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Research Paper

Experimental Investigation on Mechanical Properties of Hemp/E-Glass Fabric Reinforced Polyester Hybrid Composites

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ABSTRACT

This research work has been focusing on Hemp fibers has an alternative reinforcement for fiber reinforced polymer composites due to its eco-friendly and biodegradable characteristics. This work has been carried out to evaluate the mechanical properties of hemp/E-glass fabrics reinforced polyester hybrid composites. Vacuum bagging method was used for the preparation of six different kinds of hemp/glass fabrics reinforced polyester composite laminates as per layering sequences. The tensile, flexural, impact and water absorption tests of these hybrid composites were carried out experimentally according to ASTM standards. It reveals that an addition of E-glass fabrics with hemp fabrics can increase the mechanical properties of composites and decrease the water absorption of the hybrid composites.

1 Introduction

Researches on plastics and cements reinforced with natural fibers such as jute, sisal, coir, pineapple leaf, banana, sun hemp, straw, broom and wood fibers are done. Although natural fibers reinforced in polymer matrix are environmental friendly, they suffer from lower modulus, lower strength and relatively low moisture resistance compared to synthetic fiber reinforced composites such as glass fiber reinforced composites. Hybridization of natural fiber with stronger and more corrosion resistant synthetic fibers such as glass fibers and carbon fibers improves stiffness, strength as well as moisture resistant behaviour of the composite [1].

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The use of natural fiber reinforced plastics represents an attractive and suitable method for replacing GFRPs Natural fibers are light and renewable; they are low-cost and high-specific-strength resource. Synthetic resins, such as polypropylene and polyethylene, are commonly used as a matrix for natural fiber composites. However, those composites often display problems of fiber–matrix compatibility which results in decrease of mechanical properties [2]. These natural fiber reinforced composites are reasonably strong, lightweight, and free from health hazards, biodegradable and hence they have the potential to be used as building materials. The properties of the natural fiber reinforced composites can be improved by hybridizing with high strength synthetic fibers. Interspersing the two or more kinds of fiber in a common matrix forms the hybrid composites [3] Natural fibers can be used as reinforcements to thermoset and thermoplastic matrices [4]. Natural fibers have already been recognized for their role in composites and can be advantageously utilized for the development of environment friendly composite materials with good physical properties. It has been reported that in recent years, there has been an increasing interest in finding new cost effective applications for natural fiber-reinforced composites, especially sisal fiber—that are traditionally used for making ropes, mats, carpets, fancy articles etc. [5]. Natural fiber composites (bio-based composite materials) are mainly price-driven commodity composites that have useable structural properties at relatively low cost [6]. It has been found that these natural fiber composites possess better electrical resistance, good thermal and acoustic insulating properties and higher resistance to fracture [7]. Natural fibers include flax, hemp, jute, sisal, kenaf, coir, kapok, banana and many others. Natural fibers exhibit superior mechanical properties such as flexibility, stiffness and modulus compared to glass fibers [8].

Curaua is a natural fiber still poorly explored in relation to sisal or jute, even though it shows excellent properties (in relation to other natural fibers) such as elongation at break, tensile strength and low density, providing good specific properties. The cost of curaua fiber is similar to other vegetable fibers but curaua is considered odorless as opposed to some other fibers [9]. The reinforcing phase can either be fibrous or non-fibrous (particulates) in nature and if the fibers are derived from plants or some other living species, they are called natural-fibers. Hybrid of short fibers having same length and different diameter offer some advantage over the use of one type of fibers alone in a polymer matrix. The natural fibers like jute, sisal, hemp, kenaf, and banana are renewable, non-abrasive and can be incinerated for energy recovery. They possess a good calorific value and cause little concern in terms of health and safety during handling. In addition, they exhibit excellent mechanical properties, have low density and are inexpensive [10]. Hybridization with glass fiber provides a method to improve the mechanical properties of natural fiber composites. In this research, a hybrid of kenaf and glass as the reinforcement, epoxy as the matrix along with modified SMC as the manufacturing method improved the mechanical properties for the application of natural fibers to automotive structural components [11].

Natural fiber composite offers significant opportunities for renewable, biodegradable and recyclable materials and from sustainable sources at the same time. Natural fiber composites have low costs, tool wearing rates, production energy requirements and health and safety risks, as well as good formability, acoustic properties, and thermal insulation properties; they also exhibit no splintering function, which is ideal in some applications [12].

2 Materials and Methodology

2.1 Raw Materials

Hemp fiber is one of the naturally available fibers. Hemp fiber is one of the strongest and most durable of all natural textile fibers. Products made from hemp will outlast their competition by many years. Not only is hemp strong, but it also holds its shape, stretching less than any other natural fiber. Hemp fiber is woven in multidirectional manner to obtain hemp fabric. The Hemp fabrics of 210 gsm are purchased from Sree Lakhsmi Group, Andhra Pradesh.

Fiberglass is a lightweight, extremely strong, and robust material. Although strength properties are somewhat lower than carbon fiber and it is less stiff, the material is typically less brittle, and the raw materials are much less expensive. Common uses of fiberglass include boats, automobiles, baths, hot tubs, water tanks, roofing, pipes, and external door skins. The glass fiber of 210 GSM and chemicals are purchased from Insulation House, Bangalore.

2.2 Methodology

2.2.1 Preparation of Matrix

Matrix is prepared by mixing resin (Isophthalic Polyester Resin), accelerator (Cobalt Napthanate) and catalyst (Methy Ethyl Ketone Peroxide i.e MEKP) in the ratio 100:10:1. The matrix must be used immediately after its preparation since it gets hardened if it is kept for too long.

