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# Mechanical and Water Absorption Properties of Woven Jute/Banana Hybrid Composites

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**Abstract:** This work aims to predict the mechanical properties of woven jute/banana hybrid composite. Woven fabrics are arranged in three layers of different sequence. Resin used in this work is Epoxy LY556 with hardener HY951.Composite specimen are prepared by hand-layup techniques. The effect of layering sequence on the mechanical properties namely tensile, flexural and impact was analysed. It is found that the tensile and flexural strength of hybrid composite (Banana/Jute/Banana) is higher than that of individual composites. Similarly, the impact strength of Jute/Banana/Jute hybrid composite is better than other types of composite. It is found that the moisture absorption of woven banana fiber composite is lesser than the hybrid composite. Fractography study of the fractured specimen is carried out using scanning electron microscope to analyse the fracture behaviour of the hybrid composite.

**Keywords:** Banana fiber, Jute fiber, Woven hybrid composite, Mechanical properties, Scanning electron microscope

## Introduction

Due to ever increasing concern over environmental problems possessed by polymers, the use of natural fibers in the polymer matrix composite as reinforcing agent has got attention to several researchers. Natural fibres have many advantages over synthetic fibers such as biodegradable, low weight, low cost and acceptable properties [1-3]. When compared with the conventional reinforcing fibers (Glass, Carbon, and Kevlar) natural fibers are environmentally friendly alternatives. Due to its hollow and cellular nature, natural fibers possess excellent acoustic and thermal insulators, and also exhibit reduced bulk density [4]. Due to the short comings especially to glass fiber such as high fiber density (40 % more than Natural fibers), machining and recyclable problems natural fiber reinforced composite are attracting slowly the automotive industries [5].

John and Venkata Naidu [6] analysed effect of NaOH and Silane on the tensile properties of sisal/glass hybrid composite. SEM image shows that the chemical treatment removes the hemi- cellulose content from the fiber causing rough topography. This rough surface improves the adhesion between fiber and matrix which in turn increases the tensile strength of the hybrid composite. Mishra *et al.* [7] assessed the effect of hybridisation of glass fiber with sisal and pineapple leaf fiber. Results revealed that the alkali treatment improves the tensile and flexural strength whereas cyanoethylation treatment has improved the impact strength of the hybrid composite. Idicula *et al.* [8] investigated the mechanical properties of sisal/banana hybrid composite. The tensile strength of the hybrid composite is higher when the sisal fibers are sandwiched between banana fibers. Also the study compared the experimental tensile properties with the Series and Hirsch Model. Khalil *et al.* [9] studied the mechanical and physical properties of oil palm empty fruit bunch/glass hybrid reinforced polyester composites. Study shows that the incorporation of glass fiber has significantly increases the mechanical properties of the composite. Amico *et al.* [10] investigated the effect of stacking sequence on mechanical properties of sisal/glass fiber composite. The flexural properties of the hybrid composite increases when sisal fiber is stacked between glass fiber layers. Khanam *et al.* [11] carried out experimental investigation on Sisal/Carbon hybrid composite. Properties studied in the work are tensile, flexural and chemical resistance of the composite. Results shows that fibers treated with 18 % NaOH have improved the properties of the composite tremendously. Further, it also indicated that the chemical resistance of the untreated and treated composites is strongly resistant to all chemicals except carbon tetra chloride. Venkateshwaran and ElayaPerumal [12] reviewed the various work carried out using banana fiber as reinforcing agent.

