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Mechanical Behaviour of Natural Fibre Reinforced Composite

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Abstract
The world eagerly seeks innovative materials to address issues in current products, such as non-biodegradability, environmental pollution, carbon emissions, the greenhouse effect, disposal challenges, cost, weight, and manufacturing complexity. This study entails the fabrication of a natural fiber (NF) hybrid composite, utilizing Sisal and Roselle natural fibers as reinforcing agents, in conjunction with epoxy resin (LAPOX L12) and Hardener or catalyst (K6), with a predetermined ratio of 35:75, employing a hand lay-up method. The mechanical and physical performance of loose and Continuous Fiber Reinforcement (CLFR) and woven mat fiber reinforced (WMFR) hybrid composite laminates were systematically assessed to gauge their efficacy. Concurrently, the mechanical performance of the composites subjected to a 20-day aging process in distilled water was examined and compared with the performance of composites tested in a dry state. Findings reveal that tensile, flexural, compressive and impact properties of the composite in a dry condition surpass those of wet samples, while the impact strength demonstrates an increase post-water absorption. This comprehensive analysis contributes valuable insights into the potential engineering applications of these NF-based hybrid composites as sustainable alternatives to synthetic fiber composites and plastic products.
Keywords: *Natural Fiber, Reinforcing Agent, Hand Lay-Up, Epoxy, Hardener.*

1. Introduction
Composite materials are multiphase materials comprising of two or more components possessing special properties. Over the past few decades, composites, plastics, and ceramics have dominated the field of creating materials. Composite materials have gradually increased in volume and number of uses, relentlessly entering and dominating ne areas. Due to the enormous size of the transportation industry, the composites industry has started to realize that commercial uses of composites promise to give considerably larger business potential than the aerospace industry. Natural fibers are best for replacement of synthetic fiber as reinforcement in polymer composite because of their excellent properties such as low density, low cost, high impact resistance and high flexibility, less health hazard and eco-friendly.[1], [2], [3] Natural fiber reinforced hybrid composites are superior to petroleum-based composites because they have a higher strength-to-weight ratio, a low manufacturing cost due to their facile processes, and are environmentally beneficial. As a result, natural fiber composites have numerous advantages in commercial, industrial, and engineering applications.[4], [5] Mechanical properties of sisal fiber reinforced high density polyethylene composites have the fiber content, interfacial bonding, manufacturing process have significant effects on the tensile, compressive and impact properties of sisal fiber reinforced composites. As the fiber content increases, the tensile strength, tensile modulus, and creep-resistance of the composites increases. Interfacial adhesion between the sisal fibers and the PE matrix significantly improves properties.[6] The tensile, flexural, and impact strength of jute fiber reinforced high density polyethylene composites was found to rise with the increase in fiber loading up to 30%, according to Mohanty's study of the mechanical and viscoelastic behavior of these materials. In contrast to epoxy, storage modulus increased as fiber loading increased but damping characteristics decreased. Girish 2015 investigation on the mechanical characteristics and

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water absorption behavior of an epoxy composite reinforced with sisal and coconut coir fibers. They emphasized that sisal fiber and coconut coir epoxy composite hybridization resulted in increased mechanical qualities and decreased water absorption. Venkateswaran 2015 Investigated the effect of Sisal fiber loading on mechanical and water absorption properties of Banana fiber reinforced epoxy composite and reported that the addition of Sisal fiber results in increased mechanical properties and decreased water absorption properties of Banana fiber reinforced epoxy composite.[6], [7] [8] The primary aim of this research paper is to provide a comprehensive exploration of the manufacturing process involved in creating a hybrid composite material by reinforcing epoxy with a combination of Sisal and Rosselle fibers composites (20+15% fiber content). The study further seeks to assess the mechanical characteristics of the resulting composite through an in-depth analysis of various properties, including tensile strength, compression resistance, bending behavior, and impact resistance. The investigation also incorporates a detailed fractography study, which involves the examination of the composite's fracture surfaces to gain insights into the material's failure mechanisms. The suggested sisal-Roselle fiber reinforced epoxy hybrid composites were discovered to be excellent for low weight automobile parts, furniture, interior, home appliances, and construction applications.

2. Materials and Methods

2.1 Sample Preparation

A steel mold of dimensions 300mm x 300mm x 5mm and 300 x 300 x 12 mm was fabricated for composite preparation as shown in Fig.1a. Two mild steel (MS) plates measuring 400 x 400 x 6 mm, exhibiting excellent surface finish and flatness, were meticulously crafted as backing plates for the steel mold during compression in a compression molding machine. Additionally, an aluminum tray was prepared to accommodate all molds during fabrication, serving the primary purpose of containing spill-out resin mixtures that may occur during compression. The assembled mold, complete with back plates, was meticulously arranged, with polythene or thin plastic sheets utilized at the top and bottom of the mold plates to prevent resin adhesion and ensure a refined surface finish of the fabricated laminate. A releasing agent (silicon spray) was applied to the mold to facilitate easy removal of the laminate. Subsequently, the fiber was prepared using the hand lay-up technique. The fiber sample, comprising 15% Roselle (shown in the Fig 1.b) and 20% Sisal (shown in the Fig 1a, Fig 1c, Fig 1d & Fig 1e) natural fibers by volume, employed epoxy resin LOPOX L12 in Fig.1 b(75% by weight) and hardener K-6 in Fig.1 b(35% by weight) as adhesive agents.[9], [10], [11], [12], [13]This methodological approach adheres to established protocols for composite preparation, ensuring precision and reliability in the experimental process. Sisal and Roselle fibers were purchased in Go green products, Chennai, Tamil Nadu and Epoxy resin (LOPOX L12) manufactured by ‘ATUL Limited’ Ahmadabad, ‘Yuje Entprises’, Malleshwaram, Bangaluru.

