hours and then allowed to cool down to room temperature on its own.

Fig 6: High temperature Oven and preparation of specimen as per ASTM standard using water jet cutting machine

❖ **Preparation of specimens as per ASTM standards**

Preparation of tensile specimens as per ASTM-D3039, Compression specimens as per ASTM-D1621, Flexural specimens as per ASTM-D790 standards for unidirectional laminates.





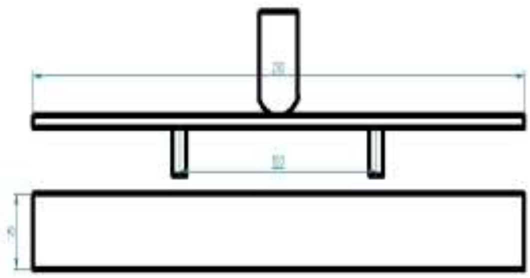


Fig 7: Geometry and dimensions of composite specimens for tensile test, compression test, Flexural test

IV. Results and discussion

Table 2: Tabulation of tensile test results:

Material	Peak load(KN)	Maximum displacement(mm)	Tensile Strength(MPA)
Hemp/Glass/Epoxywith 3mm thick laminate	15.87	11.87	145.86
Hemp/Carbon/Epoxywith 3mm thick laminate	18.39	15.50	202.38

- From the above table it is clear that Hemp/Carbon/Epoxy laminate having 3mm thickness shows more tensile strength than the Hemp/Glass/Epoxy with 3mm thick laminate.

Table 3: Tabulation of Compression test results:

Material	Peak load(KN)	Maximum displacement(mm)	Compression Strength(MPA)
Hemp/Glass/Epoxywith 3mm thick laminate	12.04	5.93	79.72
Hemp/Carbon/Epoxywith 3mm thick laminate	17.53	4.57	100.64

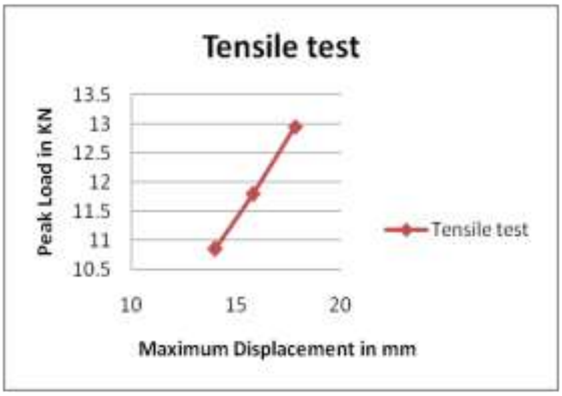
- From the above table it is clear that Hemp/Carbon/Epoxy laminate having 3mm thickness shows more Compressionstrength and load than the Hemp/Glass/Epoxy with 3mm thick laminate.

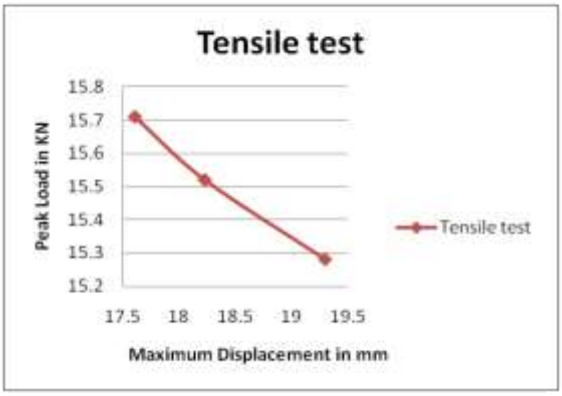
Table 4: Tabulation of Flexural test results:

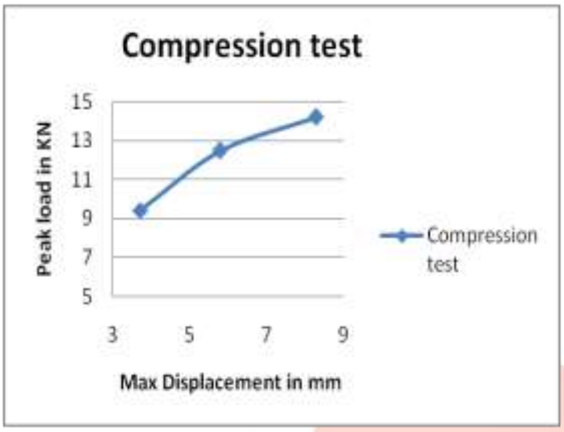
Material	Peak load(KN)	Maximum displacement(mm)	FlexuralStrength(MPA)
Hemp/Glass/Epoxywith 3mm thick laminate	0.759	8.623	8.46
Hemp/Carbon/Epoxywith 3mm thick laminate	0.869	5.84	9.975

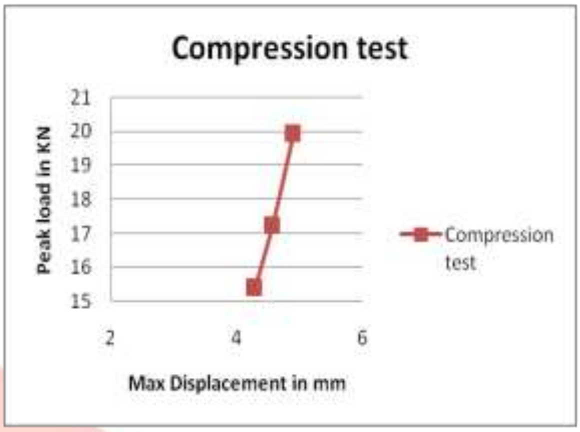
- From the above table it is clear that Hemp/Carbon/Epoxy laminate having 3mm thickness shows more flexural strength than the Hemp/Glass/Epoxy with 3mm thick laminate.