2.2.2 Fabrication of Composite Specimen

The composite specimen consists of number of layers in which glass fiber layers and hemp fiber layers are placed alternatively until we obtain required thickness. A mat with large surface area is been placed on a floor, and wax is applied on its surface to avoid the adherence of laminate to the mat. Then a layer of matrix is applied over the wax in a particular direction. Later alternative layers of hemp and glass fabrics are placed with the application of matrix in between. This is called 'Hand Lay-Up Method' (Fig 1). Perforated sheets are placed over laminates and resin absorber sheets are placed over perforated sheets and whole laminates, perforated sheets and resin absorber sheets are covered by vacuum bag and sealed. Then vacuum pressure is maintained inside vacuum bag and the laminates are cured at that pressure for four hours. The method followed above is called vacuum bagging method (Fig 2). Later the laminates are cured under normal atmospheric pressure and temperature for 12hours. For the better curing, the laminates are cured in 'Autoclave Machine' at 60 0C for four hours. After the composite material gets hardened and cured completely, the composite material is taken out from the Autoclave Machine (Fig 3). Laminate Designation is shown in Table 1.

Table 1 - Laminate Designation.

Laminates	Designations	Layers		Laminates Weights (g)	
		Hemp	Glass	Before	After
L1	G+G+G+G+G+G+G+G+G	0	9	198	403
L2	H+H+H+H+H+H+H+H+H	9	0	108	313
L3	H+G+H+G+H+G+H+G+H	5	4	148	360
L4	G+H+G+H+G+H+G+H+G	4	5	158	368
L5	H+H+G+H+G+H+G+H+H	6	3	138	346
L6	G+G+H+G+H+G+H+G+G	3	6	168	382

*Glass Fiber (G), *Hemp Fabrics (H)

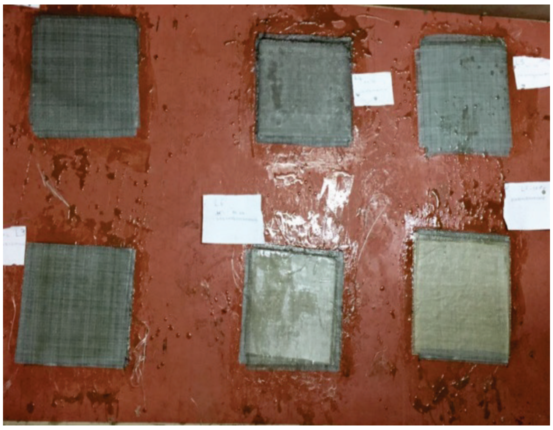

Fig. 1 – Laminates after Hand Lay-Up Method.

Fig. 2 – Vacuum Bagging Method.

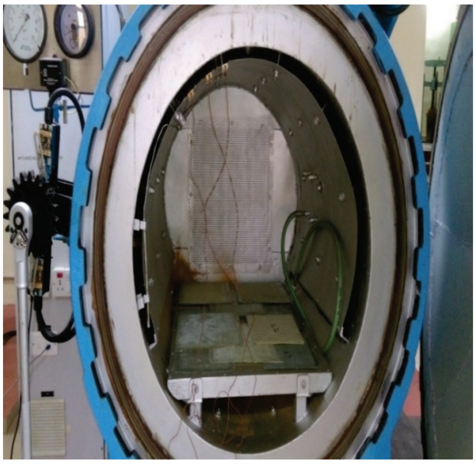

Fig 3. Laminates placed inside Autoclave.

3 Experimentation

3.1 Specimens Dimensions

Specimen prepared by hand lay-up process is cut into required dimensions. And Tensile, Flexural and Impact test specimens are obtained according to ASTM standards. Tensile test Specimen is prepared into Dog Bone shape of dimensions 115x19x3 mm^3 according to ASTM D638 standard. Flexural test Specimen is prepared into Flat shape of dimensions 90x10x3 mm^3 according to ASTM D790 standard. Impact test Specimen is prepared according to ASTM A370 standard of dimensions 63x12.7x3 mm^3.

3.2 Mechanical Testing

3.2.1 Tensile Test

The tensile strength of a material is the maximum amount of longitudinal stress that it can take before failure. The testing process involves placing the test specimen in the testing machine and applying tension to it until it fractures. The tensile force is recorded as a function of the increase in gauge length. During the application of tension, the elongation of the gauge section is recorded against the applied force. The tensile test is performed in BISS UTM of capacity 50KN. The Figure 4 shows tensile test specimen before and after test.

Fig. 4 – Tensile test Specimen before and after test.

3.2.2 Flexural Test

In composite materials specimen deflection is measured by the crosshead position. Test results include flexural strength and displacement. The testing process involves placing the test specimen in the universal testing machine and applying force to it until it fractures and breaks. The specimens used for conducting the flexural test are presented in Figure 5. The flexural test is performed on the Computerized UTM.

Fig. 5 – Flexural Test Specimen before and after Test.

3.2.3 Impact Test

During the Charpy impact testing process, the specimen must be loaded in the testing machine and allows the pendulum until it fractures or breaks. Using the impact test, the energy needed to break the material can be measured easily and can be used to measure the toughness of the material and the yield strength. The Figure 6 shows impact test specimens before and after test.

Fig. 6 – Impact Test Specimen before and after Test.

4 Results and Discussions

The use of composite materials in the different fields is increasing day by day due to their improved properties. Engineers and Scientists are working together for number of years for finding the alternative solution for the high solution materials. In the present study natural fibers are added to the glass fiber reinforced composite materials and their effect on mechanical properties is evaluated and their properties are compared. The test results for the Tensile, Flexural, Impact, Hardness and Water absorption test of the hybrid composite samples are presented.

