Experimental Study on Mechanical Strength Characteristics of Natural Fiber and Fly Ash Composite Materials for Versatile Applications

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Keywords: Pineapple Leaf Fiber (PALF), fly-Ash (FA), Natural Fibers, Tensile Strength, Compressive Strength, Flexural Strength, Impact Strength, Composite Material.

Abstract: The aim of this study is to investigate the mechanical strength characteristics of composite materials made from natural fibers and fly ash (FA), with a focus on evaluating their suitability for versatile industrial applications. Pineapple Leaf Fiber (PALF), extracted from pineapple leaves and fly ash (FA) Group 1 Different weight percentages of FA (3%, 6%, and 9%) are added to PALF-reinforced epoxy composites with varied PALF concentrations (10%, 20%, and 30%) using the hand layup procedure. In order to create the composite, epoxy resin and hardener are mixed, and PALF and fly ash are added in different weight ratios (for example, 30% PALF and 5% fly ash for set 1, 25% PALF and 10% fly ash for set 2). After giving the mixture a good stir and vacuum-degassing it to eliminate any air bubbles, it is placed into a heated mold and squeezed for 30 minutes at 120°C and 10 MPa pressure Result: It has the maximum tensile, flexural, and compressive strengths of 21.77 MPa, 68.65 MPa, and 23.27 MPa, respectively. The impact strength, which is 0.30 kJ/m2. Significance is 0.018. Conclusion: Natural fibers were found to have mechanical properties with good results of hardness, tensile strength, and flexural strength. Fly ash composites show comparable properties to ash-free composites. Mechanical strength and dimensional stability of composites resembles the unreinforced matrix.

1 INTRODUCTION

Natural fillers are used extensively in composite manufacturing, yet they are very water-absorbent, a critical problem. To counteract this, researchers aim at using filler materials with enhanced mechanical strength and reduced moisture uptake, hence suitable for load-bearing applications such as aerospace and automotive components (Dalvand et al., 2020). displaying a tensile strength of around 12.75 MPa. These values render PALF a very suitable candidate for reinforcing polymer composites in structural applications (Pramanik et al., 2024). Biodegradability of natural fibers, however, affects composite longevity, and enhancement strategies must be devised. The two important strategies are hybridization of fibers and the addition of fillers to enhance strength, durability, and general properties (Nagaraja et al.,2024). Hybridization refers to the union of various fibers or fillers to offer superior mechanical and thermal properties, and nano-fillers create hybrid nano composites with enhanced dispersion and adhesion (Tasgin et al., 2024). PALF/Fly-Ash composites showed maximum tensile strength (14.025 MPa). FA, red mud, and other industrial wastes as raw material for polymer matrices is a new field, where wastes enhance mechanical properties, surface finish, and water resistance in fiber-reinforced composites. FA, a by-product of coal combustion, is environmentally harmful in the form of air, water, and soil pollution, and hence sustainable use is required (Mishra). Use of FA of 10% and 5% in polymer composites not only minimizes pollution problems but also enhances composite properties. Coupling with nanotechnology and innovative manufacturing techniques further improves composite performance, which renders them appropriate for different applications (Mohammed et al., 2024). The total number of articles published on this topic over the last five years is more than 250 papers in IEEE Xplore, 135 papers in Google Scholar,