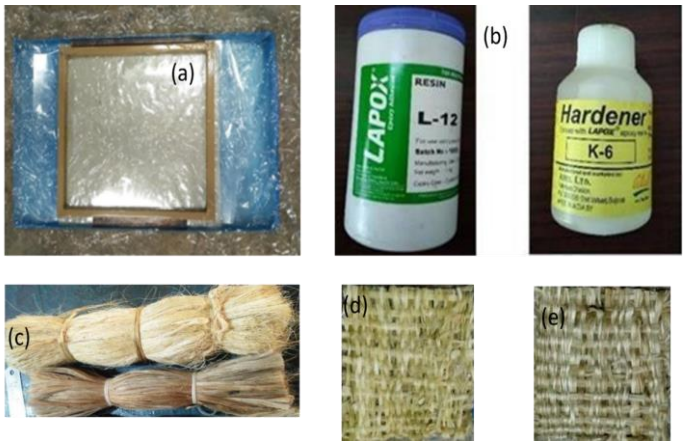

Figure 1 (a) Steel Mold and Tray Trapped with Polyethene Cover, (B) Epoxy and Hardener, (C) Sisal and Roselle Fiber Bundles, And (D), (E) Sisal and Roselle Fabricated Laminates

2.2 Test Specimen Preparation

The specimens are cut from fabricated laminate. The cutting of the composites sheet is done by the CNC machine. Weight % of reinforcement considered for laminate fabrication was given in the Table 1, and determined through rule of mixture principle [18]. The geometry of composite materials was made according to ASTM-D-638 in Fig 2.a for tension[14], ASTM-D695- 02a in Fig 2.b for compression[15],

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ASTM-D7264 in Fig 2.c for bending [16]and ASTM-A 370 in Fig 2.d & Fig 2.e for Impact test.[17] and shown in Figure 2 a,b,c and d.The tensile strength, compression strength, flexural strength was done in Universal testing machine called (SHIMADZU autograph AGX plus 1000KN) at NITK shown in Figure and Instrumented Impact tester(H IT450P/HIT300P ,ZWICKROELL,Germany) was done at CRF, NITK shown in Figure 3 a, b, c and d. In the tensile test, a uniaxial load was applied to both ends of the specimen, with three sample tested per composite type. The maximum value obtained was used for result calculations. The experimental setup for the tensile test is shown in Figure 3 a.[19] For the compressive test, a uniaxial load was applied to both ends of the specimens, with the experimental setup illustrated in Figure 3 b. These tests were conducted to evaluate the tensile and compressive strength of the fabricated composite, intended to replace items such as snack tables in flight and train, showcases, and household dustbins currently made of wood and plastics. The fabricated composite is expected to exhibit equal or greater strength compared to objects made solely of wood and plastics.[19] The three-point bend test aimed to assess the flexural strength and modulus of the composites, crucial parameters for structural materials. A crosshead speed of 1 mm/min was utilized during testing, as depicted in Figure 3 c. This test was conducted to ascertain the flexural strength of the fabricated composite, intended to replace wooden and plastic objects such as snack tables in flights and trains, showcases, household and dustbins.[19] The specimens prepared for impact test to evaluate impact strength and energy absorbed for hybrid composite specimens. Impact test of the samples has done to check the Impact strength of the fabricated composite because fabricated composite is going to replace some of the objects which are made of wood and plastics like snacks tables in flight and train, showcase and dustbins used in household applications. The fabricated composite should be of equal in strength or more than that of an object made of wood and plastics. The loading arrangement for the impact test is shown in Figure 3 d. Rule of mixture can be used to estimate the weight of fiber and epoxy to be used in composite fabrication.[18]

Table 1 Type of Composites Fabricated

Composites	Materials
Continuous Loose fiber reinforced composite (CLFR)	20 Vol. % Sisal Fiber + 15 Vol. % Roselle+10 wt. % Hardener + 55 Vol. % Epoxy
Woven Mat fiber reinforced. composite (WMFR)	20 Vol. % Sisal Fiber + 15 Vol. % Roselle+10 wt. % Hardener + 55 Vol. % Epoxy

Figure 2 Test Specimen (a) Tensile(b) Compression (c) Flexural (d) Impact e) Sisal Roselle/Epoxy Hybrid polymer composite Specimen Under Tensile Test, f) Composite Under Compression Test, g) Flexural Sample Under Test, h) Impact Sample Under Test