4.1 Tensile Test Results

The different composite specimen samples are tested in the universal testing machine (UTM) and the samples are left to break till the ultimate tensile strength occurs. Stress–strain curve is plotted for the determination of ultimate tensile strength and elastic modulus as shown in Figures 10 to 15. The load with respect to the displacement for different combination of composite specimen is presented in Figure 16. The tensile results are depicted in Table 3. In this test L1 had the highest tensile strength and Young's modulus and L2 had the lowest tensile strength and Young's modulus. It is found that tensile strength and Young's modulus decreases as the number of glass layer in the laminate decreases.

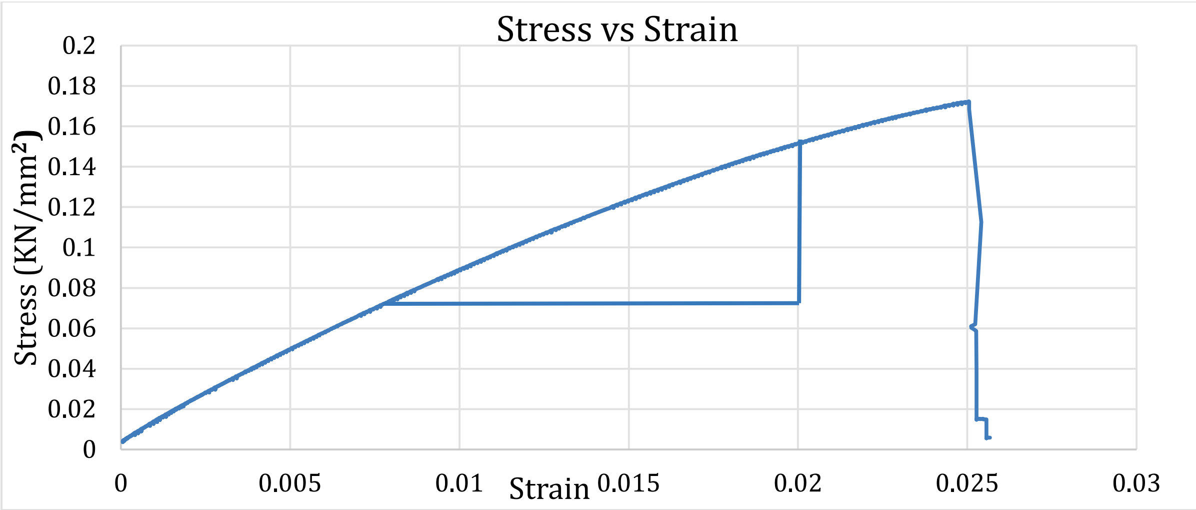

Fig. 10 – Stress vs. Strain for Laminate L1.

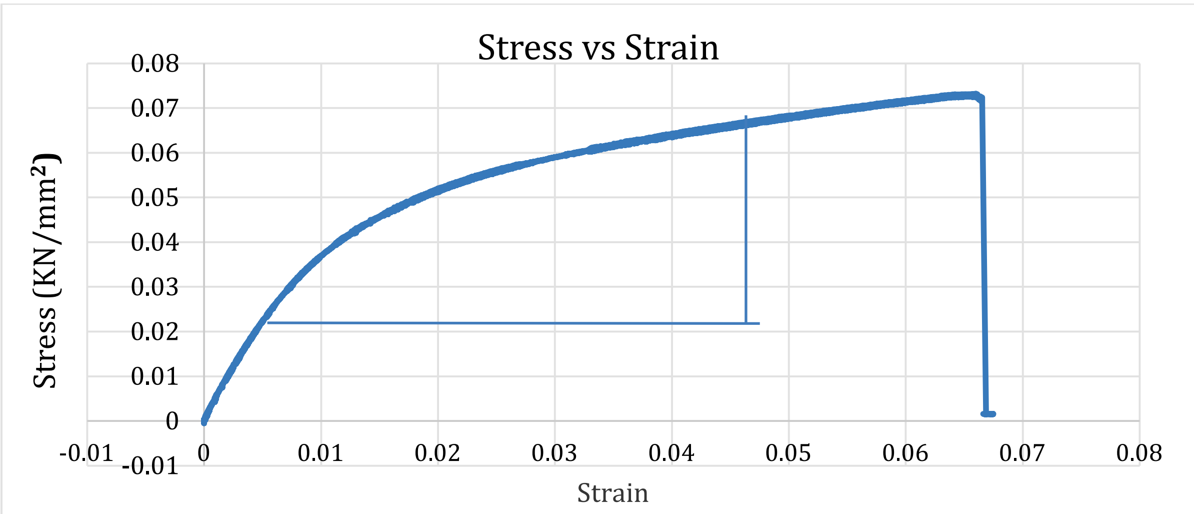

Fig. 11 – Stress vs Strain for Laminate L2.