Sapuan *et al.* [13] investigated the tensile and flexural properties of woven banana/epoxy composite. Anova analysis carried out shows that the composite made from banana/epoxy has stable behaviour. Maya Jacob *et al.* [14] studied the moisture absorption behaviour of sisal fabric reinforced with natural rubber bio-composite. Further, sisal fabric was subjected to various chemical treatments like mercerization, silanization, and thermal. Of the three methods, it is found that the thermal treatment decreases the water uptake behaviour of the composite. Pothan *et al.* [15] investigated the effect of weaving pattern on the tensile and flexural properties of sisal fabric composite. Investigation revealed that the resin permeability depends on the weaving pattern and the fiber surface morphology. It also shows that the matt type of woven composite has better mechanical properties than plain and twill types. Lai and Mariatti [16] studied the flexural and impact properties of woven betel palm composite. The study compared the properties of untreated and treated

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[NaOH] fibers at different volume fraction and it is found that the treated composite has better properties than untreated composite. Jannah *et al.* [17] analysed the effect of NaOH and Acetic Acid on flexural, impact and water absorption behaviour of banana fabric/polyester composite. Analysis indicates that the acetic acid treatment provides better mechanical and water absorption properties to composite than alkali treatment.

Laly Pothan *et al.* [18] analysed the effect of layering pattern on Banana/Glass fiber reinforced composite. Results show that the composite made of four layers of banana/glass has better storage modulus property. Mechanical properties analysis of woven jute/glass fabric hybrid composite was carried out by Sabeel Ahmed *et al.* [19]. SEM images shows that the fracture if the composite occurs at the interface between the jute and glass fabric. Further the effects of hybridization of glass fiber on low velocity impact behavior of woven jute/glass fabric composite were studied by Sabeel Ahmed *et al.* [20]. The study revealed that the impact property of the jute fabric is better than hybrid composite. Alavudeen *et al.* [21] has reviewed the various work carried out using natural fibers in woven form to fabricate composite. Review was carried out with reference to the effect of weave pattern and chemical modification on woven composite.

In this work, banana and jute fabrics were arranged in different sequence to prepare composite. The effect of this layering arrangement on the mechanical and water absorption properties are investigated. Further, with the help of micrographs, the fracture behaviour of the composite was analysed.

## Experimental

### Materials

Banana fibers were procured from local dealer and weaved manually. Each woven fabric bundle must consist of 200-250 yarns and the thickness of each layer is 1±0.2. Jute fabric was purchased from the local resources. Resin used in this work is LY556 with hardener HY951. Mixing ratio of resin and hardener is 10.1. The total fiber weight percentage used is 25 and remaining is matrix. Figure 1 and 2 shows the

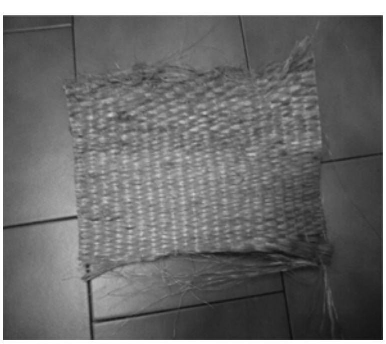

**Figure 1.** Woven banana fabric.

**Figure 2.** Woven jute fabrics.

**Table 1.** Properties of Banana fibers and Jute fibers [19,22]

| Properties | Banana fiber | Jute fiber |
|---|---|---|
| Cellulose (%) | 63-64 | 58 |
| Hemicelluloses (%) | 19 | 14 |
| Lignin (%) | 5 | 9.9 |
| Density (kg/m$^3$) | 1350 | 1300 |
| Tensile strength (MPa) | 540-900 | 400-700 |
| Young's modulus (GPa) | 34.8 | 26.5 |
| Diameter ($\mu$m) | 80-250 | 120-180 |
| Microfibrillar angle $\theta$ (degrees) | 10±1 | 12±1 |
| Cell "l/d" ratio | 100 | 150 |

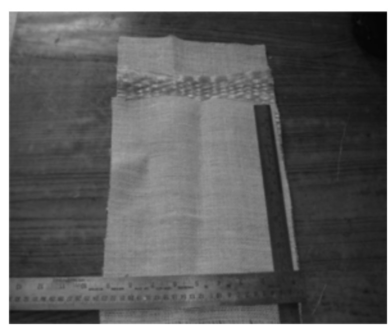

**Figure 3.** JBJ arrangements of fabrics.

**Figure 4.** BJB arrangements of fabrics.

woven banana and jute fabric. Physical and mechanical properties of the banana and jute fibers are listed in Table 1.