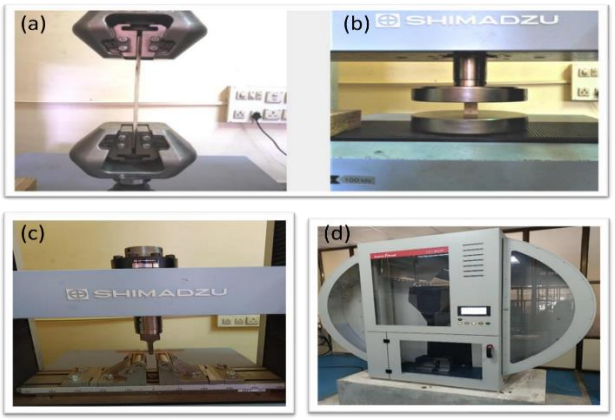

Figure 3 A) Sisal Roselle/Epoxy Hybrid Polymer Composite Specimen Under Tensile Test, B) Composite Under Compression Test, C) Flexural Sample Under Test, D) Impact Sample Under Test

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3. Result and Discussion

3.1 Tensile Properties

A total of 4 samples were tested for tensile property. The prepared samples of CFLR and WMFR were tested for both wet and dry conditions. The obtained tensile properties were recorded in the table with respective plots.

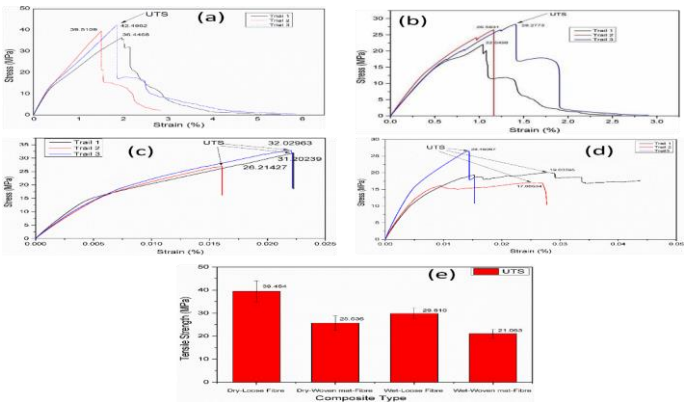

Figure 4 A) Dry-CLFR Composite, B) Dry-WMFR Composite, C) Wet-CLFR Composite, D) Wet-WMFR Composite, E) Comparison Of UTS

Tensile Strength of 35 Vol. % of untreated CLFR composite is much better than WMFR Composite (dry). The tensile strength and modulus of WMFR Composite (dry) reduced by 35% and 17% respectively. After ageing in water for 20days, UTS reduced by 24 % for CLFR and 17% for WMFR composite.[20], [21]. The tensile strength and tensile Modulus of Loose-Continuous fiber reinforced (CLFR) hybrid composite is 39.484 MPa and 4.126 GPa in dry state which is higher than woven mat fiber reinforced. (WMFR) composite of both states. All fibers are oriented in one direction that is in longitudinal direction (0o). The individual strength of all fibers embedded in matrix contributes their individual strength together gives raise better composite strength. The property is said to be anisotropic. Anisotropic Composites provide greater strength and stiffness than do isotropic materials. But the material properties in one direction are gained at the expense of the properties in other directions. [22], [23]. According to literature, the tensile strength of composite in longitudinal direction is much higher than in transverse direction. In Woven mat, the fibers are arranged equally in either direction (longitudinal transverse) Fig 4a, Fig 4b, Fig 4c, Fig 4d & Fig 4e. Volume of fibers in loading direction will be less; hence the contribution of resistance from the fibers to tensile loading is less, but the tensile properties are same in both directions. In case of Wet state, a set of samples soaked in distilled water were tested for tensile properties. The results are evident that there is decrease in the strength and modulus if composite or fiber absorbs water due to its hydrophilic character (Maximum: 10-15%). In Fig 5 a, due to moisture absorption, the adhesion or interaction between matrix and fillers gets reduced (de- bonding), this will lead to fiber pull-out. The fracture or failure observed is brittle in nature since matrix material epoxy is highly brittle in nature.[24] The failure of CLFR composite occurs at 1.761% of strain rate, which shows small ductility, but WMF exhibits little higher brittleness than CLFR composites, fails at 1.035% of strain rate. In wet state, the failure of CLFR composite occurs at 2.08% of strain rate and 2.511% for WMFR. This shows composites gain ductile properties once absorb water. Fig 5 b) SEM images reveal the occurrence of fiber rupture, providing a detailed visual representation of the structural damage, Fig c) SEM images reveal the extraction and detachment patterns of bonded materials.

