Mechanical Characterization of Cotton Fiber/Polyester Composite Material

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ABSTRACT

Development of composite from natural fiber for lower structural application is growing for long-term sustainable perspective. Cotton fiber composite material has the added advantages of high specific strength, corrosion resistance, low cost and low weight compared to glass fiber on the expense of internal components of IC engines. The primary aim of the research study is to examine the effect of the cotton fiber on mechanical properties of lower structural applications when added with the polyester resin. In this paper composite material sample has been prepared by hand Lay-Up process. A mould is locally developed in the laboratory for test sample preparation. Initially samples of polyester resin with appropriate ratio of the hardener were developed and tested. At the second stage yarns of cotton fiber were mixed with the polyester resin and sample specimens were developed and tested. Relative effect of the cotton as reinforcing agent was examined and observed that developed composite specimen possess significant improvement in mechanical properties such as tensile strength was improved as 19.78 % and modulus of elasticity was increased up to 24.81%. Through this research it was also observed that developed composite material was of ductile nature and its density decreases up to 2.6%. Results from this study were compared with relevant available advanced composite materials and found improved mechanical properties of developed composite material.

Key Words: Polyester Resin, Cotton Fiber, Hand Lay-Up Process,Thermosetting

1. INTRODUCTION

In 1960s composite materials got attention of industries with the invention of plastic composites made from natural fiber. A prime reason for selecting plastic composite was of its added advantages of improved mechanical properties, low weight and resistance to corrosion. Those polymer composite materials have become common engineering materials and were developed and manufactured for various applications such as automotive components, sporting goods, aerospace parts, consumer goods, and in the marine and oil industries.

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Due to high demand of composite materials and wide variety of industrial applications development of FRP (Fiber Reinforced Polymers) composite requires broad knowledge of the current needs of various industries. Competitive advantages such as low weight, resistance to corrosion and low maintenance cost made this type of material an attractive substitute to traditional materials such as wood, steel and concrete. The advanced FRP due to its low weight is suitable for construction of structural members in parking areas, covering sheets for vehicles and covering the construction areas in huge populated cities. Their extensive reaction to harsh environmental conditions reduces the cost associated with expensive maintenance as compared to wooden and steel members [1]. The development of polymer-based TPS (Thermoplastics Starch) materials gained much interest in recent years due to their biodegradability, low cost and wide availability. Starch can be transformed in to TPS through mixing their granular structure and plasticization in the presence of plasticizer under the action of high temperature and shear. TPS has two main limitations; (1) Poor mechanical properties; low strength, low flexure strength and low stiffness as compared to advanced fiber reinforced plastics composites. (2) High water absorption rate [2-4].

Polymer composite with fiber-reinforced materials is of two main categories normally referred to as particle reinforced materials and continuous fiber reinforced materials. Fiber used for advanced composite materials were glass fiber, cotton fiber with high strength in humid environment but degrade under elevated temperature [5-7]. In compression and sheet molding process short as well as long fiber in the form of flakes, chips, and random cuboids are employed. Composite with continuous glass fibers are made by pulling molten glass (at a temperature about 1300°C) through 0.8-3.0mm diameter dies and further high-speed stretching to a diameter of 3-19mm [8]. Hybrid composite made from rubber wood coconut shell and textile fabric enhances mechanical properties such as strength, modulus, impact strength and flexural strength [9-10]. Natural fiber such as cotton fiber in advanced composite materials with polyester resin offer an interesting alternative to petrochemical products, cotton is mainly used as low cost fiber to fill composites for interior parts in automotive industries and low load bearing structures [11-14].

This paper explores the potential use of cotton fiber with bio based polyester resins. In this research samples were developed by mixing resins with hardener. The composite material was also developed by adding the cotton as a fiber and resin as a matrix. The addition of the cotton fiber shows significant increase in tensile strength, Young's modulus, breaking energy and percentage elongation.

