International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 04 Issue: 08 August 2026
Page No: 5260 - 5264
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2026.0688

A Study on Mechanical Behaviour of Bamboo, Jute and Banana Fiber Based Hybrid Natural Composites

Sushanta Kumar Pradhan[1], Bimal Ranjan Pattanaik[2], Mamuni Arya[3], Kapil Kumar Mahanta[4], Pradeep Kuma Mohanty[5]
[1,2,4,5]Associate Professor, Dept. of ME, Radhakrishna Institute of Technology and Engineering (RITE), Khordha, Odisha, Pin-752057, India
[3]Associate Professor, Dept. of ME, Gandhi Institute of Excellent Technocrats (GIET), Bhubaneswar, Odisha, Pin-752054, India
Emails: *sushantapradhan2010@gmail.com[1], bimalranjan.10@gmail.com[2], mamuniarya@gmail.com[3], dr.kapil14@gmail.com[4], khurdapkmohanty@gmail.com[5]*

Abstract
This study investigates the mechanical response of two hybrid natural-fiber epoxy laminates: a jute-banana-bamboo (B-J-B) hybrid and a jute-Lantana camara (J-LC-J) hybrid. Both laminates were manufactured by the hand lay-up route using an alternate-ply stacking sequence, keeping the fiber-to-matrix weight ratio fixed at 40:60. Tensile coupons were machined into a dog-bone profile and flexural coupons into a flat-bar profile, in line with ASTM guidance, and both were evaluated on a universal testing machine (UTM). Inter laminar shear strength and flexural strength was derived from three-point bend data, while fracture surfaces were examined under a scanning electron microscope (SEM) to identify the governing failure mechanisms. Relative to unreinforced epoxy, both hybrid laminates showed a marked improvement in flexural and tensile response, with the jute-bamboo combination consistently outperforming the jute-banana combination. Fracto graphic evidence linked this difference to superior fiber wetting and fewer de-bonded regions in the jute-bamboo laminate, whereas the jute-banana laminate exhibited pronounced fiber pull-out and fiber breakage.
Keywords: *Bamboo Fiber; Epoxy Matrix; Hybrid Composite; Hand Lay-Up; Mechanical Testing; Natural Fiber*

1. Introduction
A composite material results from combining two or more constituents that remain physically distinct, so that the properties of the combination exceed those achievable by any single constituent on its own. Typically, a reinforcing phase - fibers, particles or sheets - is embedded within a continuous matrix phase, with the reinforcement carrying the bulk of the applied load while the more ductile matrix transfers stress between reinforcing elements, shields them from environmental degradation, and contributes toughness to the overall system. Composites are commonly classified by reinforcement geometry into fibrous and particulate types, and by matrix chemistry into metal-matrix, ceramic-matrix and polymer-matrix systems. Hybrid composites extend this concept by combining more than one type of reinforcement within a single laminate: pairing a stiffer, higher-modulus fiber with a more compliant, lower-modulus fiber allows the resulting laminate to combine load-bearing capacity with damage tolerance, and its overall mechanical response can be tuned by varying the volume fraction and stacking sequence of the constituent plies. Interest in natural-fiber reinforced polymers - based on flax, cotton, hemp, jute, sisal, kenaf, bamboo, banana and similar lignocellulosic sources - has grown steadily because these fibers are renewable, low-cost, biodegradable and largely recyclable, while still offering reasonable specific strength. They are increasingly used in transportation, construction and general consumer goods as an environmentally attractive alternative to glass and carbon reinforcement. Prior work has shown that fiber surface treatment, compatibilisation and hybridization all influence the mechanical performance of natural-fiber composites, and that jute in particular behaves as a genuine reinforcing fiber - rather than a simple filler - once properly bonded to the matrix. Building on this, the present