### Fabrication of Composites

Mould used in this work is made of well-seasoned teak wood of 300×300×3 mm dimension. The fabrication of the composite material was carried out through the hand lay-up technique. The moulds are cleaned and dried before applying epoxy. A layer of epoxy resin was poured into the mould and then woven fabric was laid uniformly over the mould, another layer of epoxy is applied over the fabric uniformly. Mats are placed parallel to one another and compressed for a curing time of 24 hrs. After initial curing, laminate is kept in compression moulding machine for post curing at pressure of 3 MPa and temperature of 50 °C for 15 minutes. After the curing process, test samples were cut to the required sizes prescribed in the ASTM standards. Figure 3 and 4 shows the trilayer arrangements (Jute/Banana/Jute [JBJ] and Banana/Jute/Banana [BJB]) of the fibers. Figure 5, 6, 7 and 8 shows the fabricated composite.

**Figure 5.** Jute fabric composite.

**Figure 6.** Banana fabric composite.

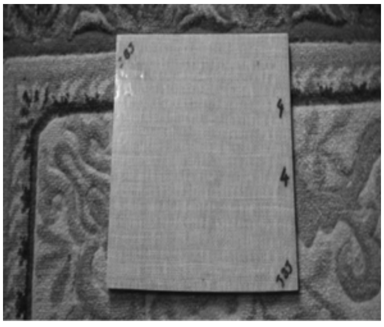

**Figure 7.** JBJ fabric composite.

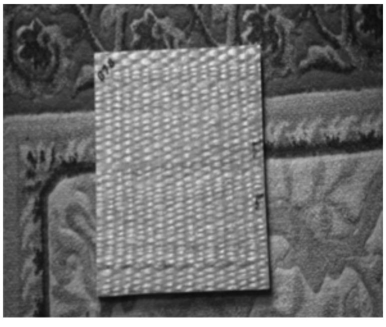

**Figure 8.** BJB fabric composite.

## Testing Standards

### Mechanical Testing

After fabrication, the test specimens were subjected to various mechanical tests as per ASTM standards. Before testing, the specimens were conditioned at a temperature of 23 °C and relative humidity (RH) of 50 % according to ASTM D 618. The standards followed were ASTM-D 3039 [25] for tensile test of composite. The test speed was maintained at 5 mm/min. The flexural strength was determined as per ASTM D 790 [26] procedure. The test speed was maintained between 1.3 and 1.5 mm/min. The impact strength of the composite specimens was determined using an Izod impact tester as per ASTM D 256 [27] Standard. In each case, five specimens were tested to obtain the average value.

### Water Absorption Test and Mechanism

Water absorption test was carried out in accordance with ASTM D570 [28] procedure to predict the diffusion and permeability coefficient of the hybrid composite. In order to study the kinetics of water absorption, specimens were submerged in water at room temperature. The samples were taken out periodically and weighed immediately, after wiping out the water from the surface of the sample and using a precise four-digit balance to find out the content of water absorbed. All the samples were dried until constant weight is reached before immersing in the water. The percentage of moisture absorption was plotted against the square root of time (hours) as shown in Figure 12. Moisture diffusion in polymer composites follows Fickian as well as non-Fickian character. The percentage of water absorption is given by:

$$\% \text{ of absorption} = (m_2 - m_1)/m_1 \quad (1)$$

where $m_1$ and $m_2$ are the weight of the dry and wet samples.

Prediction of diffusion co-efficient (D), sorption coefficient (S) and permeability coefficient (P) are discussed extensively somewhere [22]. Table 3 list the various coefficients of moisture absorption.

**Scanning Electron Microscope**

Interfacial properties, such as fiber-matrix interaction, fracture behaviour, and fiber pull-out of samples after mechanical tests were observed using Hitachi-S3400 N scanning electron microscope. The fractured portions of the samples were cut and gold coated over the surface uniformly for examination. The accelerating voltage used in this work is 15 kV.