2. MOULD DEVELOPMENT

Mould is a specialized tool used in manufacturing industries to shape material for end-user product. Products made with mould ranges from simple paper clips to complex pieces used in advanced automotive industries. In present study for mould fabrication the wood of "Acacia" was used, which is hard and strong. Wooden pieces were taken and made the four sides of mould with the help of wood planning machine. After planning process it was fixed on the shaper machine to develop cavity by using 'u' shape tool as shown in Fig. 1.

Mould was locally developed in the laboratory of 260mm length, 50mm width and 25mm depth. The cavity in the mould has rectangular shape of 260mm length, 25mm wide and 2.5mm deep has been created. A molten form of reference polyester resin was poured in cavity to get the final shape of solid material.

3. EXPERIMENTAL SETUP

3.1 Preparation of Polyester Resin Specimen

Polyester resins specimen was developed using hand lay-up process. Polyester used in development of composite is an artificial polymer made of PTA (Purified Terephthalic Acid) or it is made from dimethylester DMT (Dimethyl Terephthalate) and MEG (Monoethylene Glycol). In this experimental study former composition has been used. A substance added to a polyester resin to promote curing is approximately one ounce (28.13 cm^3) of hardener per gallon of resin. The ratio of hardener to resin can be varied up to 50% to adjust for sample thickness as working preference.

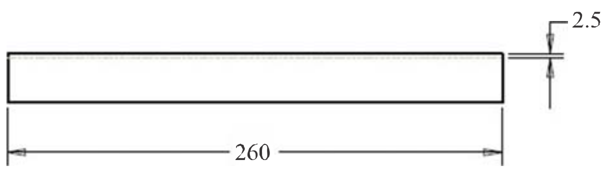

FIG. 1.(a). FRONT VIEW

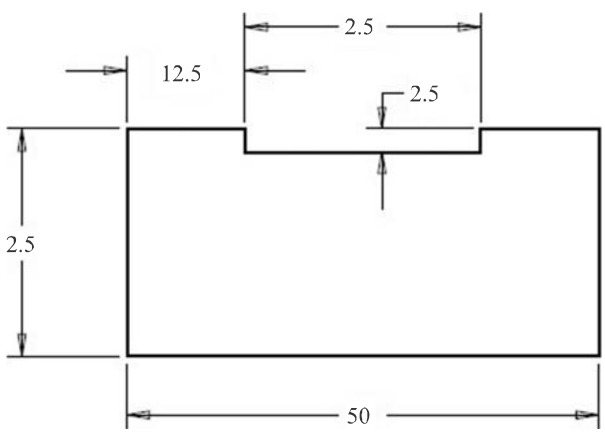

FIG. 1(b). SIDE VIEW

FIG. 1(c). MOULD

FIG. 1. DIFFERENT VIEWS OF DEVELOPMENT MOULD

In this project polyester resin and hardener were used as a filling material. Both materials were available in liquid form. The percentage of polyester was 95% and hardener used was 5%. The purpose of hardener (cobalt) was to accelerate the reaction to solidify it. For the preparation of the specimen of polyester resin, both open end sides of the mould were covered with the help of paper tape to block liquid flowing down from sides. In this experiment mould was placed on the smooth and leveled surface. Polyester resin and hardener were mixed in a beaker and poured in to the mould for sample preparation; extra material from the mould was removed with scraper. The development of reference specimen of polyester resin is shown in Fig. 2.

After 15-20 minutes the specimen was removed from the mould and placed on a flat surface for natural curing at room temperature. The final shape of developed specimen of polyester mixed with hardener is shown in Fig. 3(a-b).