IRJAEH

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 04 Issue: 08 August 2026
Page No: 5260 - 5264
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2026.0688

work evaluates two jute-based hybrid laminates, jute-banana-bamboo and jute-Lantana camara, comparing their tensile and flexural behaviour and relating the observed differences to fracture-surface morphology. A substantial body of work has examined how fiber selection, surface treatment and hybridization influence the mechanical performance of natural-fiber composites. (Li et al., 2008) investigated interfacial bonding between hydrophilic natural fibers and hydrophobic polymer matrices, comparing chemical-bonding and oxidation surface treatments through single-fiber pull-out testing, and proposed a refined method for evaluating interfacial shear strength. (Joshi et al., 2004) carried out a life-cycle comparison of natural-fiber and glass-fiber composites and concluded that natural-fiber laminates are generally more environmentally favourable, owing to lower production impacts, higher fiber loading for equivalent performance, reduced component weight and more favourable end-of-life energy recovery. (Rana et al., 1998) showed that introducing a compatibilizer into jute-reinforced laminates substantially raised flexural strength, tensile strength and impact strength at 60 wt% fibers loading, confirming that properly compatibilized jute behaves as a genuine reinforcing fibre rather than simple filler. Shah and (Saha et al., 1981) compared jute- and glass-reinforced laminates and found that, while jute reinforcement clearly improves on the neat resin, its performance remains below that of glass fiber, making it best suited to applications where moderate strength and stiffness are acceptable. (Ray et al., 2001) subjected jute fibers to alkali treatment for varying durations and reported measurable gains in fiber modulus and tenacity, together with improved flexural strength, flexural modulus and inter-laminar shear strength in the resulting vinylester composites, with the greatest composite-level benefit obtained at an intermediate treatment time. (Saha et al., 2010) reported that combined alkali-steam treatment of jute fiber raised tensile strength markedly more than alkali treatment alone, attributing the gain to the removal of non-cellulosic constituents such as lignin, pectin and hemicellulose. (Gassan et al., 1999) demonstrated that coupling agents based on maleic-anhydride-grafted polypropylene improve fiber-matrix adhesion in jute-polypropylene composites, raising flexural strength and modulus, a conclusion supported by SEM evidence of improved interfacial bonding. (Monterio et al., 1998) explored sugarcane bagasse waste as a low-cost reinforcement and obtained composites with mechanical properties broadly comparable to wood-based agglomerates, while (Hassan et al., 2000) converted bagasse fiber into a thermo-formable reinforcement through esterification and characterized the resulting dimensional stability and mechanical properties. (Ray et al., 2006) used three-point flexural testing to assess the effect of cryogenic exposure and loading rate on glass-epoxy laminates, providing a useful benchmark for rate-sensitivity studies of fiber-reinforced systems. Taken together, this literature indicates that combining natural fibers - such as jute, bagasse and Lantana camara - with a polymer matrix consistently improves mechanical performance relative to the neat resin that fiber surface treatment and compatibilisation can further enhance interfacial bonding, and that natural-fiber composites remain an economically and environmentally attractive alternative to synthetic reinforcement despite their comparatively lower absolute strength. These findings motivate the present comparison of jute-banana-bamboo and jute-Lantana camara hybrid laminates. As Shown in sTable 1 Target weight composition of the two hybrid laminates

2. Materials And Methods

2.1.Materials

Three natural fibers were used as reinforcement - jute, banana and bamboo - together with Lantana camara fiber in the second hybrid. Jute is a coarse, low-cost bast fiber composed mainly of cellulose and lignin; banana fiber[1] is a strong bast fiber commonly used in textiles and specialty paper; bamboo fiber is a cellulose-based fiber with strength comparable to conventional glass fiber. The matrix was Araldite LY556 epoxy resin, cured with Araldite HY951 hardener (viscosity 10-20 poise at 25 degC).

Table 1 Target weight composition of the two hybrid laminates

SL. NO.	JUTE %	BANANA %	BAMBOO %	EPOXY %
1	20	-	20	60
2	20	20	-	60

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 04 Issue: 08 August 2026
Page No: 5260 - 5264
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2026.0688

2.2.Fabrication of the Composite Laminates

Both hybrid laminates were fabricated by the hand lay-up technique with an alternate-ply stacking sequence, keeping the overall fiber-to-matrix weight fraction at 40:60. Epoxy and hardener were blended with a glass rod, taking care to avoid entrapped air. A release film was applied to the mould, followed by a thin resin coat; fiber plies were then laid one at a time and rolled with a cylindrical[2] mild-steel roller, alternating fiber type until eight plies had been placed. A 20 kgf dead weight was applied and the laminate cured for 72 hours. Two hybrids were produced in this way: a banana-jute-bamboo (B-J-B) hybrid and a jute-Lantana camara-jute (J-LC-J) hybrid, each with two plies of each fiber type[3].