## Results and Discussion

**Mechanical Properties**

The mechanical properties namely tensile strength and flexural strength are calculated from load vs. displacement plots obtained after corresponding tests.

Figure 9 shows the tensile proeprties of the various composite tested. From figure, it is found that the trilayer composite of Banana/Jute/Banana has better tensile strength and modulus of 54.6 MPa and 13.69 GPa respectively. Also, it shows that the trilayer composite of Jute/banana/Jute has lesser tensile properties than the individual banana fiber composite. Many researchers [23-25] shown that stacking sequence plays significant role in determining the mechanical properties of the composite. All the work indicates that high strength fiber as skin improves the mechanical properties of the sandwich composite which is also evident here. The high strength and modulus woven banana fiber priovided at the top andbottom layer withstand the applied load where as core(jute) absorb and distribute the loads uniformly.

Figure 10(a) and (b) shows the variation of flexural properties of various composite tested. It is found that similar trend as seen in tensile properties are followed here also. Sandwich composite of trilayer Banana/Jute/Banana exhibits higher flexural strength and modulus as 91.665 MPa

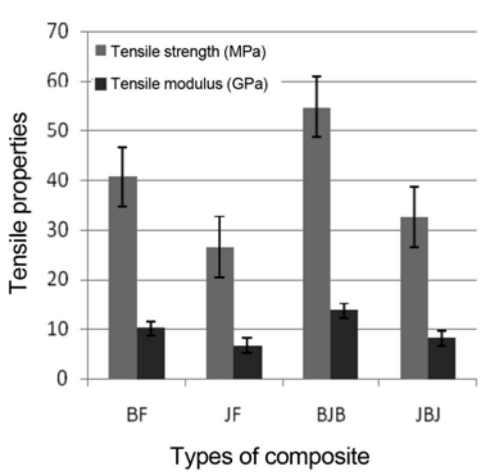


**Figure 9.** Tensile properties of various composite.

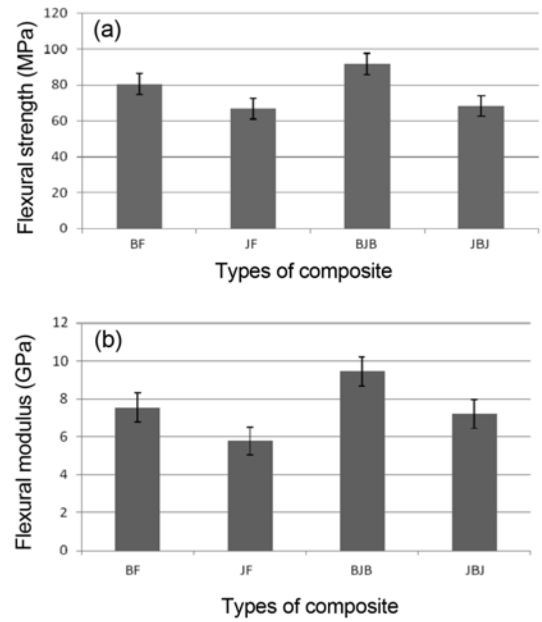


**Figure 10.** Flexural properties of various composite.

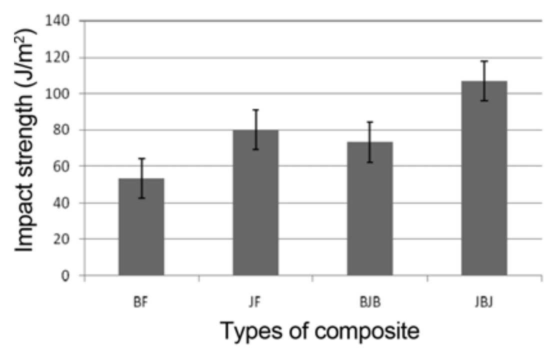


**Figure 11.** Impact strength of various composite.

and 9.44 GPa respectively. This shows that the addition of banana fiber as skin layer increases the strength and stiffness of jute fibe composite. The basic bending theory proposes that under bending load top layer subjected to compression and bottom layer subjected to tension and middle layer is subjected to shear. From this basic theory, it is understood that the main load carring members are skin in sandwich composite and hence skin layers should be made of high strength fibers so that it withstand high load and hence improves the properties of the composite. Hence the composite made of Banana/Jute/Banana exhibit higher flexural strength and modulus than the Jute/Banana/Jute or the composite made of individual fibers. It also confirms that eventhough hybirdisation improves the properties of the composite, the layering sequence has much more effect on the flexural proeprties of the composite.