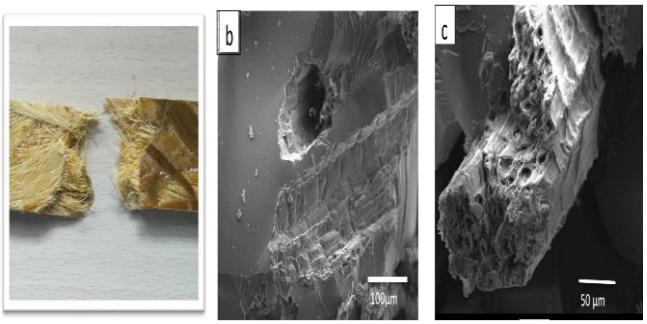

Figure 5 (a) Pull Out and De-Bonding of Fiber B) Fiber Rupture, C) Pull Out and De-Bonding Traces

Tensile modulus is dependent on the fiber property in a composite material and can be affected because of water absorption, whereas the tensile strength of the composite is more sensitive to fiber-matrix interface, shown in Table 2.[25]

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Table 2 Tensile Properties

Type of composite	Dry Loose-Continuous				Wet Loose-Continuous			
Trails	UTS (MPa)	AVG UTS in MPa	Avg Max. Strain in %	Modulus in GPa	UTS in MPa	AVG UTS in MPa	Avg Max. Strain in %	Modulus in GPa
1	36.447	39.484	1.761	4.126	31.202	29.810	2.088	3.265
2	39.511				26.214			
3	42.496				32.030			
Type of composite	Dry Woven-Mat				Wet Woven-Mat			
1	22.050	25.636	1.035	3.456	19.034	21.063	2.511	2.897
2	28.277				17.665			
3	26.583				26.491			

3.2 Compression Test

The composite specimens were tested for Compressive properties in UTM and obtained tensile properties are recorded in the table with respective plots, shown in Fig 6a, Fig 6b, Fig6c, Fig 6d & Fig 6e. On keen observation of the tabulated results, the changes in the compression strength and modulus are same as that of tensile properties. Here also, the compression strength and modulus of CLFR composite is 90.270 MPa at 6.089% of strain rate comparatively higher than WMFR composite in both wet and dry condition test. But strain rate reduces as composite absorbs water, which is opposite to the tensile nature. Compressive Strength and modulus of WMFR Composite (dry) reduced by 17% and 33% respectively. After ageing in water for 20days, US reduced by 43 % for CLFR and 38% for WMFR composite.[26] Fig 7-a), b) and c) shows that during compression, the water trapped in hydrophilic structure is squeezed. The internal pressure on fiber wall of the composite increases, as it reaches too critical. Value the crack starts propagating (rupture the fiber), and sample fails quickly without showing much strain rates as in case of tensile. In dry state, the drop in compression strength from CLFR (77.344MPA) to WMFR composite 63.719 MPa is too large. In wet state the drop in compression strength is too small (43.868MPa to 39.369MPa). The strength is highly sensitive to the nature of fiber stacking used in dry state, but lesser in wet state irrespective of type composite. Fig 7 d) In SEM image, there is evident failure at the fiber-matrix interface, specifically in a dry condition, whereas Fig 7 e) SEM images reveal extensive damage and sudden failure, shown in Table 3.[25]

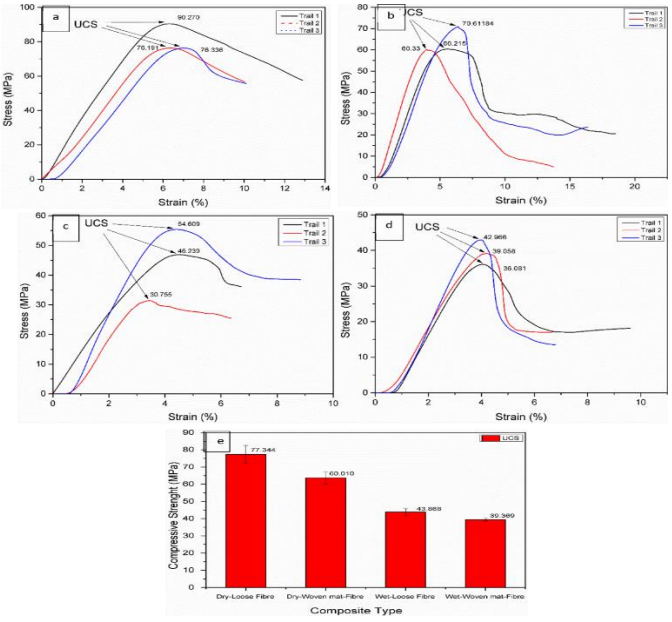

Figure 6 A) Dry-CLFR Composite, B) Dry-WMFR Composite, C) Wet-CLFR Composite, D) Wet-WMFR Composite, E) Comparison of UCS.

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Page No: 2114- 2125
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0288

Table 3 Compressive properties

Type of composite	Dry-Continuous-Loose Fiber (CLFR)				Wet-Continuous-Loose Fiber (CLFR)			
Avg of best of 3 trails	UTS in MPa	AVG UTS in MPa	Avg Max. Strain %	Modulus in GPa	UTS in MPa	AVG UTS in MPa	Avg Max. Strain %	Modulus in GPa
1	90.270	**77.344**	6.089	**18.626**	46.239	**43.868**	4.503	**14.540**
2	76.336				30.755			
3	76.191				54.609			
Type of composite	Dry - Mat Fiber Composite (WMFR)				Wet - Mat Fiber Composite (WMFR)			
1	70.612	**63.719**	4.762	**12.454**	36.081	**39.369**	4.048	**9.912**
2	60.331				39.058			
3	60.215				42.966			