2.3.Specimen Preparation and Testing

Cured laminates were cut into test coupons using a wire hacksaw. Tensile specimens were machined to a dog-bone profile (150 x 10 x 5 mm) and tested under uni-axial loading on a universal testing machine (Instron 1195). Flexural specimens were cut to a flat-bar profile (20 x 150 x 5 mm) and evaluated using a three-point bend (short-beam shear) test with a 75 mm span, in accordance with ASTM guidance; inter laminar shear strength and flexural strength were calculated from the recorded load-extension data. Fracture surfaces were examined using a JEOL JSM-6480LV scanning electron microscope after sputter-coating with platinum to improve conductivity[4].

3. Results And Discussion

3.1.Flexural Test

Three-point bend tests were carried out on rectangular specimens (150 x 20 x 5 mm) with a 75 mm span for both laminates; the recorded data are summarized in Table 2. The flexural strength was calculated as 155.5 MPa for the jute-banana-bamboo laminate and 310.9 MPa for the jute-Lantana camara-jute laminate, both well above the 130-136 MPa typical of neat epoxy. Although the maximum loads recorded for the two hybrids were similar, the jute-bamboo-containing laminate sustained a noticeably larger extension before[5] failure, which accounts for its markedly higher flexural strength. As shown in Table 2. Three-point bend test data for the two hybrid laminates, As shown in Figure 1 Variation of force with extension in the 3-point bend test[6].

Table 2 Three-point bend test data for the two hybrid laminates

SAMPLE	*L (MM)*	*B (MM)*	*T (MM)*	*EXT (MM)*	*LOAD (N)*
B-J-B	150	20	5	1.45	701.0
J-LC-J	150	20	5	1.86	691.1

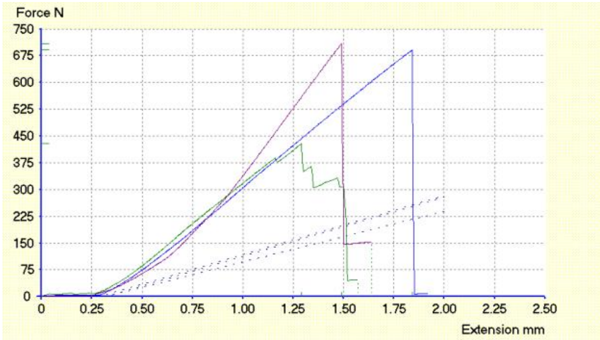

Figure 1 Variation of force with extension in the 3-point bend test

3.2.Tensile Test

Tensile tests were performed on dog-bone specimens (150 x 10 x 5 mm) for both laminates, with results summarised in Table 3. Neat epoxy typically shows a tensile strength of 62-72 MPa; both hybrid laminates exceeded this baseline once fiber loading reached 20% for each fiber type[7]. As in the flexural test, the jute-Lantana camara-jute laminate recorded both a higher extension at failure and a substantially higher maximum load than the jute-banana-bamboo laminate, indicating that the tensile response is governed primarily by the fiber combination and the resulting load-transfer efficiency at the fiber-matrix interface. As shown in Table 3 Tensile test data for the two hybrid laminates.

Table 3 Tensile test data for the two hybrid laminates

SAMPLE	L (MM)	B (MM)	T (MM)	EXT (MM)	LOAD (N)
B-J-B	150	20-10	5	2.803	859.3
J-LC-J	150	20-10	5	3.168	1651.7

3.3.SEM Analysis

SEM examination of the flexural fracture surfaces highlighted clear differences between the two

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 04 Issue: 08 August 2026
Page No: 5260 - 5264
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2026.0688

hybrids. The jute-banana laminate (Figure 2A) showed extensive fiber damage, including visible fiber breakage, fiber removal and de-bonding at the fiber-matrix interface, consistent with its comparatively lower flexural strength. In contrast, the jute-bamboo[8] laminate (Figure 2B) exhibited a higher degree of fiber wetting, with no obvious fiber pull-out or fiber fracture, although a small number of isolated voids were still present. This closer fiber-matrix contact is consistent with the superior flexural and tensile strength measured for the jute-bamboo hybrid. As shown in Figure 2 SEM micrographs of the flexural fracture surface: (A) jute-banana laminate, (B) jute-bamboo laminate[9].