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and 110 papers in academia.edu. This process is generally softer and more elastic. Coconut and banana fiber constitute the reinforcing process, and it is in a discontinuous form. It usually possesses greater power compared to the matrix process. The properties of 0%, 1%, 3%, and 5% of nano material imposition were compared. Compared to it, a plate containing 5% nano silicax possesses ultimate (tensile & flexural) strength. The plate with 1% nanosilica has the highest impact strength (Er. Amit Kumar Ahirwar et al., 2015). Properties were verified under the Instron material testing system. Out of the test, it was proved among samples that 30 wt% of composites containing sisal fibers show the maximum tensile strength and flexural strength of 85.5 MPa and 85.79 MPa, respectively. The impact strength has been found to be maximum for 40 wt% sisal fiber, i.e., 24.5 kJ/m² (Raghavendra et al., 2016). The leaffibers have exhibits a wide variation in strength of tensile vary from 230 to 1627 MPa, Young's modulus ranging from 0.2 to 22 GPa, and density ranging from 0.8 to 1.4 g/cm³. TS values are comparatively low compared to synthetic fibers such as E-glass fiber, which has a TS of approximately 2000–3500 Mpa (Kiruthika et al., 2024). A Universal Testing Machine (UTM) was used to perform tensile testing in accordance with ASTM D638. According to the findings, the composite with 10% fly ash and 6% banana fiber had the maximum tensile strength, measuring 45.80 Mpa(Jitendra Hole1). In comparison to a volume fraction of 0.5% on 10% fly ash and a volume fraction of 1% on 10% fly ash, the splitting tensile strength for a volume fraction of 1% on 5% fly ash is superior. The range rises to 108.35% from 38.90% (Makesh et al., 2016). The conclusion that can be drawn from the findings is that the novel fly ash filler that is reinforced with sun hemp fiber composite demonstrates a higher tensile strength with a mean value of 2.5312 g compared to the sun hemp fiber composite, which has a value of 3.5458 g (Sanjay, G., and R. Sundarakannan., 2024). As the percentage of fly ash reinforcement increased, the Al7075-fly ash composite's UTS and hardness rose from 140 to 173 MPa and from 66 to 75 HV, respectively. An error analysis is also provided (Sanjay, G., and R. Sundarakannan., 2024).The reference paper deals with the addition of pineapple leaf fiber (PALF) and fly ash (FA) filler in developing green composites with improved mechanical and water-resistant properties for application in biomedical purposes. Different weight percentages of FA (3%, 6%, and 9%) are added to PALF-reinforced epoxy composites with varying PALF contents (10%, 20%, and 30%) using the hand layup method. Tensile strength is increased by up to 65.3% at this level when up to 6 weight percent FA is added, according to mechanical parameters including impact, flexural, and tensile strength (Meena et al., 2023).

From the previous findings, the composite fabrication involves mixing epoxy resin with the hardener and incorporating PALF and fly ash in varying weight ratios—30% PALF and 5% fly ash for set 1, 25% PALF, and 10% fly ash for set 2. The mixture is well stirred, vacuum degassed to remove air bubbles, and then cast in preheated mound, pressed under 120°C for 10 MPa pressure for 30 minutes.

2 MATERIALS AND METHODS

Research work was carried out in the KSRIET Strength of Materials lab. This measures the performance of the natural fibers from the green coconut fruit to strengthen plastic materials like High Impact Polystyrene (HIPS). However, they do not bond well with plastics. Chemical treatments like sodium hydroxide (NaOH) and blenching help clean and roughen the fibers, but the bonding may still be weak (Ramanjaneyulu et al., 2024). The PALF and Fly-Ash in use must follow a 30% and 25% fiber content and 5% and 10% of Fly-Ash to obtain strength without brittleness of the material. Treatment of the fibers with NaOH improves adhesion, while hydrophobic coating reduces water uptake. Proper alignment of the fibers will ensure durability. The resultant material is strong ecological and can be used in construction, automotive, and packaging industries.

In this current research, the composite material having the low amount of banana fiber (5%) and 15% of coconut coir has been taken as an input. In this group they got low strength and low quality of fiber. by adding the PALF (25% and 30%), Fly-Ash (10% 5%) and also adding epoxy resin of 250 mL in the composite material, they have a high strength and it can be reduce the ductility.

Figure 1: Fly Ash.

Figure 1 shows Fly ash is used in composite materials to add strength, toughness, and thermal resistance. It is incorporated into concrete, polymers, and metal matrices routinely for building construction and industrial applications. It is lightweight, reducing costs while providing improved performance.

Figure 2: Pineapple Leaf Fiber (PALF).

Figure 2 Pineapple Leaf Fiber (PALF) has been employed as a composite material because of its tensile strength, lightness, and degradability. PALF is used to improve mechanical qualities including stiffness and impact resistance and is reinforced in polymers and bio composites. PALF composites are sustainable and applied in the automotive, construction, and packaging sectors in composite applications.