Table 4 Flexural properties

Avg of best of 3 trails	Dry-Continuous-Loose Fiber (CLFR)				Wet - Continuous Loose Fiber (CLFR)			
	UFS in MPa	AVG UFS in MPa	Avg Max. Strain %	Modulus in GPa	UFS in MPa	AVG UFS in MPa	Avg Max. Strain %	Modulus in GPa
1	150.085	**126.084**	3.725	**8.246**	60.340	**66.942**	3.958	**5.199**
2	105.131				66.404			
3	123.035				74.082			
Dry - Mat Fiber Composite (WMFR)					**Wet - Mat Fiber Composite (WMFR)**			
1	82.950	**78.841**	2.615	**5.233**	47.222	**46.363**	3.380	**4.369**
2	79.193				46.870			
3	74.381				44.998			

3.3 Flexural Strength

Flexural strength and modulus of composite are important parameters which decide the suitability of component in particular application. The Test results are tabulated as follows. Flexural strength and modulus of WMFR Composite (dry) reduced by 37% and 36% respectively shown in Table 4. After ageing in water for 20days, the US reduced by 47 % for CLFR and 41% for WMFR composite. Flexural strength is higher for dry condition than aged in water as well compared to Woven mat composites.

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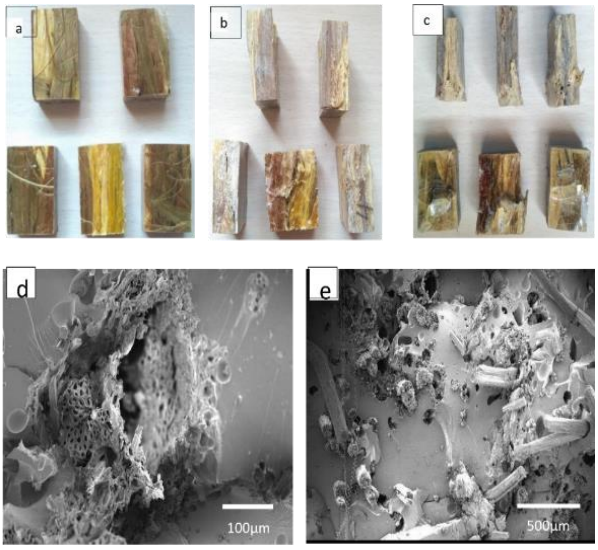

Figure 7 a) Compression Samples Before Test, B) Dry-CLFR, C) Wet-WMFR Samples After Test. D) Fiber - Matrix Failure (Dry), E) Severe Damage and Abrupt Failure

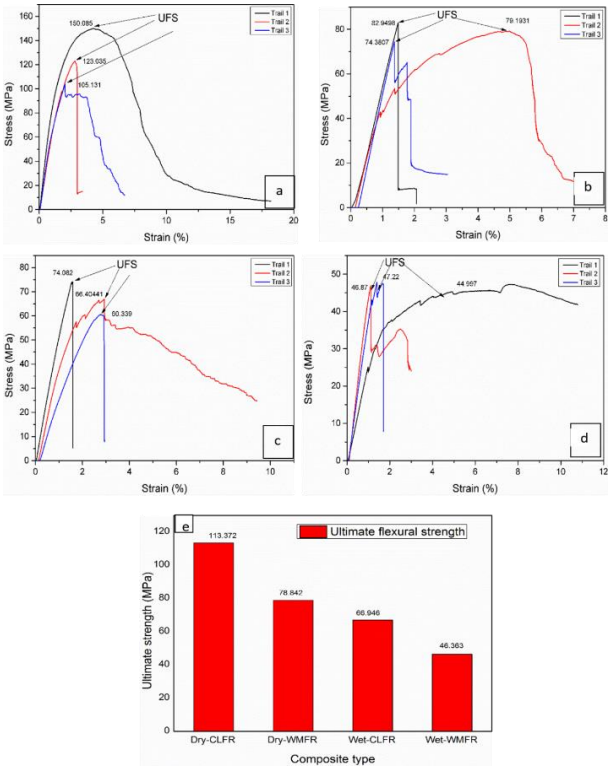

Figure 8 a) Dry-CLFR Composite, B) Dry-WMFR Composite, C) Wet-CLFR Composite, D) Wet-WMFR Composite, E) Comparison Of UFS