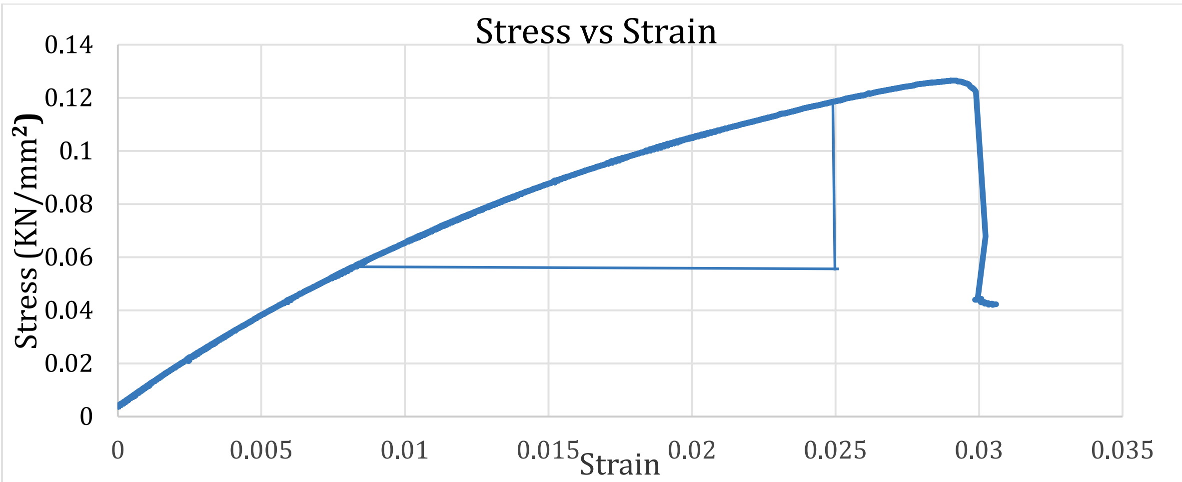

Fig. 12 – Stress vs Strain for Laminate L3.

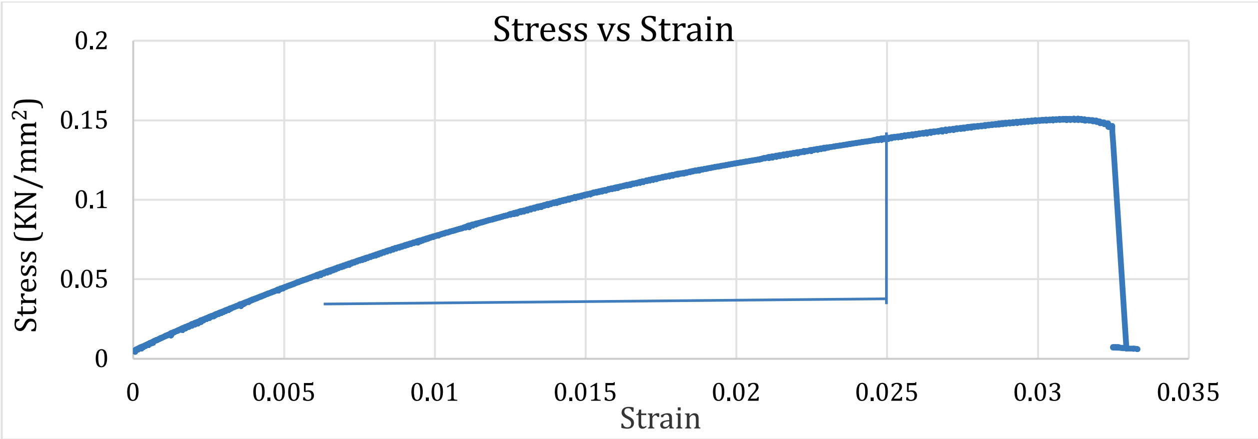

Fig. 13 – Stress vs strain for Laminate L4.

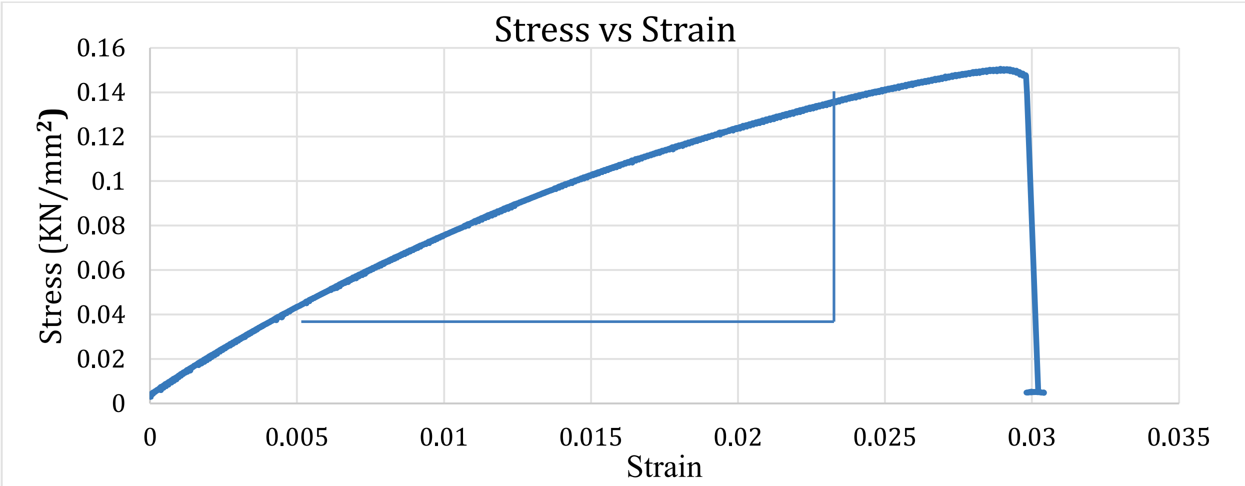

Fig. 14 – Stress vs strain for Laminate L5.