Figure 11 shows the impact strength of the composite. It shows that the composite made of Jute/Banana/Jute has highest impact strength than Banana/Jute/Banana or the composite of individual fibers. Basic aim of the impact test is to know the energy absorbing capacity (toughness) of the material when subject to high strain rate. From Table 2 it can be seen that the impact strength of Jute/Banana/Jute [JBJ] composite is 106.67 J/m whereas for Banana/Jute/Banana composite is 73.33 J/m. The composite made of Banana/Jute/Banana [BJB] layer has lower impact strength than the jute fiber composite (80 J/m) this is because of lower impact strength of banana fiber as skin. Hence the higher impact strength of jute layer as skin in Jute/Banana/jute composite has better impact strength as jute fiber absorb more energy than banana fiber. The comparative properties of various composite are shown in Table 2.

Statistical analysis using one way analysis of variance (ANOVA) was carried out for tensile, flexural and impact strength of the various composite are carried out and listed in Table 4, 5 and 6 respectively.

ANOVA analysis shown in Table 4, 5 and 6 divides the source of variance as between and within group. The P-value used is less 0.05 and also from the tables it can be concluded that the $F_{crit}$ is lesser than F value null hypothesis can be rejected and accepting alternative hypothesis which says there is a significant effect on layering sequence on the mechanical strength of the composite with 95 % accuracy level.

Since ANOVA does not reveal the differences between the means of layer arrangement, Duncan Multiple Range test

**Table 2.** Comparison of various properties of composite

| Fiber | Tensile strength (MPa) | Tensile modulus (GPa) | Flexural strength (MPa) | Flexural modulus (GPa) | Impact strength ($J/m^2$) |
|---|---|---|---|---|---|
| BF | 40.69 | 10.72 | 80.564 | 7.55 | 53.33 |
| JF | 26.53 | 6.32 | 66.67 | 5.78 | 80 |
| BJB | **54.76** | **13.69** | **91.66** | **9.44** | 73.33 |
| JBJ | 32.63 | 8.16 | 78.26 | 7.21 | **106.67** |

**Table 3.** Diffusion and permeability study of layered composites

| Type of composite | Percentages of water uptake at infinite time $Q_\infty$ (%) | Sorption coefficient $S$ | Diffusion coefficient $D$ ($mm^2/s$) | Permeability coefficient $P$ ($mm^2/s$) |
|---|---|---|---|---|
| Banana fiber | 21.25 | 1.37 | 1.509E-05 | 1.92E-05 |
| Jute fiber | 28.64 | 1.74 | 1.973E-05 | 2.44E-05 |
| BJB | 31.81 | 1.90 | 2.1923E-05 | 3.04E-05 |
| JBJ | 35.04 | 2.20 | 2.6867E-05 | 3.63E-05 |

**Table 4.** ANOVA test for tensile strength of various layering sequence of composite

| Source of variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between groups | 2235.349 | 3 | 745.1162 | 266.5277 | 7.26E-14 | 3.238872 |
| Within groups | 44.73028 | 16 | 2.795643 | | | |
| Total | 2280.079 | 19 | | | | |

(SS) Sum of the squares, (df) degree of freedom, and (MS) mean square.

