A Study of Mechanical Properties of Natural Fiber Reinforced Composites

[1]Tushar Kumbhar, [2]Dr. S.S.Chavan,[3]Dr.S.M.Shendokar
[1]Research Scholar,[2]Professor,[3]Professor
[1,2] Mechanical Department Bharati Vidyapeeth (Deemed to be University) College of Engineering, Pune- Satara Road, Pune, India.
[3]Mechanical Department Bharati Vidyapeeth College of Engineering, Lavale Pune, India.

Abstract: There is increasing awareness of need of eco-friendly and biodegradable products. This promote to the development of natural fiber reinforced composite for various applications in the field of interior parts of aerospace, marine and automobile industry, in construction industry etc. To check feasibility of natural fiber composite (NFC) we have tested mechanical properties of as per ASTM standards for jute, flax and banana with matrix epoxy. The hand lay-up technique was used to prepare these samples. The mechanical properties such as tensile strength, impact strength and compressive strength were determined and compared.

***Keywords* - Natural fiber reinforced composite (NFRC), Hand lay-up technique, Mechanical properties**

I. INTRODUCTION

In recent years, there is a growing interest of material scientist and engineers in all over the world in the research and development of natural fiber reinforced composites (NFRC). Today natural fiber is an interesting option for the synthetic fibers used in the composite technology. Although many studies have been conducted in which the conventional materials were substituted with natural fiber such as kenaf, bagasse, jute, ramie, hemp and oil palm etc. in engineering applications [1-9]. Due to their attractive benefits such as light weight, moderate strength, low material cost, renewable and environment friendly over synthetic composite material they have variety of applications in automobiles, robots, spacecraft and in marine industries [10-12]. The research in the exploration of natural fiber has been done because of the high cost of synthetic fibers and health hazards of asbestos fiber[13]. Das et al. [14] has tried to improve the mechanical properties of composite with combination of unidirectional oriented jute fiber as reinforcement material and the general purpose polyester resin as the matrix material. Satyanarayana [15] has done research in the inclusion of the natural fibers in polymer matrix composite (PMC) and characterization of their new composites, with and without subject on to environmental conditions.

In early years, natural fibers were used to make rope, twine and course sacking materials. All the studies have assisted engineers and material scientist with the design structure and efficient use of the natural fibres. But still some modifications in the fiber is required and also needed to improve mechanical properties for composites product. The efficiency of the fiber reinforced composites (FRC) also depends on the processes used for manufacturing that the ability to transfer stress from the matrix to fiber [16].A composite may be defined as a physical mixture of two or more different materials. The mixture has properties which are generally better than those of any one of the materials [17]. It is necessary to use combinations of materials to solve problems because any one material alone cannot do so at an acceptable cost or performance. These composites were made in easy design structures and simple shapes by placing the structural elements on top of one other to create the required design. In this study natural fiber reinforced composites were made by hand lay-up method and their mechanical properties were investigated in order to assess its suitability [18].

II. MATERIAL AND METHODS

2.1 Materials and System

While preparing specimens the equipment and materials used are fibers which has selected randomly of jute, flax and banana, resin epolam 5015.

2.2 Hand Lay-Up Technique

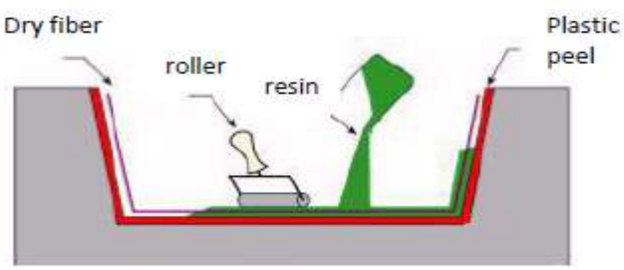

Figure 1: Hand laminating

In composite fabrication process hand lay-up is an open moulding process which is the simplest and oldest of all other processes. It is a low volume and especially suited for simple structure components. The reinforcing roving or woven fabric is placed manually in the open mold, and resin is applied, brushed over and into the glass plies. Entrapped air is removed manually with rolling the rollers over the plies to complete the structure.