FIG. 2. POLYESTER RESIN SAMPLE DEVELOPMENT

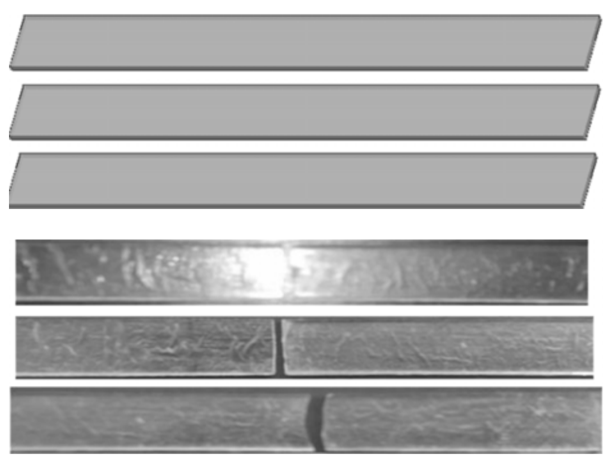

FIG. 3(a-b). POLYSTER RESIN SAMPLES BEFORE TEST

3.2 Development of Composite Specimen

For the development of composite specimen ten small equal spaced cuts were marked using with the help of sharp blade on both sides of the mould and ten straight cotton yarns were rolled and hold them in the cuts on both ends. Ten parallel and equal spaced cotton yarns were placed in the mould as shown in Fig. 4.

The final shapes of cotton fiber reinforced composite specimens are shown in Fig. 5.

SSTM-20KN computerized tensile testing machine was used to test the mechanical behavior of the developed polyester resin samples and composite material samples.

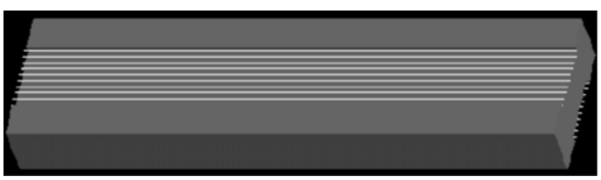

FIG. 4. PLACEMENT OF COTTON YARNS IN A MOULD

4. RESULTS AND DISCUSSION

4.1 Tensile Test

4.1.1 Polyester Resin Sample Test

Polyester resin samples were developed in laboratory and tested on tensile testing machine. Four samples of the material were tested and data were recorded as shown in Fig. 6. It was examined that at tensile load of 1453N strength developed was of 2297.17MPa and modulus of elasticity of 30.247 GPa was achieved.