**Table 5.** ANOVA test for flexural strength of various layering sequence of composite

| Source of variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between groups | 1455.251 | 3 | 485.0838 | 181.1914 | 1.47E-12 | 3.238872 |
| Within groups | 42.83503 | 16 | 2.677189 | | | |
| Total | 1498.086 | 19 | | | | |

**Table 6.** ANOVA test for impact strength of various layering sequence of composite

| Source of variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between groups | 7275.975 | 3 | 2425.325 | 1341.446 | 2.02E-19 | 3.238872 |
| Within groups | 28.9279 | 16 | 1.807994 | | | |
| Total | 7304.903 | 19 | | | | |

(DMRT) was conducted. DMRT was widely used procedure for comparing all means of all pairs. It rank all the means in decreasing or increasing order based on preference of character under study. In this work DMRT was conducted with P-level of 0.05 and ranked the properties in descending order. The Duncan results are listed in Table 7, 8, and 9 for Tensile, Flexural and Impact properties.

From Table 7 it is found that mean of Banana and jute affects the mean of JBJ type tensile properties. Table 8 also shows the similar kind of observation for flexural properties. Table 9 used to display the effect of means by DMRT, it shows that individual means has no significant effect on impact properties of the composite.

**Table 7.** Duncan multiple range test for tensile properties

| Order | Tensile strength (MPa) | Tensile modulus (GPa) | Grade |
|---|---|---|---|
| 3 | 54.76 | 13.69 | a |
| 1 | 40.69 | 10.73 | b |
| 4 | 32.63 | 8.16 | bc |
| 2 | 26.53 | 6.33 | c |

**Table 8.** Duncan multiple range test for flexural properties

| Order | Flexural strength (MPa) | Flexural modulus (GPa) | Grade |
|---|---|---|---|
| 3 | 91.66 | 9.44 | a |
| 1 | 80.56 | 7.55 | b |
| 4 | 78.26 | 7.21 | bc |
| 2 | 66.67 | 5.78 | c |

**Table 9.** Duncan multiple range test for impact strength

| Order | IS | Grade |
|---|---|---|
| 4 | 106.67 | a |
| 2 | 80 | b |
| 3 | 73.33 | c |
| 1 | 53.33 | d |

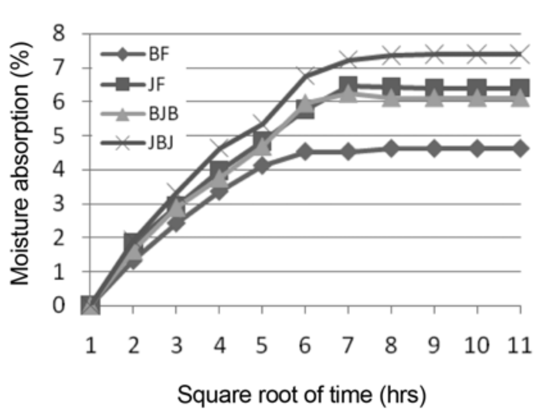


**Figure 12.** Moisture absorption behaviour of various composite.

## Water Absorption Properties

Water absorption behaviour of the composites and various parameters associated with it are predicted using equation given [22]. It is found that the moisture absorption becomes stabilize around 50 hrs for banana composite. For jute composite water absorption rate becomes constant around 64 hrs. Figure 12 shows that hybridisation of jute with banana fibers has slightly decreases the moisture uptake behaviour of jute fiber composite all the composite. Further, Figure 12 show that when jute fiber was placed as skin layer there is tremendous increase in the moisture absorption rate of the hybrid composite and becomes stabilizes around 80 hrs. Also Figure 12 shows the moisture absorption percentage as 4.6, 6.4, 6.8 and 7.4 respectively for composite made of banana fibers, jute fibers, BJB and JBJ respectively. For various type of composite tested, banana fiber composite has lowest percentage of moisture absorption. The trilayer composite of JBJ has highest moisture absorption percentage of 7.4 because of affinity of jute fibers towards moisture. Since, jute fiber has highest sorption, diffusion and permeability coeffecients than banana fiber resulting in high moisture absorption capability to the composite of JBJ sequence as evident from Table 3.