Figure 2: Hand molding process (Applying resin)

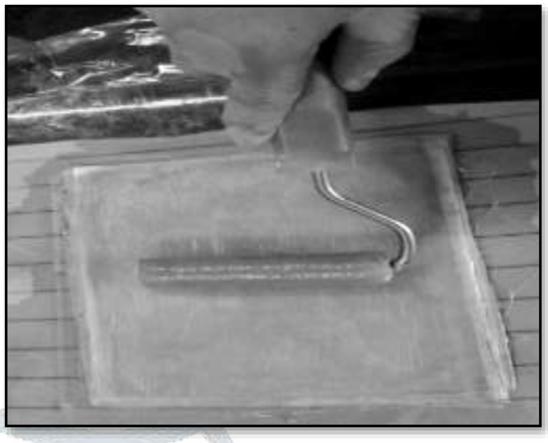

Figure 3: Hand molding Process (Rolling out resin)

Polyesters and epoxies which can cure at room temperature are mixed with the hardner and catalyst, which hardens the fiber reinforced resin composite without external heat. There is no need of investment in equipment as it takes place at room temperature and is used for a wide variety of products. It is an open mould process which is also known as contact moulding. This manufacturing process is suitable for prototypes and low volume production of composite material parts. The cloth or fibers are placed manually layer by layer into the mould. A matrix material in the form of resin is applied on the fibers and rolled onto the fiber using hand roller. Number of layers can be added on one another and after dried completely the composite part can be removed from the mould. While placing the fibers their orientations can be changed layer by layer to get improved result upto certain limit. The hand lay-up process is very flexible as it can produce different kind of geometry from very small to very large size. The cycle time to produce a part is very long and only small series can be produced.

Various steps involved in the hand lay-up process are as discussed below:
Step 1: Cut down the fiber as per the required dimensions.
Step 2: Place the peel ply of polythene sheet.
Step 3: Place nylon cloth which will act as separator
Step 4: Apply the resin over nylon cloth and place fibers uniformly over it.
Step 5: Repeat the step 4 for number of layers.
Step 6: Again place nylon cloth at the top
Step 7: Allow it cure for several hours and then separate the composite from mold.

The resin used for preparation of sample was Epolam 5015 and hardner. The weight percentage of resin to hardner taken as 100:30. After curing the Jute, Flax and Banana samples are as shown in figure 4, 5 and 6 respectively.

Figure 4: Jute sample

Figure 5: Flax sample

Figure 6: Banana sample

After curing composite was separated from the mould and the specimens were cut according to the ASTM standards.

2.3 Material Characterization

Machine Used – Universal Testing Machine:

Universal Testing Machine is shown in figure 7 and the specification of the same are as follows,

Figure 7: Universal Testing Machine at Praj Metallurgical Laboratory Kothrud, Pune.

- Make-Star Testing Systems, India
- Model-STS 248
- Load Cell -100 kg max
- Accuracy = ±1%
- Cross Head -5mm/min
- Least count of reading-0.1N

2.3.1 Tensile Test

The tensile tests were performed using a universal testing machine Model-STS 248.The length, width and the thickness of the specimens were kept according to ASTM D 638 and are 200 mm x 19 mm x 3 mm, see CATIA drawing in figure 8. The tensile tests were carried out according to ASTM D 638. The tensile strengths were calculated from this test.

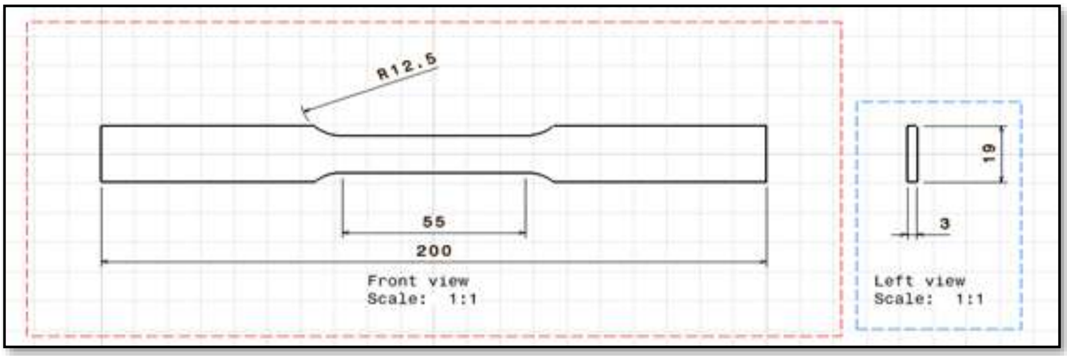

Figure 8: Tensile Test – ASTM D 638

2.3.2 Compression Test

Compression tests were performed using a testing machine in accordance to ASTM D 695 standards. For the compression test, samples with dimensions of 80 mm x 19 mm x 3 mm were used see CATIA drawing in figure 9. The compression strengths were evaluated.