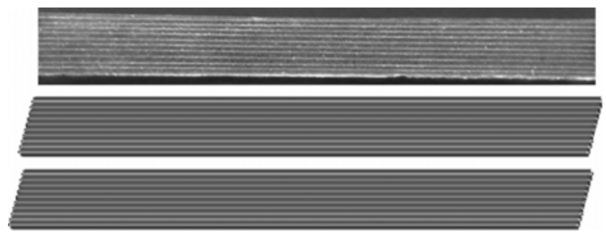

FIG. 5(a). COMPOSITE MATERIAL SAMPLES BEFORE TEST

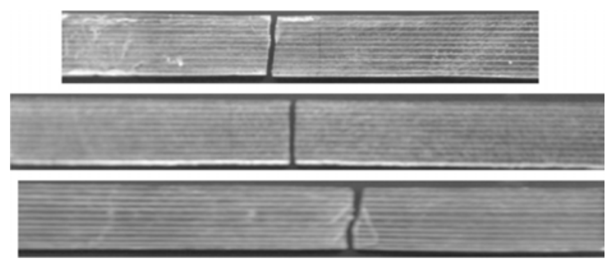

FIG. 5(b). COMPOSITE MATERIAL SAMPLES AFTER TEST

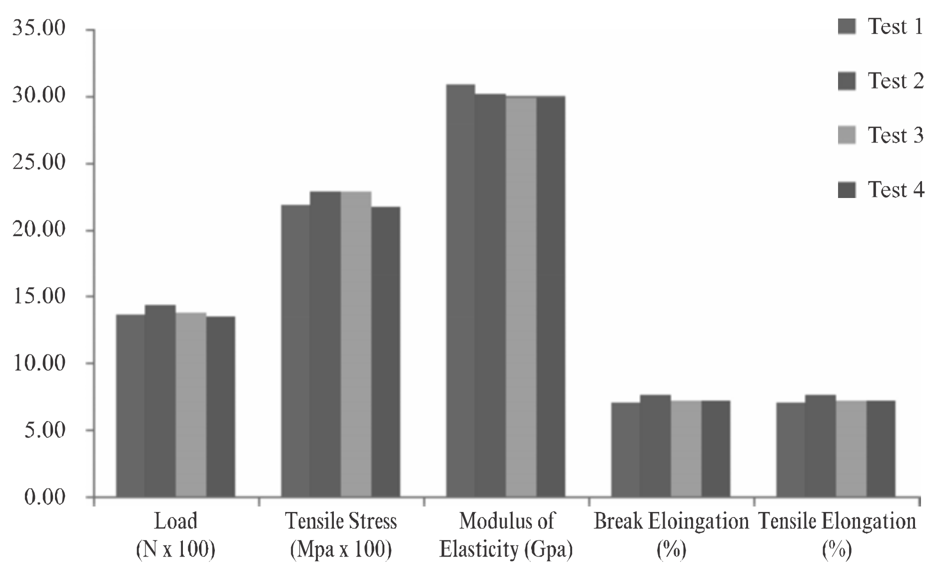

FIG. 6. TENSILE CHARACTERISTICS OF POLYESTER RESIN SAMPLE

4.1.2 Cotton Reinforced Fiber Test

Cotton fiber yarn is smaller in its cross-sectional area and it was difficult to test a single thread therefore a mould has been specially designed for holding yarns of cotton fiber at equal spaced in the mould cavity with the capacity to test ten yarns of cotton fiber at a time. Cotton yarns selected for tensile test were of 200mm actual length and 100mm of gauge length and total cross sectional area of ten combined yarns was 0.49 mm^2.

Four consecutive tests were conducted for the cotton yarns, mechanical characteristics of cotton yarns subjected to tensile load is shown in Fig. 7. It was examined that at a tensile load of 59.53N, the modulus of elasticity was of 14.76GPa, maximum tensile stress developed was of 1212.83MPa and maximum tensile elongation of gauge length was of 1.09%. Experimental data showed significant improvement in tensile characteristics as compared to data cited in Table 1 [15]. These obtained values will be compared with the specimen of composite material.

4.1.3 Composite Material Specimen Test

Basic process parameters in fabrication of composite are pressure, temperature and time, pressure compact the material and create articles of assigned shape. Temperature and time variation in manufacturing of composites are determined by occurance of the physical crystallization and chemical curing process in the material. In addition the duration of the manufacturing process is function of the rate of heating or cooling of the process material, which determines equalization temperature over thickness. In this experimental testing hand lay-up process was used and curing process was naturally carried out at room temperature. Four composite material specimens were tested on tensile machine, all specimens were of 260mm long, 25mm wide and 2.5mm depth.

To examine variation in tensile characteristics of composite material, four similar tests were conducted. Fig. 8 shows the mechanical characteristics of the composite material. When composite material was subjected a tensile load of 1814.23N stresses developed in material was 2902.76MPa and modulus of elasticity attains the value of 41489MPa.

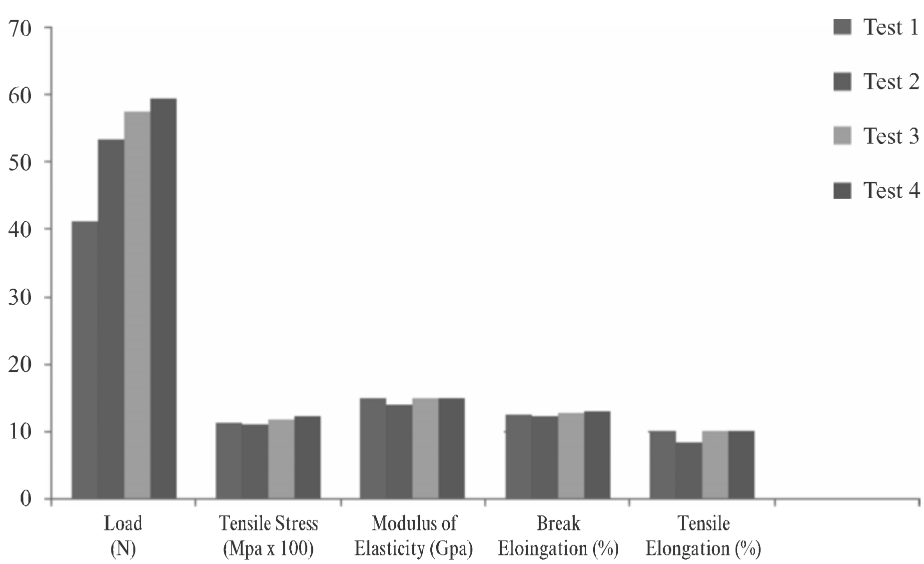

FIG. 7. TENSILE CHARACTERISTICS OF COTTON YARNS

4.2 Hardness Test

Hardness test of polyester resin reference specimens and composite material specimens were conducted by using Portable Hardness Tester machine. The observed data from ten consecutive tests is summarized in tabular form as shown in Table 1.