## Morphological Analysis

Tensile fracture specimens of the composite are subjected to scanning electron microscope to understand the fracture behaviour. Figure 13 shows the SEM micrograph of jute fabric composite, it shows that the composite failure occurs due to presence of voids created due to fiber pull out. The presence of voids due fiber pull out and voids between fiber and matrix, indicate poor fiber matrix adhesion which in turn results in poor mechanical properties. Figure 14 shows the SEM image of JBJ composite. It shows that the skin layer made of jute fiber came out from matrix earlier than banana fibers. This is because the jute fiber has lower strength and stiffness than banana fiber fails early resulting in poor tensile property. SEM image of BJB sample is shown in Figure 15. It shows the better fiber matrix adhesion and the failure of

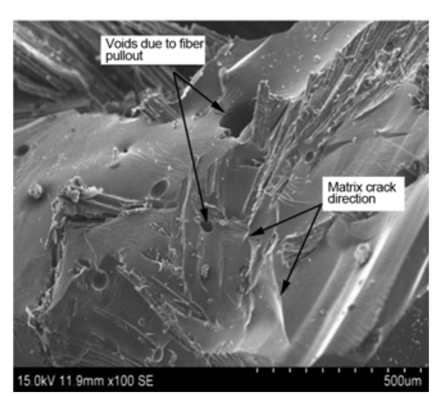


**Figure 13.** SEM of Jute fabrics composite.

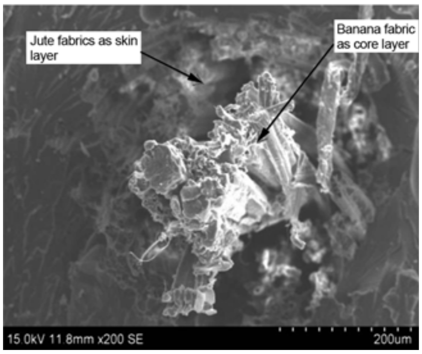


**Figure 14.** SEM of JBJ composite.

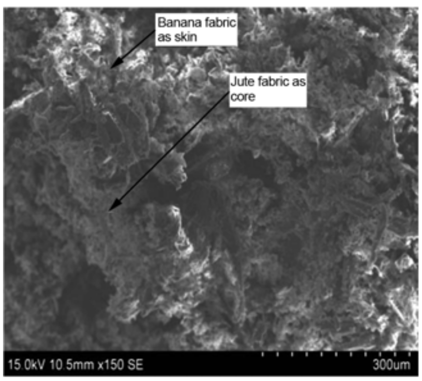


**Figure 15.** SEM of BJB composite.

core layer will happen only after the failure of skin layer. Hence they results in better mechanical property than the individual fibers and JBJ hybrid composite.

## Conclusion

The effect of layering sequence and hybridisation of jute fabrics with banana fabric on the mechanical and water absorption properties was studied. It is observed that the layering pattern has significant effect on the tensile, flexural and impact properties of the composite. Even though woven jute fibers were hybridized with woven banana fiber, the effect of hybridisation is lesser when compared with the effect of layering sequence. Further, it is observed that composite of Banana/Jute/Banana is suitable for applications encountering tensile and bending loads. For application encounters impact loading, composite of Jute/Banana/Jute trilayer is suitable. From the SEM image analysis, it is found that the failure of composite occurs at the interface between the layers of the fabrics than fiber pull out. ANOVA analysis also shows the layering pattern has significant effect on the mechanical strength of the composite. Further, Duncan's Multiple Range Test was conducted to predict the effect of means with the different layer arrangement.