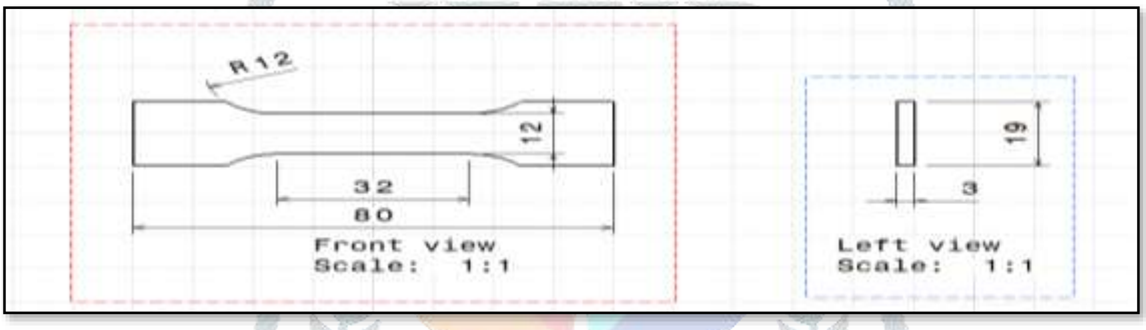

Figure 9: Compression Test – ASTM D 695

2.3.3 Izod Impact Test

The impact strength of notched specimen was determined by using an impact tester according to ASTM D 256 standards. The specimen dimensions are 64mm x 13mm x 3mm see CATIA drawing in figure 10. In each case three specimens were tested to obtain average value.