From the hardness test of composite specimens it was examined that cotton is of ductile nature when it is reinforced with polyester resin as its hardness decrease as compared to polyester specimen.

At the second stage comparative study of the reference samples of polyester resin, cotton yarns and developed samples of composite material has been carried out as shown in Fig. 9. It was observed that load carrying capacity of the composite is of 1814N which is higher as compared to load carrying capacity of reference polyester resin material and cotton fiber reinforced material.

Similarly comparison of tensile strength of various materiels under study has been carried out. It was observed that there is a linear relationship in tensile strength in all developed specimens, the maximium strength value of reference polyester material was 2297.12MPa and composite specimen withstand the value of 2902.49 MPa as shown in Fig . 10.

Modulus of elasticity of the developed specimen of composite material is important property to compare with

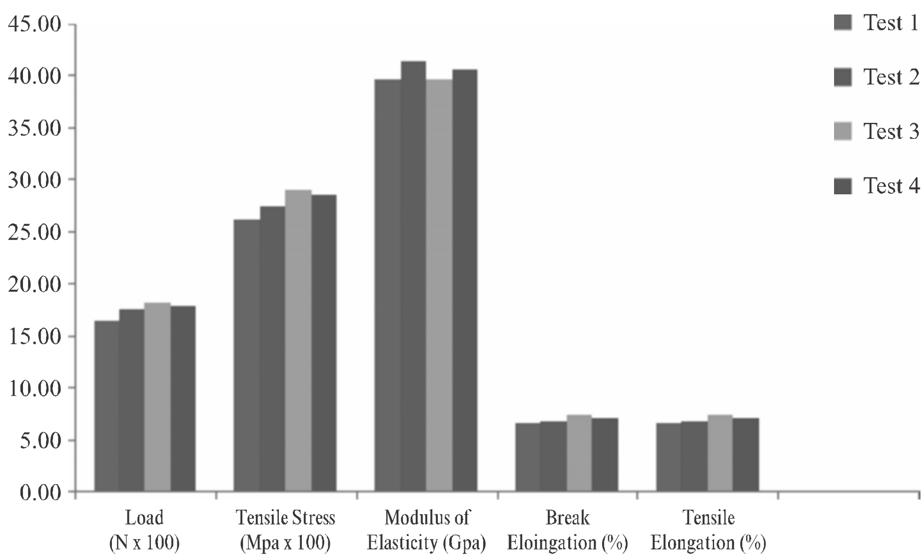

FIG. 8. TENSILE CHARACTERISTICS OF COMPOSITE SPECIMEN

TABLE 1. HARDNESS TEST OF REFERENCE POLYESTER AND COMPOSITE SPECIMENS

Test No.	1	2	3	4	5	6	7	8	9	10	Mean
Reference Specimens (BHN)	508	476	570	522	464	572	529	581	479	491	519.2
Composite Specimens (BHN)	559	503	498	468	479	478	503	490	503	572	505.3

reference polyester resin specimen. It was observed that composite material specimen has attain value of 41.49GPa of modulus of elasticity as compared to modulus of elasticity of reference polyester resin value of 30.92GPa and modulus of elasticity value of cotton yarns was 14.86GPa as shown in Fig. 11.