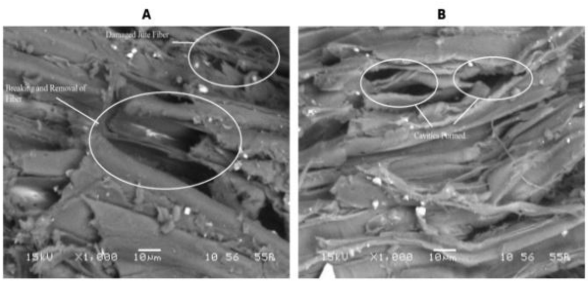

Figure 2 SEM micrographs of the flexural fracture surface: (A) jute-banana laminate, (B) jute-bamboo laminate

Conclusion

Jute, banana and bamboo fibers were successfully combined with epoxy resin, at a 40:60 fibre-to-matrix weight ratio, to fabricate two hand-lay-up hybrid laminates whose mechanical performance was well above that of the neat resin. Relative to neat epoxy (130-136 MPa flexural strength, 62-72 MPa tensile strength), 20% fibre loading raised the flexural strength to 155.5 MPa for the jute-banana-bamboo hybrid and to 310.9 MPa for the jute-Lantana camara-jute hybrid, with a corresponding increase in tensile strength for both laminates. The jute-Lantana camara-jute laminate sustained greater elongation than the jute-banana-bamboo laminate in both tests, and this greater elongation - rather than a large difference in maximum load - was the principal reason for its higher calculated strength. Fracture-surface examination showed that the jute-bamboo-containing laminate achieved better fiber wetting and interfacial bonding than the jute-banana laminate, which displayed pronounced fiber pull-out, fiber breakage and debonding. Overall, of the two hybrid combinations investigated, the jute-Lantana camara-jute laminate offered the better balance of flexural and tensile properties.

Acknowledgements

The authors thank the Department of Mechanical Engineering for providing the laboratory facilities used to fabricate and test the composite laminates reported in this work.

References

[1]. Li, Y., Hu, C., & Yu, Y. (2008). Interfacial studies of sisal fiber reinforced high density polyethylene (HDPE) composites. Composites Part A, 39, 570-578.
[2]. Joshi, S. V., Drzal, L. T., Mohanty, A. K., & Arora, S. (2004). Are natural fiber composites environmentally superior to glass fiber reinforced composites, Composites Part A, 35, 371-376.
[3]. Rana, A. K., Mandal, A., Mitra, B. C., Jacobson, R., Rowell, R., & Banerjee, A. N. (1998). Short jute fiber-reinforced polypropylene composites: Effect of compatibilizer. Journal of Applied Polymer Science, 69, 329-338.
[4]. Shah, A. N., & Lakkad, S. C. (1981). Mechanical properties of jute-reinforced plastics. Fibre Science and Technology, 15, 41-46.
Ray, D., Sarkar, B. K., Rana, A. K., & Bose, N. R. (2001). The mechanical properties of vinylester resin matrix composites reinforced with alkali-treated jute fibers. Composites Part A, 32, 119-127.
[5]. Saha, P., Manna, S., Roy Chowdhury, S., Sen, R., Roy, D., & Adhikari, B. (2010). Enhancement of tensile strength of lignocellulosic jute fibers by alkali-steam treatment. Bioresource Technology, 101, 3182-3187.
[6]. Gassan, J., & Bledzki, A. K. (1999). Possibilities for improving the mechanical properties of jute/epoxy composites by alkali treatment of fibers. Composites Science and Technology, 59, 1303-1309.
[7]. Monteiro, S. N., Rodriguez, R. J. S., De

Souza, M. V., & D'Almeida, J. R. M. (1998). Sugar cane bagasse waste as reinforcement in low cost composites. Advanced Performance Materials, 5(3), 183-191.

[8]. Hassan, M. L., Rowell, R. M., Fadl, N. A., Yacoub, S. F., & Christiansen, A. W. (2000). Thermoplasticization of bagasse II: Dimensional stability and mechanical properties of esterified bagasse composite. Journal of Applied Polymer Science, 76, 575-586.

[9]. Ray, B. C., (2006). Loading rate sensitivity of glass fiber-epoxy composite at ambient and sub-ambient temperatures, Journal of Reinforced Plastics and Composites, 25(5), 479-490.