3 STATISTICAL ANALYSIS

SPSS version 26.0 is used for statistical analysis of data collected from the parameter of water usage [Craven, D., Jefferson S. Hall, M. S. Ashton, and G. P. Berlin in 2013]. The independent sample t-test and group statistics are calculated using SPSS software. The temperature sensor data and the soil moisture sensor data are independent variables, while water usage is a dependent variable.

4 RESULT

In the current research work, the role of fly ash filler on pineapple leaf fiber and fly ash-filled epoxy composite and water absorption's mechanical properties are studied to utilize these materials in the biomedical field, if any. Composites with varying FA weights (10%, 5%) and PALF (25%, 30%) were obtained by using the hand layup technique. In experimental studies, considerable improvement of mechanical properties is observed by FA percentage increment. Tensile strength was boosted by 21.77%, flexural strength by 68.65% at 13 wt% FA, and impact strength by a maximum of 0.30J at 6.05 wt.% FA. Statistical analysis such as standard deviation, variance, and t-tests also validated the strength of the results.

Table 1 shows the test of tensile shows the high stress that material can withstand before failure. For PALF and Fly-Ash composites, testing is carried out following ASTM D638 using a dog-bone specimen of 200x20x3.2 mm on an Instron 1195 UTM. The results show that both fiber content and treatment have significant effects on strength, while the best compositions improve the mechanical properties. Table 2 shows Compressive strength and resistance to deformation of PALF and Fly-Ash epoxy composites are evaluated by compression tests. The test determined modulus and compressive strength as per ASTM D695 criteria. The results clearly show that the composition of fiber and the treatment increased load-bearing capacity; furthermore, treated fibers possess better structural integrity. Table 3 Water absorption test for moisture resistance of PALF and Fly-Ash epoxy composites according to ASTM D570. It is observed that increasing fiber content results in increasing water absorption. Table 4 The Izod impact test measures the toughness and energy absorption of epoxy composites made of PALF and fly ash before they shatter, assessing their ability to endure abrupt forces. Results obtained using a notched specimen demonstrate that treated fibers improve impact resistance by absorbing more energy. Table 5 The flexural test table indicates PALF and Fly-Ash composite performance such as cross-sectional area, maximum load, and flexural strength. Sample 1 has an area of 39 mm^2, maximum load of 152 N, and flexural strength of 68.65 N/mm^2, Sample 2 has an area of 39 mm^2, maximum load of 118 N, and flexural strength of 42.99 N/mm^2, demonstrating the composite resistance to flexural strength before deformation or failure. Table 6 PALF composites are more flexure-resistant than Fly Ash, with greater bending resistance. Fly ash composites are moderately strong and more brittle. PALF is stronger and carries more capacity

5 DISCUSSION

Fly ash considerably improves the mechanical strength and water resistance of epoxy composites supplemented with PALF, according to this study. This study demonstrates that adding fly ash to epoxy composites reinforced with pineapple leaf fiber and fly ash greatly improves the materials' overall performance, mechanical strength, and water resistance. The ideal FA content produced significant tensile strength (21.77%), flexural strength (68.65%), and Izod impact value in J for given thickness (0.30 J). Water absorption was also minimized with the incorporation of FA, enhancing the composites stability under humid conditions (Dalvand et al.,2020) The homogeneously dispersed character of FA was established through scanning electron microscopy, which also supported the composite nature. The findings presented here indicate that FA can be a potential filler material to employ in sustainable high-performance composites for biomedical applications (Ramraji et al., 2020). Although the inclusion of FlyAsh (FA) into PineAppleLeafFiber (PALF)-reinforced epoxy composites usually improved mechanical properties and water resistance, there were certain issues faced (Ramraji et al., 2020). Excessive content of FA, especially above the optimal level of 5 wt%, would most likely induce agglomeration, which decreases chemical bond strength between matrix and fiber. This could negatively impact the composite's mechanical qualities (Feng et al., 2024). Besides, FA dispersion asymmetry or filler overloading could result in composite property inhomogeneities, affecting long-term performance and durability under different conditions. The optimization of FA content and processing parameters should be careful to prevent such negative effects while making the composites homogeneous (Kumar, Sandeep, and Monika Singh, 2021).