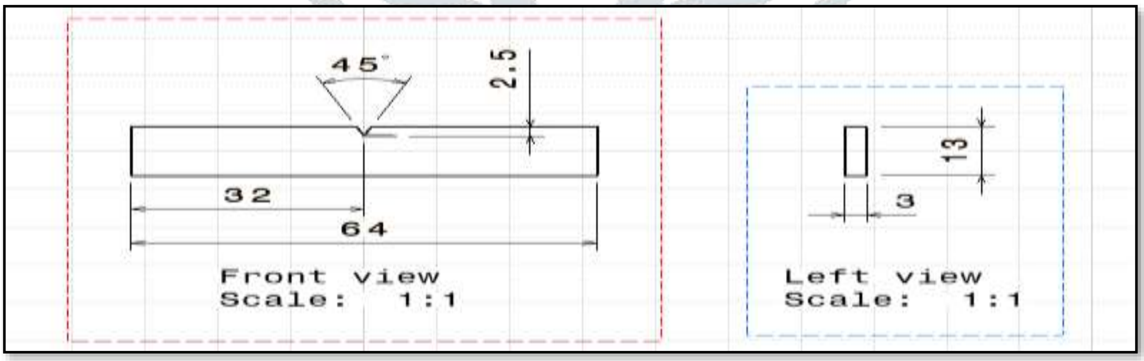

Figure 10: Izod Impact Test – ASTM D 256

2.4 Specimen Testing

A) Tensile Test of Jute

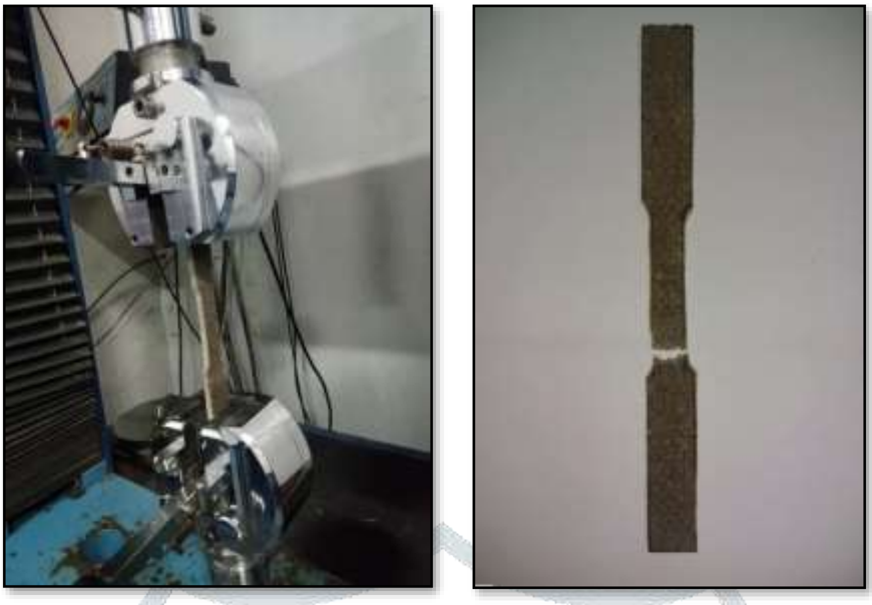

Figure 11: Tensile test of jute specimen

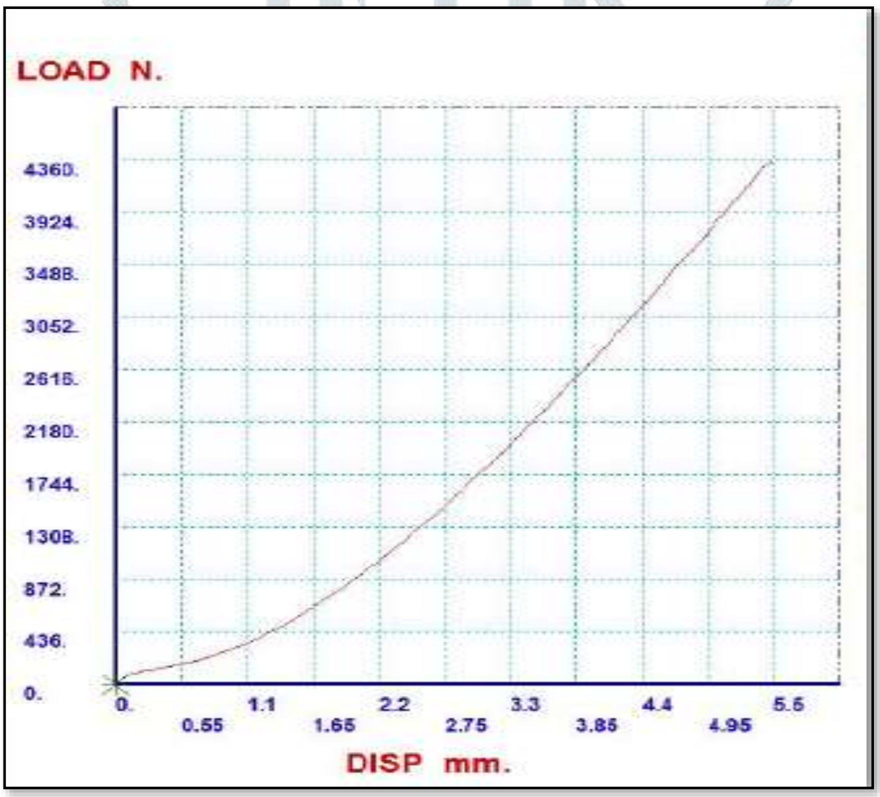

Figure 12: Jute tensile test graph

The test was conducted at 25^0C temperature. Pre tension load was 0 N. As in the Figure 12 the maximum load that has given was 4356.1 N. The displacement speed was at 10 mm/min. Maximum elongation was 4.231% that is 5.5 mm in total. The specimen got failed at maximum**tensile strength53.393 MPa**.

B) Compression Test of Jute

Figure 13: Compression test of jute specimen

Figure 14: Jute compression test graph

Figure 13 shows compression test of jute and the specimen after the test. As per the figure 14, the peak load was 8271.2 N. Peak compression happened was 8.25% that is 6.6mm. Maximum **compression strength** was **111.496 MPa**.

C) Tensile Test of Banana

Figure 15: Tensile test banana specimen

Figure 16: Banana tensile test graph

Figure 15 shows the tensile test of banana specimen and actual specimen after the test. The test was conducted at 25^{0}C surrounding temperature. As we can observe in figure 16 that peak load given to the specimen was 2830.24 N, at which the peak elongation occurred was 3.467% that is 5.2mm. The maximum **tensile strength** the specimen was **48.043 MPa.**

D) Compression Test of Banana

Figure 17: Compression test banana specimen

Figure 18: Banana compression test graph

Compression test of banana specimen as shown in figure 17 with the specimen after test. Maximum load sustained by the specimen was 4174.8 N, as per the figure 18 and peak compression occurred at this load was 11.6% that is 5.8mm. **Compression strength** of this bananan specimen was **95.185 MPa**.