Flexural strength of CLFR composite is high due to the increase of transferred load from matrix to the fibers, because of the higher adhesion at interface zone (fiber-matrix) region, and due to the property of cellulose fibers as flax fiber to support bending loads shown in Fig 8a, Fig 8b, Fig 8c, Fig 8d & Fig 8e. Figure 9 a) and b) shows the flexural failure mode for both dry and water immersed samples occurs in the same way. The specimen fails suddenly in a linear mode at the bottom surface of the specimen. As a result of the fact that there is no inter-laminar failure at the thickness of the specimen, shear failure mode does not occur. Flexural strength for water immersed samples decreases. This decrease can be attributed to the increase in the percentage of water absorption that can lead to the formation of higher number of micro-cracks because of fiber swelling which in turn weaken the fiber-matrix interface region when bending loads are applied.[27] In this study, to observe that the CLFRC and WMFRC samples (35 Vol. % fiber content) have a higher flexural strength in dry state compared to after water immersion, a decrease of 47.5% was found. It could be due to swelling and de- bonding of the fibers, previously mentioned, that can fill up the gaps between fiber and matrix. There are four types of laminae failure: fiber breaking, matrix micro cracks matrix de-bonding, and delamination. There were bumps on all stress versus strain curve results for all the specimens. This happened because when subjected to a three- point loading, specimen entered the elastic phase first as shown with a linear curve in a stress versus strain curve then plastic phase as shown with a non-linear curve in the stress versus strain. After the plastic phase, the specimen endured maximum load then gone fail on some lamina. An increase of water absorption quantity, flexural strength decreases. It may be because of the weak interfacial adhesion between fiber and matrix, because of the appearance of hydrogen chemical bonds between the cellulose fiber (Sisal and Roselle) and the water molecules.[28] Flexural strain of the samples with water absorption, as can be seen in plot, increased compared to dry samples. After water immersion, once the loss of cellulose

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Page No: 2114- 2125
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https://doi.org/10.47392/IRJAEH.2024.0288

has taken place natural fiber reinforced composites approach to be ductile. The molecules of water behave as plasticizer elements, leading to an increase of the maximum strain of the composite after water absorption. Figure 9- c) examining SEM images reveals the intricate details of matrix cracking in materials ,d) the SEM images reveal fractures that extend along the interface, e) the SEM images reveal the fiber-matrix debonding phenomenon resulting from the water molecule's attack, f) examining the fiber surface through SEM reveals distinct irregularities, g) examining the damage and extraction of fibers through SEM imagery provides detailed insights into the extent of fiber damage and the occurrence of pull -out phenomena. A change was found in the values of modulus because of the water absorption. Tensile modulus decreased for all samples after water immersion compared to dry specimens. Flexural modulus decreases 36% and 16.5% for CLFRC and WMFRC samples, respectively.

3.4 Impact Test

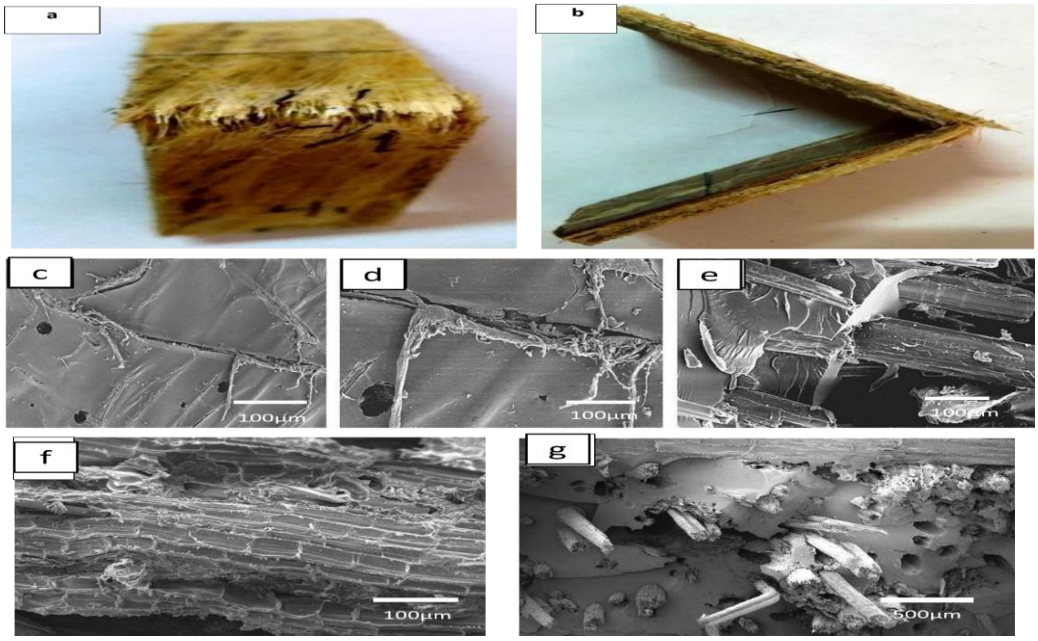

Figure 9 A) Outer Layer Under Tension. B) Fiber Pull-Out, C) Matrix Cracking, D) Fracture Running Along the Interface And E) Fiber–Matrix De-Bonding Due to Attack by Water Molecule, F) Fiber Surface Irregularities, G) Fiber Damage and Pull-Out.

Impact strength is an important property that gives an indication of overall material toughness. Impact strength of fibre- reinforced polymer is governed by the matrix– fibre interfacial bonding, and the properties of both matrix and fibre. When the composites undergo a sudden force, the impact energy is dissipated by the combination of fibre pullouts, fibre fracture and matrix deformation. [26] Normally in fibre-reinforced polymer composites, the impact strength increases as fibre content increases because of the increase in fibre pull out and fibre breakage. Energy absorbed and Impact strength of hybrid composites are tested in dry, and water aged state. The results are tabulated below. Tabulated results show the measured impact strength of hybrid composite before and after water ageing. Impact strength (IS) and Energy Absorbed of WMFR Composite (dry) reduced by 37.8% and 47.7% respectively. After ageing in water for 20days, IS increased by 54 % for CLFR and 65% for WMFR composite.