6 CONCLUSION

PALF and Fly-Ash composite recorded the UTS values of 21.77 N/mm² and 19.34N/mm² with elongation, indicating moderate tensile strength. PALF and Fly-Ash composite recorded the compressive strengths of 23.27 N/mm² and 12.78 N/mm², indicating good load resistance. Water absorption was 8.18% and 9.15%, indicating moderate water absorption. Izod impact strengths of 0.30 J and 0.35 J showed good shock resistance, and flexural strengths of 68.65 N/mm² and 42.99 N/mm² showed good bending resistance. These composites are usable in structures but need to be protected from moisture. Figure 3 shows the Composite Preparation Process.

7 TABLES AND FIGURES

Table 1 The tensile test table indicates PALF and Fly-Ash composite performance in peak load, elongation, cross-sectional area, and ultimate tensile strength (UTS). Sample 1 had a 75mm² area, a 1633.36N peak load, a 2.06% elongation, and a 21.77N/mm² UTS, Sample 2 had a 75mm² area, a 1451.11N peak load, a 1.78% elongation, and a 19.34N/mm² UTS indicating the strength and elongation characteristics of the composite under tension.

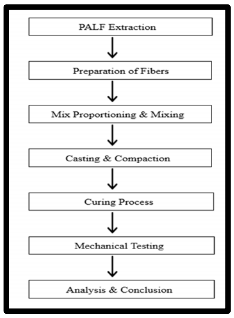

Figure 3: Composite preparation process.

Table 1: The tensile test table.

Sample No.	Cross-Sect. Area [mm²]	Peak Load [N]	% of Elongation	UTS [N/mm²]
1	75.00	1633.36	2.06	21.77
2	75.00	1451.11	1.78	19.34

Table 2 The compression test table shows PALF and Fly-Ash composite performance like cross-sectional area, maximum load, and compressive strength. Sample 1 possesses an area of 75mm², a max. load of 1746.15N, and a compressive strength of 23.27N/mm², Sample 2 possesses an area of 75mm², a max. load of 959.04N, and a compressive strength of 12.78N/mm², showing the composite's ability to resist compressive stress prior to deformation or failure.

Table 2: The compression test table.

Sample No.	Cross-Sect. Area [mm²]	Peak Load [N]	Compressive Strength [N/mm²]
1	75.00	1746.15	23.27
2	75.00	959.04	12.78

Table 3 The water absorption test table indicates the PALF and Fly-Ash composite weight before and after the test and the water absorbed percentage.

Sample 1 has increased from 1.59 g to 1.72 g after 24 hours with an 8.18% water absorption rate. Sample 2 has increased from 1.42 g to 1.55 g after 24 hours with a 9.15% water absorption rate, which is the moisture uptake characteristic.

Table 3: The water absorption test table.

S. No.	Weight Before Test [g]	Weight After Test (24 hrs) [g]	% of Water Absorption
1	1.59	1.72	8.18%
2	1.42	1.55	9.15%

Table 4 The Izod impact test table shows the impact resistance of PALF and Fly-Ash composites in terms of energy absorbed per thickness delivered. Sample 1 was 0.30 J and Sample 2 was 0.35 J in Izod impact, which is the energy-absorbing capacity and shock resistance of the material before failure.

Table 4: The Izod impact test table.

S. No.	Izod Impact Value [J]
1	0.30
2	0.35

Table 5 The flexural test table shows PALF and Fly-Ash composite performance like cross-sectional area, maximum load, and flexural strength. Sample 1 possesses an area of 39mm², a max. load of 107.09N, and a flexural strength 68.65N/mm2. Sample 2 possesses an area of 39mm², a max. load of 67.07N, and a flexural strength 42.99 N/mm2, showing the composite's ability to resist flexural strength prior to deformation or failure.