E) Tensile Test of Flax

Figure 19: Tensile test of flax specimen

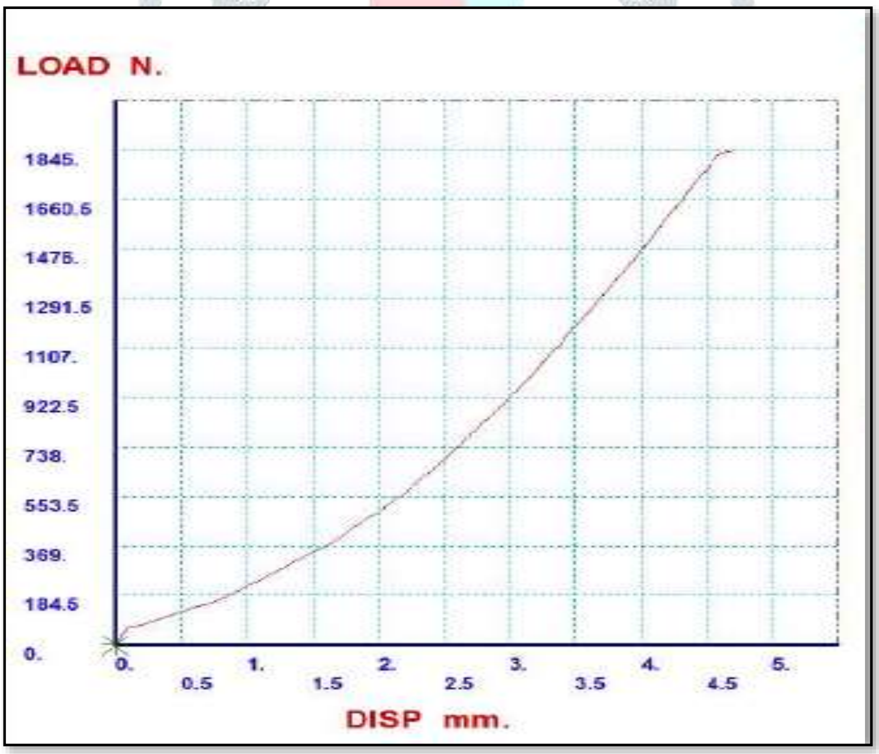

Figure 20: Flax tensile test graph

The tensile test of the flax specimen as shown in figure 19 was conducted at 25^0C. So as per the figure 20 the maximum load given to the specimen at the break point was 1844.36 N and the break elongation was 3.133% that is 4.7mm. **Tensile strength** of flax specimen was **36.924 MPa**.