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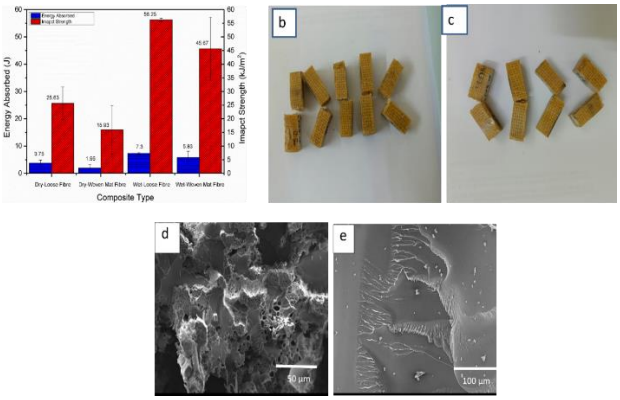

Figure 10 A) Impact Strength and Energy Absorbed B) Dry Samples-Brittle Fracture Due to Impact Loading (C-Type Failure), C) P And H Type Failure Due Increase in Ductility Due Water Absorption, D) Brittle Fracture Due to Impact Loading, E) Softening of Matrix Phase During Fracture.

The results indicate that impact strength of hybrid composites is slightly increased after 20days water ageing. The impact strength of samples of CLFR and WMFR increased drastically compared with un-aged samples respectively. This may be explained by the effect of water ageing improves the strength due to the increasing ductility caused by the water in the matrix. Toughness increases since composite gains ductility once absorbs the water in hydrophilic. As water increases the mass of composite inertia also increases hence must force is required to break the samples, in turn we can say toughness and impact resistance increases. The tested samples Figure10 b) reveal that, the dry samples undergone 'C' type failure that complete breakage or part off, whereas Figure 10 c) shows that water aged samples undergone 'P' and 'H" type failure that is partial and hinged. Figure10 d) SEM images expose the presence of brittle fracture patterns attributed to the effects of impact loading, whereas Figure10 e) SEM images reveal a noticeable softening in the matrix phase as it undergoes fracture, shown in Table 5.

Table 5 Impact Properties

Impact test results							
Sample condition	Composite Type	Sl No.	Energy Absorbed in 'J'	Average Energy Absorbed in 'J'	Imapct Strength in 'J/m^2	Average Imapct Strength in 'kJ/m^2	Failure Type
DRY	Continuous-Loose Fiber	1	4.26	3.75	28.82	25.63	C
		2	3.17		22.84		H
		3	3.81		25.23		H
	Woven Mat fiber	1	2.69	1.96	20.86	15.93	H
		2	1.53		11.97		H
		3	1.67		14.95		H
WET	Continuous-Loose Fiber	1	7.49	7.30	56.22	56.25	P
		2	7.19		56.59		P
		3	7.22		55.95		H
	Woven Mat fiber	1	7.31	5.83	50.96	45.67	P
		2	5.07		39.41		C
		3	5.12		46.65		P
C- Complete, H- Hinged, P- Partial							

International Research Journal on Advanced Engineering Hub (IRJAEH)
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Page No: 2114- 2125
https://irjaeh.com
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Conclusion

Sisal and Roselle (35 Vol. % of fiber content) / Epoxy hybrid composites are fabricated by hand layup technique followed by a compression molding technique. CLFR and WMRF geo-polymer hybrid (Sisal and Roselle) composite has been fabricated and the effect of water absorption on the mechanical properties of the composite is evaluated. The presence of CLFR and WMRF layers in the geo-polymer composite significantly increased all mechanical properties (e.g., flexural strength, flexural modulus and impact strength) compared to un- reinforced geo-polymer. This remarkable enhancement is due to the unique properties of fibres in withstanding the bending force and resisting fracture force compared to brittle geo-polymers. fabricated the composite and done testing, the results are compared with composites made from jute, banana, pineapple, bamboo fiber, softwood, and plywood results and found satisfactory. Strength of 35 Vol. % of untreated CLFR composite having better than WMFR Composite (dry). The tensile strength and modulus of WMFR Composite (dry) reduced by 35% and 17% respectively. After ageing in water for 20days, UTS reduced by 24 % for CLFR and 17% for WMFR composite. Compressive Strength and modulus of WMFR Composite (dry) reduced by 17% and 33% respectively. After ageing in water for 20days, the US reduced by 43 % for CLFR and 21% for WMFR composite. Flexural strength and modulus of WMFR Composite (dry) reduced by 37% and 36% respectively. After ageing in water for 20days, the US reduced by 47 % for CLFR and 41% for WMFR composite. Impact strength (IS) and Energy Absorbed of WMFR Composite (dry) reduced by 37.8% and 47.7% respectively. After ageing in water for 20days, IS increased by 54 % for CLFR and 65% for WMFR composite. SEM analysis revealed that fiber pull-out, de-bonding, matrix softening, fiber rupture, sliding tracks, debris, cracks were the reasons for the failure composite.