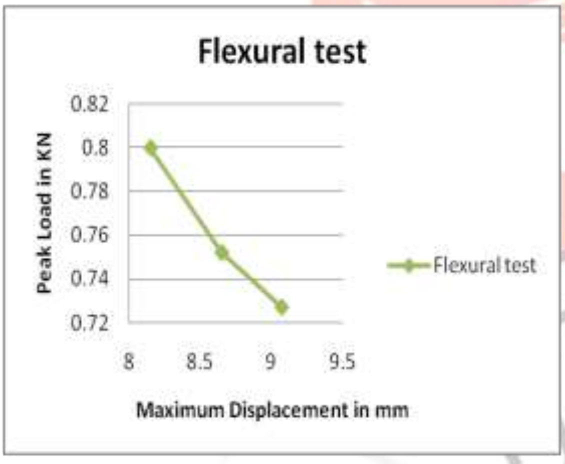
5.4 Comparison of tensile test, compression test, flexural test for Hemp/Glass/Epoxy and Hemp/Carbon /Epoxy laminates (Peak load vs Max Displacement graph)

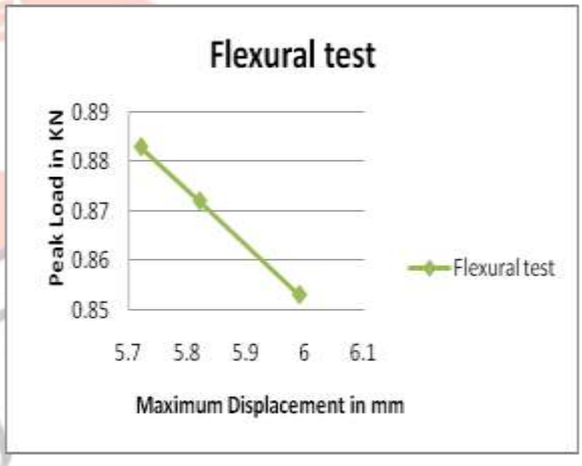




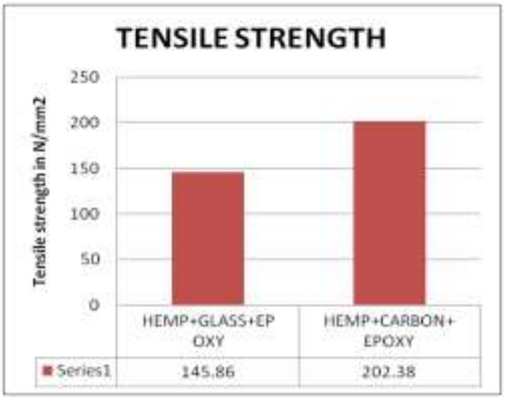


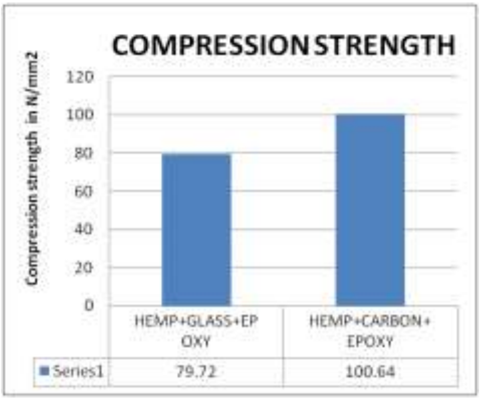


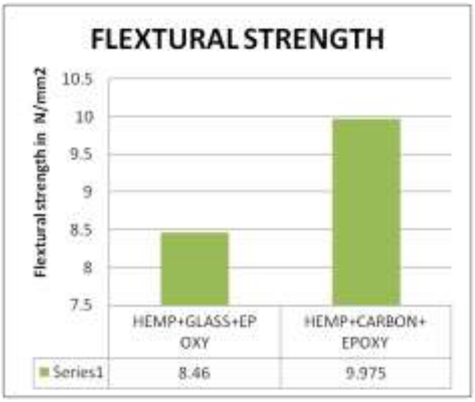




Comparison of tensile strength, compression strength, flexural strength for Hemp/Glass/Epoxy and Hemp/Carbon /Epoxy laminates







V.CONCLUSIONS

- Specimens with varying thickness of laminates are fabricated by simle hand layup techniqe and they are:
  - Hemp/Glass/Epoxy laminate composite (3mm thickness)
  - Hemp/Carbon/Epoxy laminate composite (3mm thickness)
- From the composite s the test specimens have been prepared in accordance with the ASTM standards for tensile,compression and flextural strength determination.
- In the overall study, the strength of Hemp/Carbon/Epoxy laminates has higher value than that of Hemp/Glass/Epoxy laminates.

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