F) Compression Test of Flax

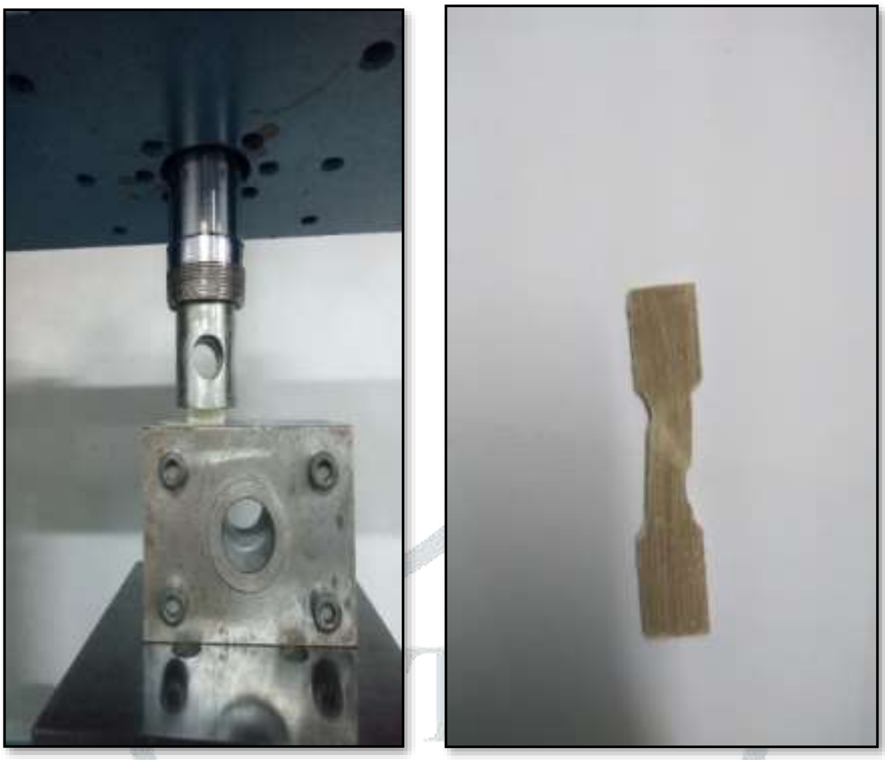

Figure 21: Compression test of flax specimen

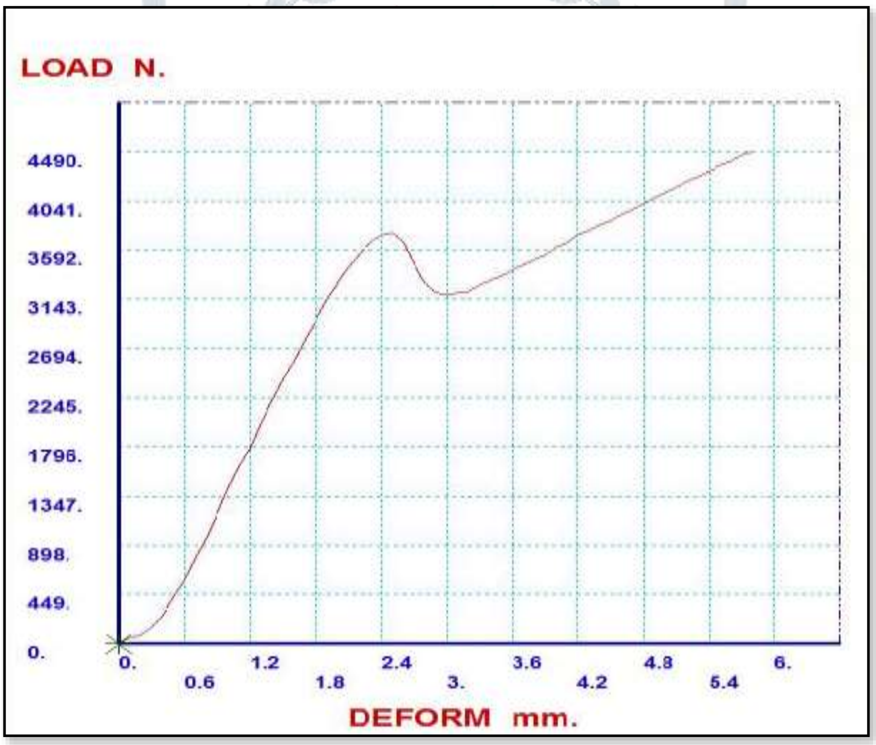

Figure 22: Flax compression test graph

As shown in figure 21 the compression test of flax specimen was carried out. The peak compression observed was 11.6% that is 5.8mm, at peak load of 4488.4 N as we can seen in figure 22. The **compression strength** of flax specimen was **102.335 MPa**.

G) Impact Test of Banana

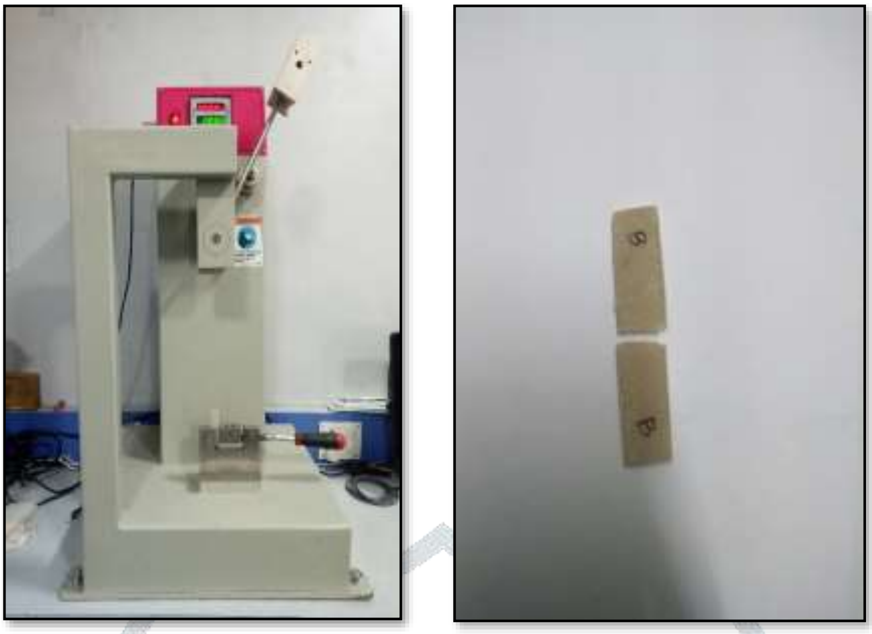

Figure 23: Impact test of banana specimen

Impact testing of jute, banana and flax specimen has done and their results has mentioned in table 1. Figure 23 shows impact testing machine and the banana specimen after test

III. RESULTS AND DISCUSSION

The test results are shown and discussed in this section. Average values of three specimens of the tensile test, the compression test, and the impact test are tabulated in **Table 1**. The results obtained from the various tests are presented and possible reasons for the mechanical behavior of the composite are discussed.

Table 1: Mechanical properties of various composite laminate

Mechanical properties	Jute Laminated	Banana Laminated	Flax Laminated
Tensile strength (MPa)	53.39	48.08	36.92
Compression strength (MPa)	111.49	95.18	102.33
Impact strength (J/m)	37.00	71.40	116.6

3.1. Tensile Strength

Figures 23show the tensile strength of the jute, banana and flax fibres. From the histograms, it is obvious that jute laminate displayed the highest (53.39 MPa) tensile strength, followed by banana laminate while the flax showed the lowest (36.92 MPa) tensile strength.

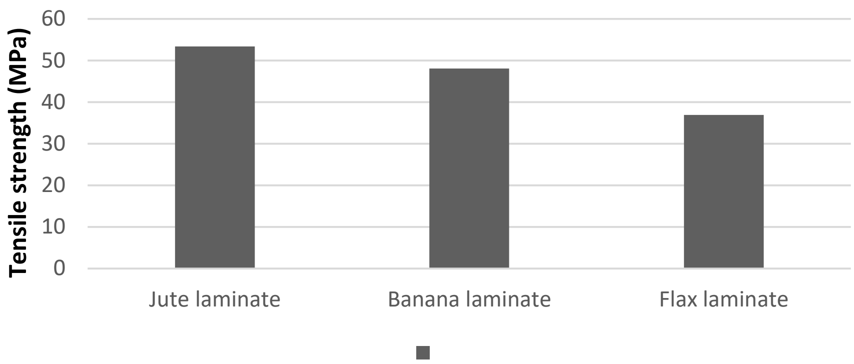

Figure 23: Tensile strength of natural fibre reinforced laminate samples

3.2 Compression Strength

Figure 24shows the measured compression strength of natural fibres. The compression strength decreases from jute laminate with highest (111.49 MPa) compression strength, banana laminate (102.33 MPa), while flax laminate showed the least (95.18 MPa) compression strength.