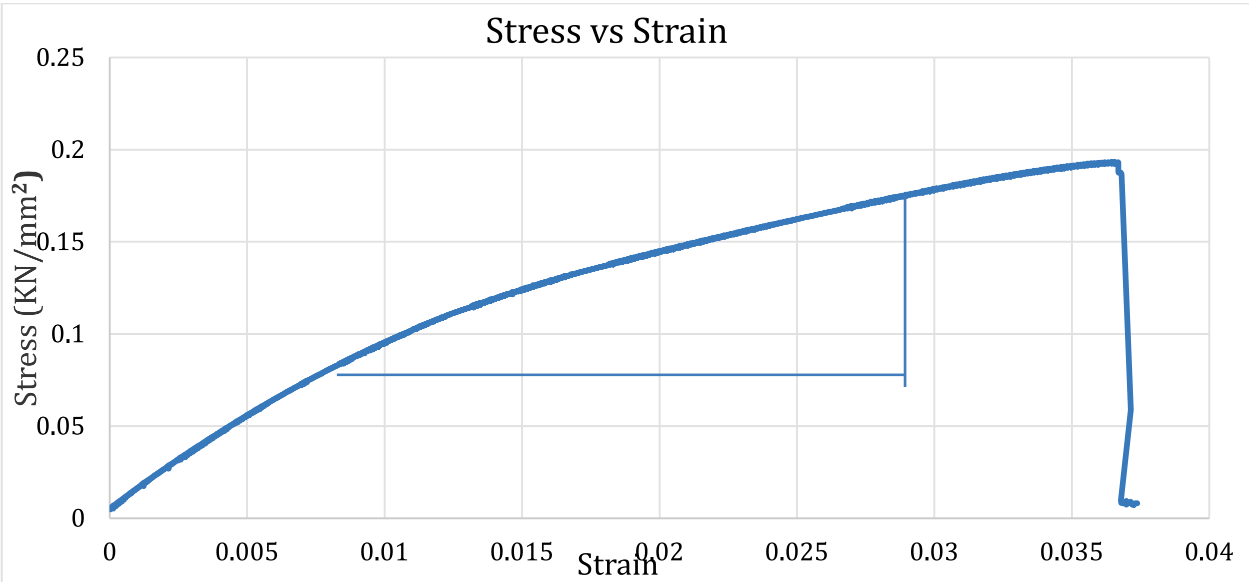

Fig. 15 – Stress vs strain for Laminate L6.

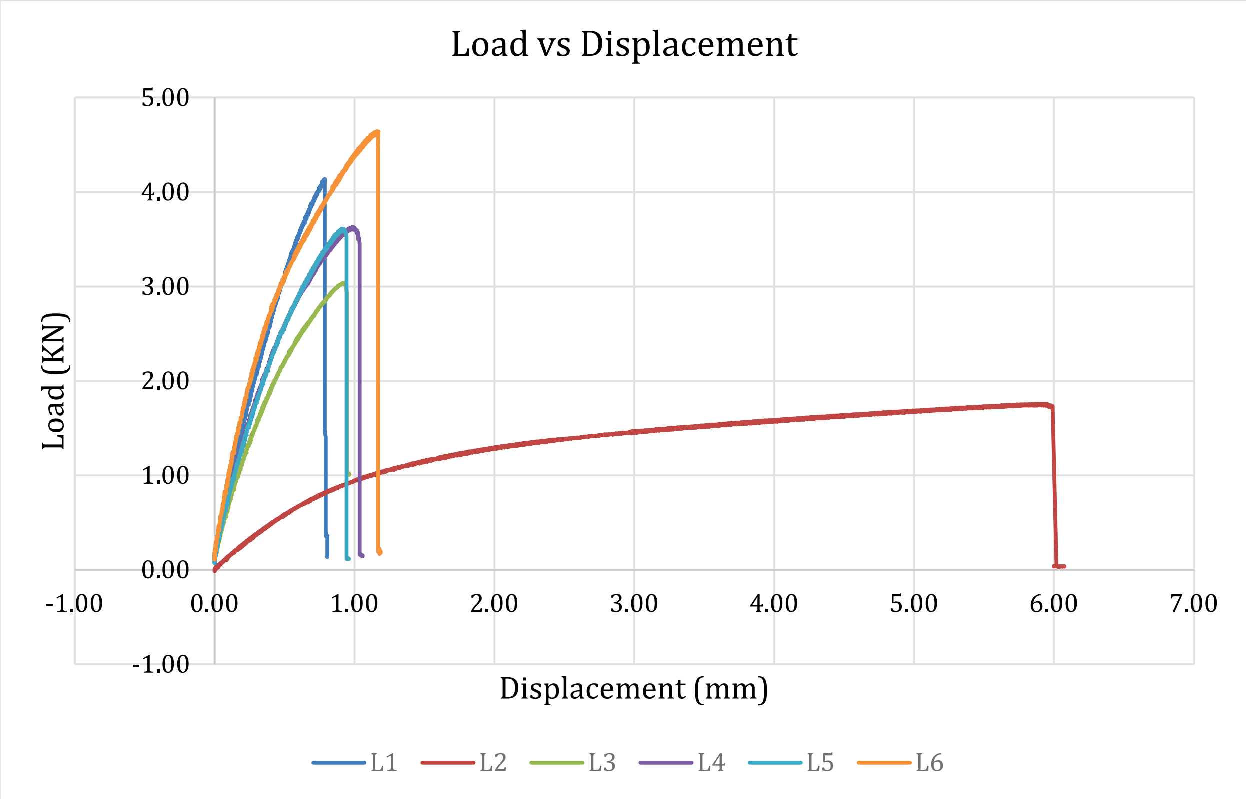

Fig. 16 – Load vs Displacement for all the Laminates.