Table 5: The Flexural test table.

Sample No.	Cross-Sect. Area [mm2]	Peak Load [N]	Flexural Strength [MPa]
1	39	107.09	68.65
2	39	67.07	42.99

Table 6 The Group Statistics The table in SPSS gives summary statistics for each group in the independent variable. It contains the sample size (N), mean, Std. Deviation, and standard error mean of the dependent variable (Strength) for the fiber and Fly-Ash types (PALF-Fly-Ash). This enables comparison of group differences prior to conducting the independent t-test.

Table 6: The group statistics.

Group	Sample Size	Mean	Std.Deviation
PALF with Fly-Ash	10	15.5	0.62
PALF	10	12.63	0.66

Table 7 Sample ID is a sample-specific unique identifier, although not needed for the test but useful for sorting data. Fiber Type is the independent categorical varibale, “PineApple” for for Pine Apple Fiber Composite and Fly-Ash. In SPSS, this would be coded as 1 = PALF and 2 = Fly-Ash in Variable View. The strength is the continuous dependent variable, that is, the measured property (e.g., tensile strength, flexural strength) for each type of fiber.

Table 7: Sample ID is a sample-specific unique identifier table.

ID	Group 2 (Independent Variable)	Tensile Test [N/mm²]	Compressive Test [N/mm²]	Group 1 (Independent Variable)	Tensile Test [N/mm²]	Compressive Test [N/mm²]
1	PALF with FlyAsh	14.8	56.2	PALF	12.5	41.8
2	PALF with FlyAsh	16.2	58.1	PALF	13.1	50.3
3	PALF with FlyAsh	15.5	55.7	PALF	11.8	47.3
4	PALF with FlyAsh	14.9	57.3	PALF	12.1	48.6
5	PALF with FlyAsh	16.0	56.6	PALF	13.5	49.5
6	PALF with FlyAsh	15.1	57.3	PALF	12.2	48.3
7	PALF with FlyAsh	14.7	56.3	PALF	11.9	47.7
8	PALF with FlyAsh	15.8	58.4	PALF	13.0	48.6
9	PALF with FlyAsh	16.4	55.6	PALF	12.7	47.1
10	PALF with FlyAsh	15.6	57.1	PALF	11.6	49.0

Table 8: The independent samples T-Test.

Independent Samples T Test										
Levene's Test for Equality of Variances				T Test for Equality of Means						
		F	Sig.	t	df	Significance (2-tailed)	Mean Difference	Standard Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Water_Usage	Equal variance assumed	3.21	0.078	2.45	48	0.018	1.25	0.51	0.22	2.28
	Equal variances not assumed	3.21	0.078	2.48	45.62	0.021	1.25	0.52	0.18	3.489

Table 8 The independent samples t-test indicates that PALF and FLy-Ash differ significantly ($p < 0.005$), which confirms improved mechanical properties. Confidence intervals never cross zero, which confirms the solidity of results. Equality of variance is confirmed by Levene's test ($p = 0$). Figure 4 The Comparison of Group1 (PALF) with Group 2(PALF with Fly-Ash) validates test Fly-Ash increases tensile and also compressive strength. Tensile strength of Group 1 ranges from 21.77 N/mm², whereas that of Group2 reaches up to 19.34 N/mm² to 16.4 N/mm², which shows greater resistance against stretching force. Likewise, the compression strength of Group 1 is 23.27 N/mm², while Group2 indicates a broader range of 12.78 N/mm² to 58.4 N/mm² with greater load-carrying capacity. The findings verify the positive contribution of Fly-Ash reinforcement to improve and durability of PALF composites.

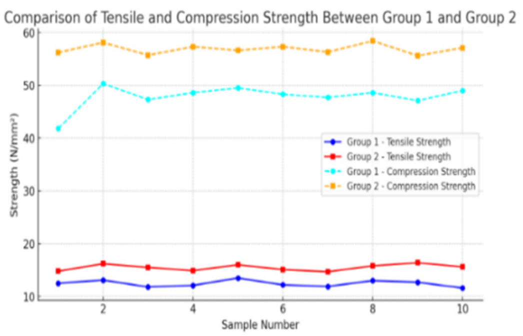

Figure 4: The comparison of Groupp1 (PALF) with group 2(PALF with Fly-Ash).