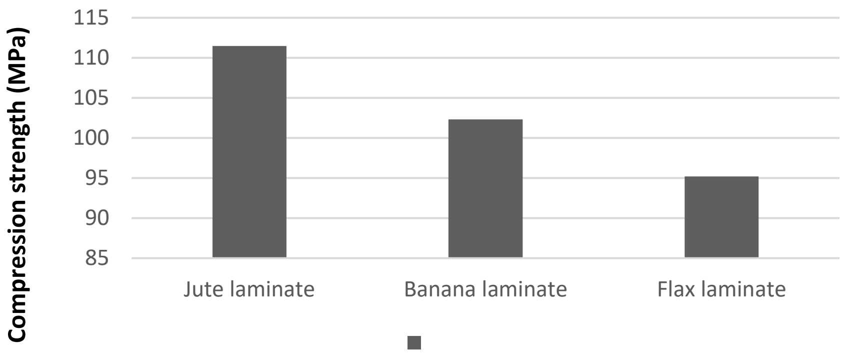

Figure 24: Compression strength of natural fibre reinforced laminate samples

3.3. Impact Strength

Figure 25shows the izod impact strength results of reinforced fibre laminates. The flax laminate tested displayed higher impact strength (116.6 J/m) next to banana laminate (71.40 J/m), while the jute displayed the lowest (37.00 J/m).

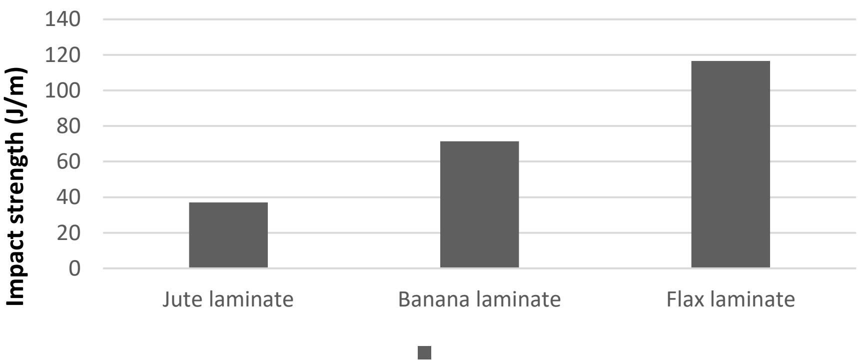

Figure 25: Impact strength of natural fibre reinforced laminate samples

The alkalization treatment of fibers can help in improving the chemical bonding between the resin and fiber resulting in superior mechanical properties. It has been reported by several authors that mechanical properties of composites were improved by the modification of fibers [19].

IV. CONCLUSIONS

The experimental research on mechanical properties of natural fiber reinforced composites (NFRC) leads to the following conclusions:

1) The natural fiber composite manufactured provides an opportunity of replacing existing materials with a higher strength, low cost alternative also they are environmentally friendly.

2) Mechanical properties viz., Tensile strength and Compressive strength of the jute and banana fiber reinforced composite material is having greater value than that of flax reinforced composite. Hence jute and banana fibers can be good reinforcement candidates for high performance polymer composites.

3) The impact strength of flax fiber reinforced composite is greater than banana and jute fiber, but the impact strengths of banana and flax are almost same so they can be alternative for one another in terms of natural fiber composites.

V. ACKNOWLEDGMENT

I would like to show my gratitude to my guide professor Dr.S.S.Chavan sir for sharing his pearls of wisdom with me during this research. I am also thankful to all my teachers and other staff of Mechanical department of Bharti Vidyapeeth for their continuous support.

REFERENCES

[1] R. Karnani, M. Krishnan and R. Narayan, "Biofiber Reinforced Polypropylene Composites," *Polymer Engineering and Science*, Vol. 37, No. 2, 1997, pp. 476-483.

[2] A. M. MohdEdeerozey, M. A. Harizan, A. B. Azhar and M. I. Zainal Ariffin, "Chemical Modification of Kenaf Fibers," *Materials Letters*, Vol. 61, No. 10, 2007, pp. 2023-2025. doi:10.1016/j.matlet.2006.08.006

[3] E. Robson, "Surface Treatment of Natural Fibre," EC/ 4316/92, 1993.