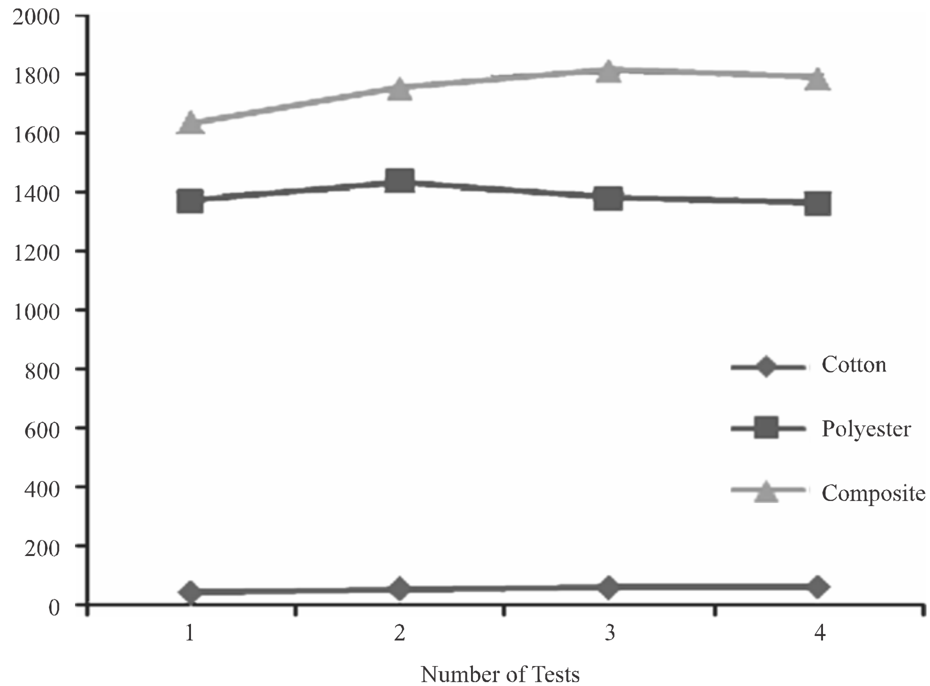

FIG. 9. COMPARISON OF TENSILE LOAD

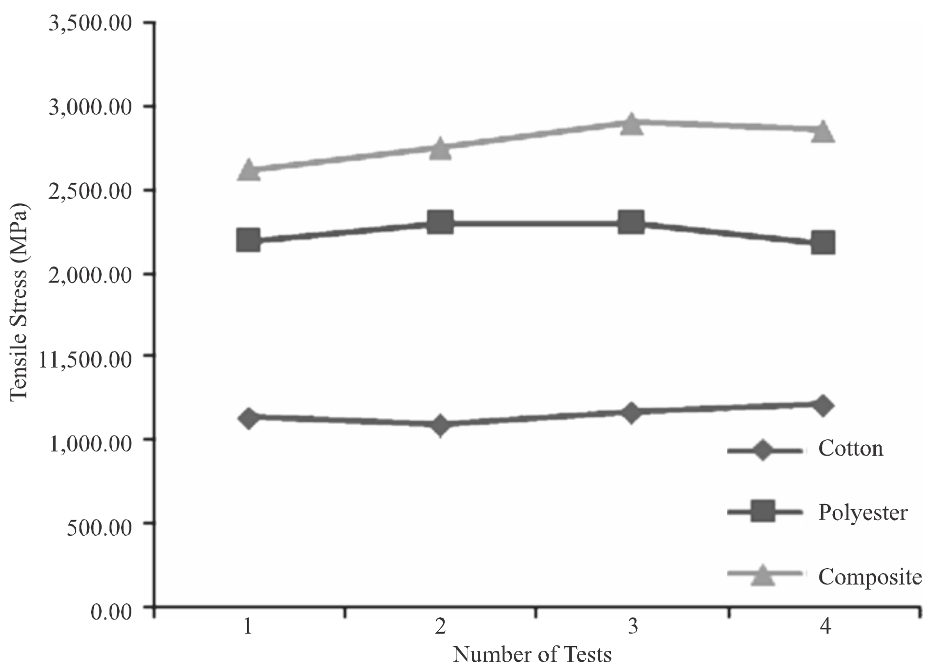

FIG. 10. COMPARISON OF TENSILE STRENGTH

Finally the observed properties of the developed material were compared with closely related developed composite materials. Comparison of various composite material properties are shown in Table 2.