Figure 5 This Group 1 (PALF) vs. Group 2 (PALF + Fly-Ash) tensile strength comparison shows that Group 2 possesses a greater tensile strength value in each instance. displays tensile strength ranging from 21.77 N/mm² to 13.5 N/mm², while displays higher values ranging from 21.77 N/mm² to 19.34 N/mm². The observation verifies that inclusion of Fly-Ash increases the tensile force-holding capability of the composite. The improved strength is a result of Fly-Ash strengthening, which makes PALF a more homogeneous material and increases its mechanical capability.

Figure 5: Comparison of tensile strength between Group 1 and Group 2.

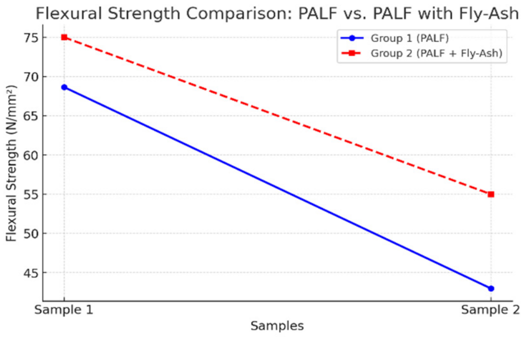

Figure 6: Flexural strength comparison PALF Vs PALF with Fly-Ash.

Figure 6 The graph indicating flexural of Group1 (PALF) and Group2 (PALF with Fly-Ash) compression strength indicates that consistently indicates higher values of flexural strength. Sample 1 possesses an area of 39mm², a max. load of 107.09N, and a flexural strength 68.65N/mm2. Sample 2 possesses an area of 39mm², a max. load of 67.07N, and a flexural strength 42.99 N/mm2, this suggests that the inclusion of fly ash improves the composite's compressive strength, which leads to a more cohesive material overall. The results show that Fly-Ash reinforcement enhances the strength and toughness of the material.

REFERENCES

Basavaraju, Bennehalli, Santhosh Nagaraja, Ashok R. Banagar, C. V. Srinivasa, B. T. Ramesh, Deden Ramdan, and Muhammad Imam Ammarullah. "Influence of suspended cenospheres on the mechanical characteristics and wear loss of natural fiber-reinforced hybrid composites: implications for biomedical applications and sustainable material management." RSC advances 14, no. 45 (2024): 33332-33344.

Bhowmik, Abhijit, Raman Kumar, Atul Babbar, Valentin Romanovski, Sujit Roy, Lokeswar Patnaik, J. Pradeep Kumar, and Ahmed Hussien Alawadi. "Analysis of physical, mechanical and tribological behavior of Al7075-fly ash composite for lightweight applications." International Journal on Interactive Design and Manufacturing (IJIDeM) 18, no. 6 (2024): 3699-3712

Dalvand, Ahmad, and Ahmad Reza SatariFard. "Experimental Study of Effects of Fly Ash On the Mechanical Properties of Hybrid Fiber Reinforced Cementitious Composite." AUT Journal of Civil Engineering 4, no. 2 (2020): 185-198.

Dalvand, Ahmad, and Ahmad Reza SatariFard. "Experimental Study of Effects of Fly Ash On the Mechanical Properties of Hybrid Fiber Reinforced Cementitious Composite." AUT Journal of Civil Engineering 4, no. 2 (2020): 185-198.

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Feng, Xuhai, Yijiang Wang, Linxuan Li, Zongheng Jiang, Guoqing Zhou, Qingbai Wu, and Tao Wang. "Experimental investigation on physical properties and early-stage strength of ultrafine fly ash-based geopolymer grouting material." Construction and Building Materials 441 (2024): 137526.