[4]H. A. Sharifah and P. A. Martin, "The Effect of Alkalization and Fibre Alignment on the Mechanical and Thermal Properties of Kenaf and Hemp BastFibre Composites: Part 1 -Polyester Resin Matrix," *Composites Science and Technology*, Vol. 64, No. 9, 2004, pp. 1219-1230.

[5]B. F. Yousif, K. J. Wong and N. S. M. El-Tayeb, "An Investigated on Tensile, Compression and Flexural Properties of Natural Fibre Reinforced Polyester Composites," *ASME International Mechanical Engineering Congress and Exposition*, Seattle, 11-15 November 2007, pp. 619- 624.

[6] Y. MohdYuhazri, P. T. Phongsakorn and H. Sihambing, "A Comparison Process between Vacuum Infusion and Hand Lay-Up Method toward Kenaf/Polyester Composite," *International Journal of Basic & Applied Sciences*, Vol. 10, No. 3, 2010, pp. 63-66.

[7] T. Nishino, K. Hirao, M. Kotero, K. Nakamae and H. Inagaki, "Kenaf Reinforced Biodegradable Composite," *Composites Science and Technology*, Vol. 63, No. 9, 2003, pp. 1281-1286. doi:10.1016/S0266-3538(03)00099-X

[8] H. A. Sharifah, P. A. Martin, J. C. Simon and R. P. Simon, "Modified Polyester Resins for Natural Fibre Composites," *Composites Science and Technology*, Vol. 65, No. 3-4, 2005, pp. 525-535. doi:10.1016/j.compscitech.2004.08.005

[9] P. Wamubua, J. Ivens and I. Verpoest, "Natural Fibres: Can They Replace Glass in Fibre Reinforced Plastics?" *Composites Science and Technology*, Vol. 63, No. 9, 2003, pp. 1259-1264. doi:10.1016/S0266-3538(03)00096-4

[10] Lai C.Y., Sapuan S.M., Ahmad Yahya N., and Dahlan K.Z.H.M. (2005). "Mechanical and Electrical Properties of Coconut Coir Fibre Reinforced Polypropylene Composites", *Polymer Plastics Tech. Eng*., 44(4), pp. 619-632.

[11] Sapuan S.M., and Maleque M.A. (2005). "Design and Fabrication of Natural Woven Fabric Reinforced Epoxy Composite for Household Telephone Stand", *Materials and Design*. 26(1), pp. 65-71.

[12] Arib M.N., Sapuan S.M., Hamdan M., Paridah M.T., and Dahlan K.Z.H.M., (2006). "Mechanical Properties of Pineapple Leaf Fibre Reinforced Polypropylene Composites", *Materials and Design*, 27(5), pp. 391-396.

[13] S. Agbo, "Modelling of Mechanical Properties of a Natural and Synthetic Fiber Reinforced Cashew Nut Shell Resin Composites," M.Sc. Thesis, University of Nigeria, 2009.

[14] Das B.N., Rana A.K., Mishra S.C., Tripathy S.S., Mishra, H.K. and Padhi B.N. (1999), "Novel Low Cost Jute Polyester Composites (Part-I) Processing, Mechanical Properties and SEM Analysis", *Polymer Composite*, Vol. 20(1), pp. 62-71.

[15] Satyanarayana S., (1990). "Natural Fiber Polymer Composites", *Cement Concrete Composites*, 12(2), pp. 117-136.

[16] S. Shibata, Y. Cao and I. Fukumoto, "Press Forming of Short Natural Fiber Reinforced Biodegradable Resin: Effects of Fiber Volume and Length on Flexural Properties," *Polymer Testing*, Vol. 24, No. 8, 2005, pp. 1005- 1011. doi:10.1016/j.polymertesting.2005.07.012

[17] Shantanu Pawar, Dr. S. S. Chavan and Dr. P. V. Jadhav "Design & Analysis of Sandwich Composite Leaf Spring For HMV" International Journal of Mechanical Engineering and Technology (IJMET) Volume 8, Issue 9, September 2017, pp. 01–17 ISSN Print: 0976-6340 Impact Factor 9.22 opus Indexed

[18] Shantanu Pawar, Dr. S. S. Chavan and Dr. P. V. Jadhav "A Review: Computer Aided Analysis for Weight Optimization of Leaf Spring Using Intermediate Layers of GFRP and CFRP" International Journal of Innovative Research In Technology, Volume 4 Issue 1 July 2017 ISSN : 2349 – 600, page no 217-223 Impact factor 5.8

[19] M. Idricula, S. K. Malhota, K. Joseph and S. Thomas, "Dynamic Mechanical Analysis of Randomly Oriented Intimately Mixed Short Banana/Sisal Hybrid Fibre Reinforced Polyesters Composites," *Composites Science and Technology*, Vol. 65, No. 7-8, 2005, pp. 1077-1087. doi:10.1016/j.compscitech.2004.10.023