## References

1. J. Biagiotti, D. Puglia, and Jose M. Kenny, *J. Nat. Fib.,* **1**, 37(2004).
2. S. V. Joshi, L. T. Drzal, A. K. Mohanty, and S. Arora. *Composites: Part A* **35**, 371 (2004).
3. B. Madsen, A. Thygesen, and H. Lilholt, *Compos. Sci. Technol*., **69**, 1057 (2009).
4. G. Bogoeva-Gaceva, M. Avella, M. Malinconico, A. Buzarovska, A. Grozdanov, G. Gentile, and M. E. Errico. *Polym. Compos.*, **28**, 98 (2007).
5. J. Holbery and D. Houston, *J. Minerals, Metals Mater. Soc.*, **58**, 80 (2006).
6. K. John and S. Venkata Naidu, *J. Reinf. Plast. Compos.,* **23**, 1815 (2004).
7. S. Mishra, A. K. Mohanty, L. T. Drzal, M. Misra, S. Parija, S. K. Nayak, and S. S. Tripathy, *Compos. Sci. Technol*., **63**, 1377 (2003).
8. M. Idicula, N. R. Neelakantan, Z. Oommen, K. Joseph, and S. Thomas, *J. Appl. Polym. Sci*., **96**, 1699 (2005).
9. H. P. S. Abdul Khalil, S. Hanida, C. W. Kang, and N. A. Nik Fuaad, *J. Reinf. Plast. Compos.,* **26**, 203 (2007).
10. S. C. Amico, C. C. Angrizani, and M. L. Drummond, *J. Reinf. Plast. Compos.,* **29**, 179 (2010).
11. P. Noorunnisa Khanam, H. P. S. Abdul Khalil, M. Jawaid, G. Ramachandra Reddy, C. Surya Narayana, and S. Venkata Naidu, *J. Polym. Environ*., **18**, 727 (2010).
12. N. Venkateshwaran and A. ElayaPerumal, *J. Reinf. Plast Compos*., **29**, 2387 (2010).
13. S. M. Sapuan, A. Leenie, M. Harimi, and Y. K. Beng, *Mater. Des*., **27**, 689 (2006).
14. M. Jacob, K. T. Varughese, and S. Thomas, *J. Appl. Polym. Sci.,* **102**, 416 (2006).
15. L. A. Pothan, Y. W. Mai, S. Thomas, and R. K. Y. Li, *J. Reinf. Plast Compos.,* **27**, 1847 (2008).
16. W. L. Lai and M. Mariatti, *J. Reinf. Plast Compos*., **27**, 925 (2008).
17. M. Jannah, M. Mariatti, A. Abu Bakar, and H. P. S. Abdul Khalil, *J. Reinf. Plast. Compos.,* **28**, 1519 (2009).
18. L. A. Pothan, P. Potschke, R. Habler and S. Thomas, *J. Compos. Mater.*, **39**, 1006 (2005).
19. K. Sabeel Ahmed, S. Vijayarangan, and C. Rajput, *J. Reinf. Plast. Compos*., **25**, 1549 (2006).
20. K. Sabeel Ahmed, S. Vijayarangan, and A. Kumar, *J. Reinf. Plast. Compos.*, **26**, 959 (2007).
21. A. Alavudeen, M. Thiruchitrambalam, N. Venkateshwaran, and A. Athijayamani, *Rev. Adv. Mater. Sci.,* **27**, 146 (2011).
22. N. Venkateshwaran, A. Elayaperumal, A. Alavudeen, and M. Thiruchitrambalam, *Mater. Des.,* **32**, 4017 (2011).
23. H. P. S. Abdul Khalil, C. W. Kang, A. Khairul, R. Ridzuan and T. O. Adawi, *J. Reinf. Plast. Compos.,* **28**, 1123 (2009).
24. M. Jawaid, H. P. S. Abdul Khalil, and A. Abu Bakar,

*Mater. Sci. Eng. A,* **528**, 5190 (2011).
25. ASTM D 3039, Standard Test Method for Testing Tensile Properties of Polymer Matrix Composite.
26. ASTM D790-07, Standard Tests Method for Testing Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Material.
27. ASTM D256-06a, Standard Test Method for Determining Izod Pendulum Impact Resistance of Plastics.
28. ASTM D570-98 (Reapproved 2005), Standard Test Method for Water Absorption of Plastics.