Table 3 - Tensile Test Results.

Laminate	Young's Modulus (GPa)	Tensile Strength (GPa)
L1	6.33	0.438
L2	0.70	0.050
L3	3.69	0.438
L4	4.27	0.467
L5	4.04	0.508
L6	5.24	0.425

4.2 Flexural Test Results

Three point bend test was carried out in an UTM machine in accordance with ASTM standard to measure the flexural strength of the composites. All the specimens were of rectangular shape having dimension of 90x10x3 mm^3. The span length was 75mm. The load vs displacement figures are plotted from Figures 17 to 22. The flexural test results chart is shown in Figure 23. The experiment was conducted on six specimens of composite laminates. In this test L1 had the highest flexural strength and L2 had the lowest Flexural strength. It is found that Flexural strength decreases as the number of glass layer in the laminate decreases.

Formula to calculate flexural strength,

$$\text{Flexural Strength} = (3PL) / (2wt^2) \quad (1)$$

Where, P = Peak Load in KN, L = Gauge Length in mm, w = Width of the Specimen in mm and t = Thickness of the Specimen in mm

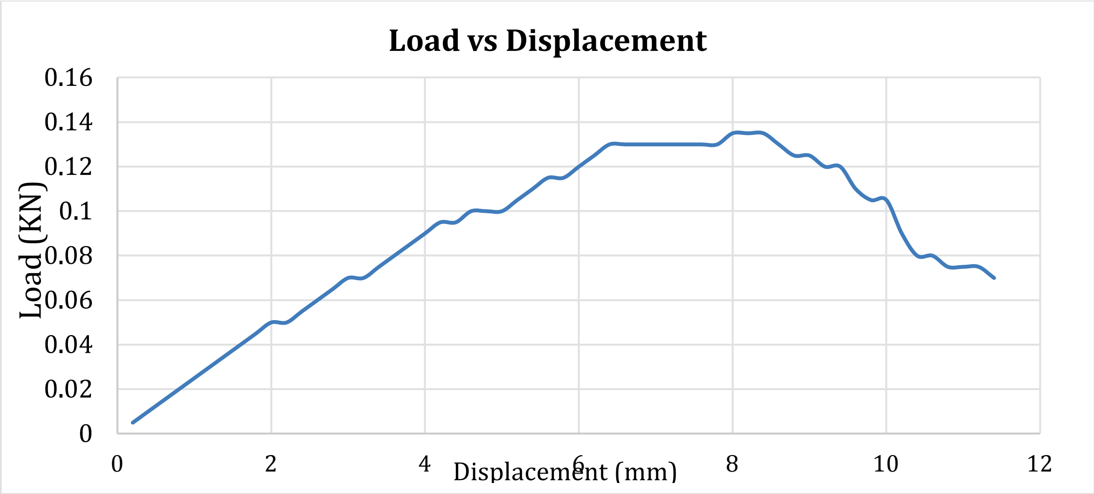

Fig. 17 – Load vs Displacement for Laminate L1

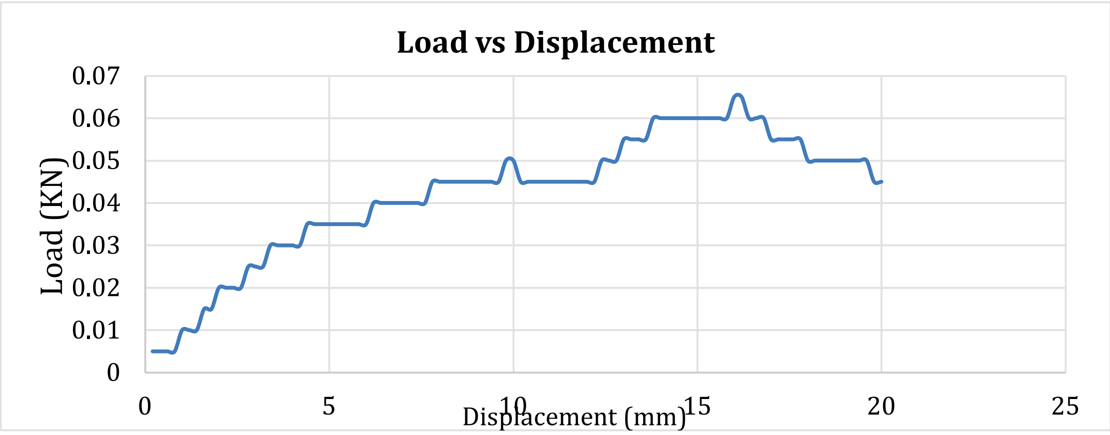

Fig. 18 – Load vs Displacement for Laminate L2

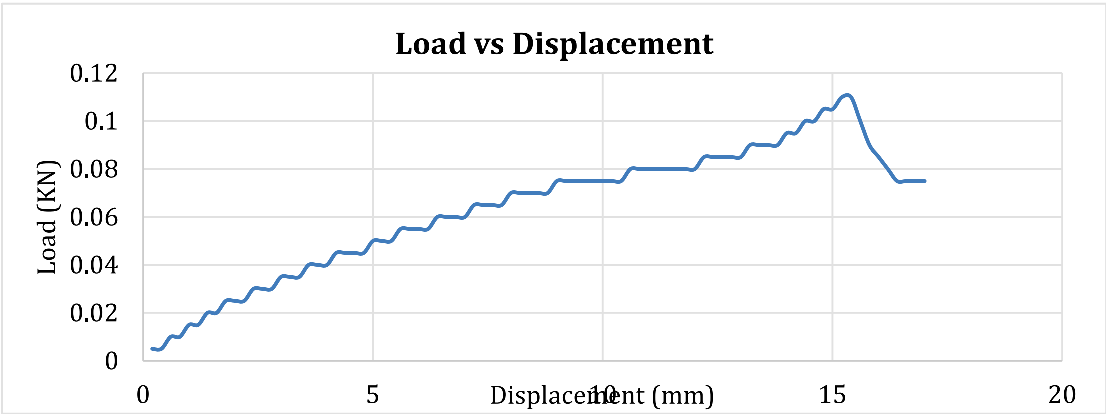

Fig. 19 – Load vs Displacement for Laminate L3

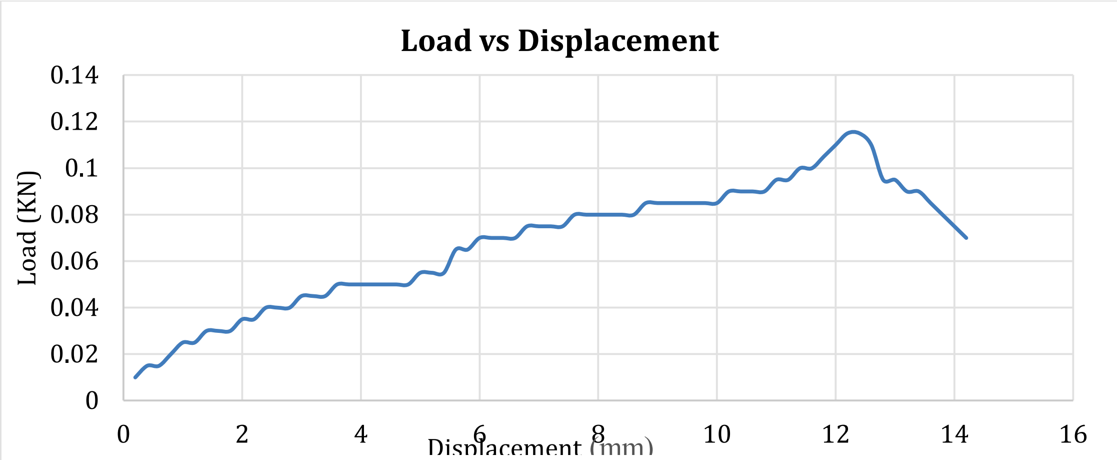

Fig. 20 – Load vs Displacement for Laminate L4.

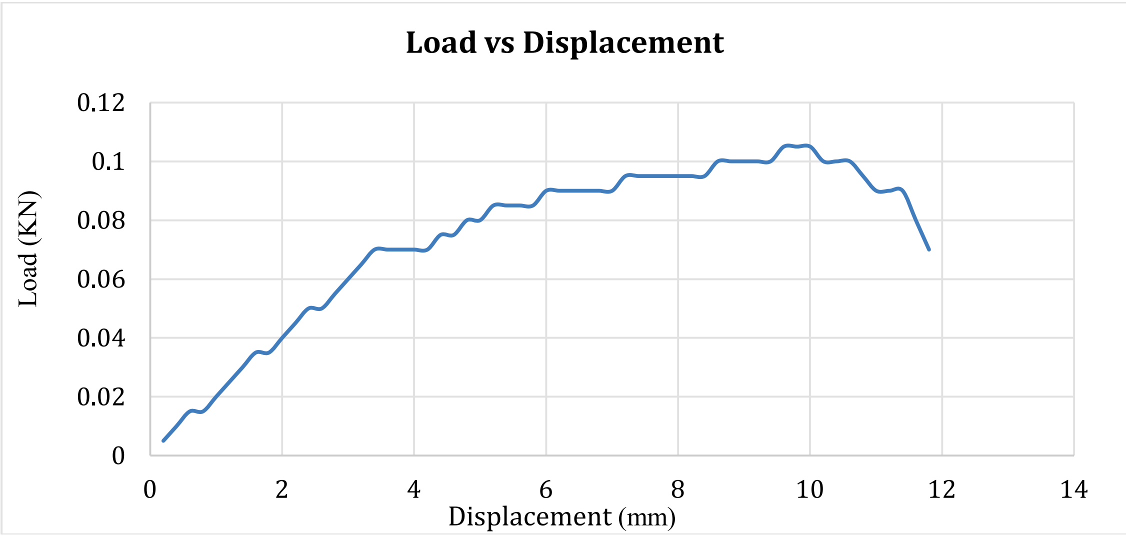

Fig. 21 – Load vs Displacement for Laminate L5.