In Table 2 comparative study of the developed composite material with Taj, et. al. [16] has been carried out. Developed composite material shows significant improvement in its mechanical behavior. Improvement in tensile strength of developed martial is very high as shown in 5th column of Table 2. One added advantage of developed composite martial is that its density is very low and will be highly applicable in weight constrained structural applications.

Hand lay-up process was used for the preparation of specimen of composite material and specimen of polyester resin. Curing process of the developed sample specimen was a natural one at room temperature of 28^{o}C for 24 hours.

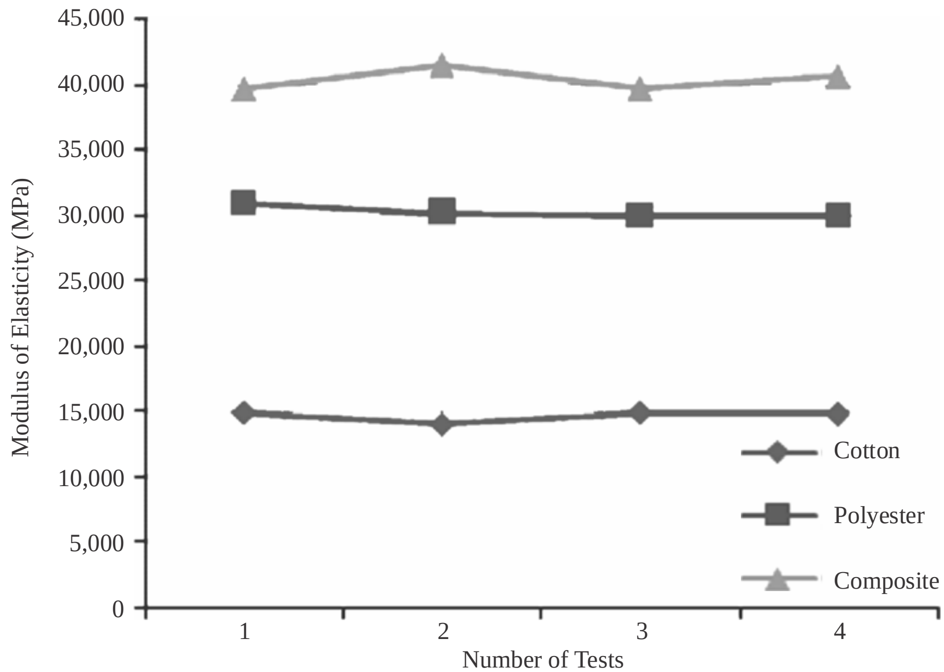

FIG. 11. COMPARISON OF MODULUS OF ELASTICITY

TABLE 2. COMPARISON OF PROPERTIES OF MATERIAL WITH DEVELOPED COMPOSITE MATERIAL

Mechanical Characteristics for Tensile Test	Closely Related Composites			Developed Composite
	E-Glass UD	Kevlar Fabric	E-Glass Fabric	
Tensile Stress (MPa)	1,000	480	440	2902.69
MOE (GPa)	40	30	25	41.49
Tensile Elongation(%)	2.5	1.6	1.7	6.8
Density (g/cm^3)	1.90	1.40	1.90	1.14

5. CONCLUSIONS

Effects of cotton fiber on mechanical properties of developed composite sample were examined. Tensile test for both cotton and polyester resin were conducted separately. There was significant overall improvement in tensile strength and modulus of elasticity of developed composite material It was observed that tensile strength was 19.78% and modulus of elasticity was 24.81% improved. Reduction in tensile elongation of 6.29% was also detected in composite material. During the hardness test it was examined that developed composite material was of a ductile nature as its hardness decreased up to 2.6% as compared with polyester material reference specimen.

Density of the composite at 1.14 g/cm^3 was also compared to same category of the thermoplastic composites. The usage of natural FRP will grow in the future not only in the automotive industry but also in applications in the consumer market. Cotton fiber with its morphological and mechanical properties can play a more vital role to optimize products with improved strength and impact properties.

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