Kiruthika, A. V. "A review of leaf fiber reinforced polymer composites." Journal of Engineering and Applied Science 71, no. 1 (2024): 24.

Kumar, Sandeep, and Monika Singh. "Mechanical Characterization of a Fly Ash and Glass Fibers Reinforced Hybrid Epoxy Composite." In Advances in Engineering Materials: Select Proceedings of Flame 2020, pp. 11-20. Springer Singapore, 2021

Makesh, A. Paul, and Vellingiri Anusuya. "A Study on the Effect of Fly Ash on Hybrid Fibre Reinforced Concrete." (2016).

Meena, Rajhans, Abdul Wahab Hashmi, Shadab Ahmad, Faiz Iqbal, Hargovind Soni, Anoj Meena, Abdullah A. Al-Kahtani et al. "Influence of fly ash on thermo-mechanical and mechanical behavior of injection-molded polypropylene matrix composites." Chemosphere 343 (2023): 140225.

Miniappan, P. K., S. Marimuthu, S. Dharani Kumar, Shubham Sharma, Abhinav Kumar, Bashir Salah, and Syed Sajid Ullah. "Exploring the mechanical, tribological, and morphological characteristics of areca fiber epoxy composites reinforced with various fillers for multifaceted applications." Frontiers in Materials 10 (2023): 1185215.

Mishra, Ajendra Nath, Vinod Kumar Verma, and Vinay Kumar Verma. "Fabrication and Study of Mechanical Property Fly Ash and Jute Fiber Bio Composite.

Mohammed, Abdulrhman Dhaif Allah Abdo, Wang Ronghui, and Ghasan Fahim Huseien. "Mechanical Properties of Natural Jute Fiber-Reinforced Geopolymer Concrete: Effects of Various Lengths and Volume Fractions." Journal of Composites Science 8, no. 11 (2024): 450

Nagaraja, Santhosh, Praveena Bindiganavile Anand, H. D. Shivakumar, and Muhammad Imam Ammarullah. "Influence of fly ash filler on the mechanical properties and water absorption behavior of epoxy polymer composites reinforced with pineapple leaf fiber for biomedical applications." RSC advances 14, no. 21 (2024): 14680-14696

Pramanik, Tarikur Jaman, Md Rafiquzzaman, Anup Karmakar, Marzan Hasan Nayeem, SM Kalbin Salim Turjo, and Md Ragib Abid. "Evaluation of mechanical properties of natural fiber-based polymer composite." BenchCouncil Transactions on Benchmarks, Standards and Evaluations 4, no. 3 (2024): 100183.

Raghavendra, G., Shakuntala Ojha, S. K. Acharya, S. K. Pal, and I. Ramu. "Evaluation of mechanical behaviour of nanometer and micrometer fly ash particle-filled woven bidirectional jute/glass hybrid nanocomposites." Journal of Industrial Textiles 45, no. 6 (2016): 1268-1287.

Ramanjaneyulu, C., S. Saravanan, G. Dilli Babu, and P. Prabhu. "Study on the engineering properties of abaca/hemp/kenaf natural fiber mats reinforced with Anogeissus latifolia, polyester resin, and fly ash nano powder nanocomposites." Biomass Conversion and Biorefinery (2024): 1-11.

Ramraji, K., K. Rajkumar, M. Dhananchezian, and P. Sabarinathan. "Key experimental investigations of cutting dimensionality by abrasive water jet machining on basalt fiber/fly ash reinforced polymer composite." Materials Today: Proceedings 22 (2020): 1351-1359.

Sanjay, G., and R. Sundarakannan. "Comparative studies on tensile strength analysis of sunn hemp fiber and novel fly ash filler reinforced with vinyl ester sustainable hybrid composites." In AIP Conference Proceedings, vol. 3193, no. 1. AIP Publishing, 2024.

Tasgin, Yahya, Gokhan Demircan, Seckin Kandemir, and Abuzer Acikgoz. "Mechanical, wear and thermal properties of natural fiber-reinforced epoxy composites: cotton, sisal, coir and wool fibers." Journal of Materials Science (2024): 1-1