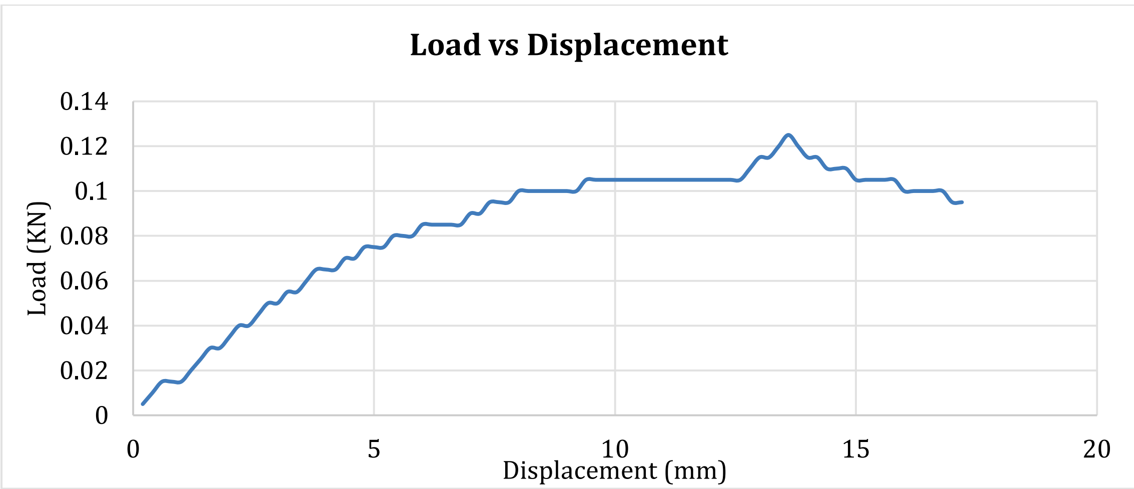

Fig. 22 – Load vs Displacement for Laminate L6.

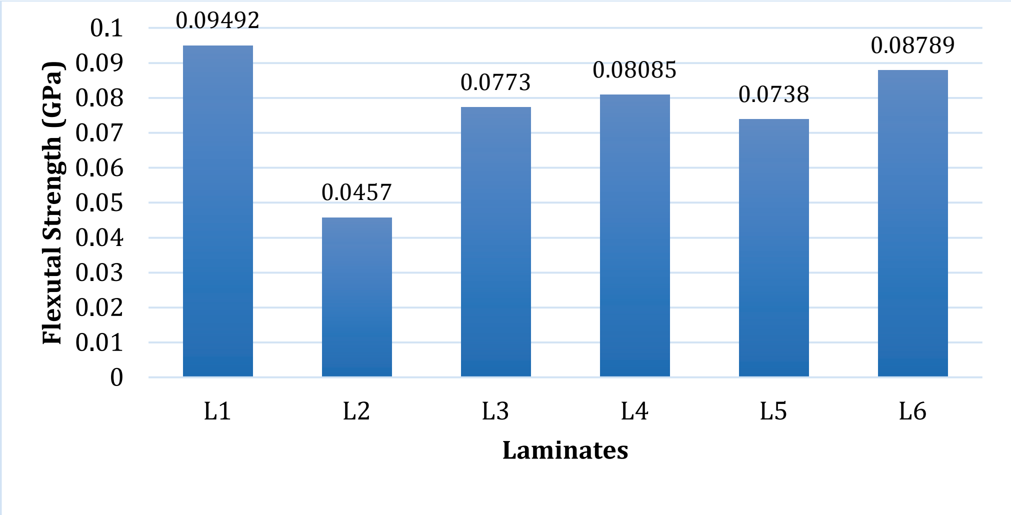

Fig. 23 – Bar chart showing flexural strength of different laminates.

4.3 Impact Test Results

Charpy Impact Test was carried out to determine the impact properties of the material. The Charpy impact test, also known as the Charpy V-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. In this test L1 had the highest Impact energy and L2 had the lowest Impact energy. It is found that Impact energy decreases as the number of E-glass layer in the laminate decreases shown in Figure 24.

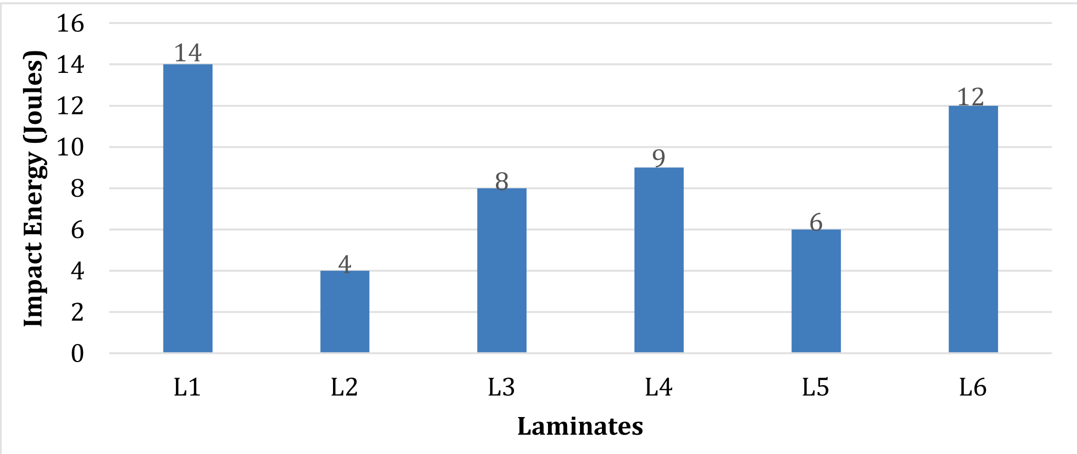

Fig. 24 – Impact test results of various laminates.

5 Conclusion

This experimental study on mechanical behavior of Hemp - Glass Fiber Reinforced Polyester composites leads to the following conclusions:

- It has been noticed that the mechanical properties of the composites such as tensile strength, flexural strength, impact strength of the composites are also greatly influenced by the layer sequence.
- From the tensile test it is found that , the maximum tensile strength was for laminate L1 (0.438 GPa) and minimum was for laminate L2 (0.0508 GPa)
- Flexural test result shows that, laminate L1 has the highest flexural strength (0.09492 GPa) and laminate L2 has the lowest flexural strength (0.0457 GPa)

- It is found from the impact test that, impact strength of laminate L1 is the highest (14 J) and impact strength of laminate L2 is the lowest (4 J)

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