References

[1].L. Kerni, S. Singh, A. Patnaik, and N. Kumar, “A review on natural fiber reinforced composites,” Mater Today Proc, vol. 28, pp. 1616–1621, 2020, doi: 10.1016/j.matpr.2020.04.851.

[2].R. Vijayan and A. Krishnamoorthy, “Review On Natural Fiber Reinforced Composites,” Mater Today Proc, vol. 16, pp. 897–906, 2019, doi: 10.1016/j.matpr.2019.05.175.

[3].S. V. Joshi, L. T. Drzal, A. K. Mohanty, and S. Arora, “Are natural fiber composites environmentally superior to glass fiber reinforced composites?,” Compos Part A Appl Sci Manuf, vol. 35, no. 3, pp. 371–376, Mar. 2004, doi: 10.1016/j.compositesa.2003.09.016.

[4].N. M. Nurazzi et al., “A Review on Natural Fiber Reinforced Polymer Composite for Bullet Proof and Ballistic Applications,” Polymers (Basel), vol. 13, no. 4, p. 646, Feb. 2021, doi: 10.3390/polym13040646.

[5].H. P. S. Abdul Khalil, I. U. H. Bhat, M. Jawaid, A. Zaidon, D. Hermawan, and Y. S. Hadi, “Bamboo fibre reinforced biocomposites: A review,” Mater Des, vol. 42, pp. 353–368, Dec. 2012, doi: 10.1016/j.matdes.2012.06.015.

[6].A. Alavudeen, N. Rajini, S. Karthikeyan, M. Thiruchitrambalam, and N. Venkateshwaren, “Mechanical properties of banana/kenaf fiber-reinforced hybrid polyester composites: Effect of woven fabric and random orientation,” Materials & Design (1980-2015), vol. 66, pp. 246–257, Feb. 2015, doi: 10.1016/j.matdes.2014.10.067.

[7].X. Zhao, R. K. Y. Li, and S.-L. Bai, “Mechanical properties of sisal fiber reinforced high density polyethylene composites: Effect of fiber content, interfacial compatibilization, and

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e ISSN: 2584-2137
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https://doi.org/10.47392/IRJAEH.2024.0288

manufacturing process," Compos Part A Appl Sci Manuf, vol. 65, pp. 169–174, Oct. 2014, doi: 10.1016/j.compositesa.2014.06.017.

[8]. K. Palanikumar, M. Ramesh, and K. Hemachandra Reddy, "Experimental Investigation on the Mechanical Properties of Green Hybrid Sisal and Glass Fiber Reinforced Polymer Composites," Journal of Natural Fibers, vol. 13, no. 3, pp. 321–331, May 2016, doi: 10.1080/15440478.2015.1029192.

[9]. D. Ray, B. K. Sarkar, A. K. Rana, and N. R. Bose, "The mechanical properties of vinylester resin matrix composites reinforced with alkali-treated jute fibres," Compos Part A Appl Sci Manuf, vol. 32, no. 1, pp. 119–127, Jan. 2001, doi: 10.1016/S1359-835X(00)00101-9.

[10]. M. Ramesh, K. Palanikumar, and K. H. Reddy, "Comparative Evaluation on Properties of Hybrid Glass Fiber-Sisal/Jute Reinforced Epoxy Composites," Procedia Eng, vol. 51, pp. 745–750, Jan. 2013, doi: 10.1016/J.PROENG.2013.01.106.

[11]. M. Jawaid, H. P. S. Abdul Khalil, A. Hassan, R. Dungani, and A. Hadiyane, "Effect of jute fibre loading on tensile and dynamic mechanical properties of oil palm epoxy composites," Compos B Eng, vol. 45, no. 1, pp. 619–624, Feb. 2013, doi: 10.1016/j.compositesb.2012.04.068.

[12]. Md. R. Hossain, Md. A. Islam, A. Van Vuurea, and I. Verpoest, "Tensile Behavior of Environment Friendly Jute Epoxy Laminated Composite," Procedia Eng, vol. 56, pp. 782–788, 2013, doi: 10.1016/j.proeng.2013.03.196.

[13]. A. Gopinath, M. S. Kumar, and A. Elayaperumal, "Experimental Investigations on Mechanical Properties Of Jute Fiber Reinforced Composites with Polyester and Epoxy Resin Matrices," Procedia Eng, vol. 97, pp. 2052–2063, 2014, doi: 10.1016/j.proeng.2014.12.448.

[14]. R. Quintana, J.-W. Choi, K. Puebla, and R. Wicker, "Effects of build orientation on tensile strength for stereolithography-manufactured ASTM D-638 type I specimens," The International Journal of Advanced Manufacturing Technology, vol. 46, no. 1–4, pp. 201–215, Jan. 2010, doi: 10.1007/s00170-009-2066-z.

[15]. T. Tezel, V. Kovan, H. E. Camurlu, and E. S. Topal, "Designing and Manufacturing of Polymer-Foam Hybrid Materials Using Fused Deposition Modeling," Adv Eng Mater, vol. 21, no. 6, Jun. 2019, doi: 10.1002/adem.201800840.

[16]. R. Krishna Adhikari and B. S. Keerthi Gowda, "Exploration of mechanical properties of banana/jute hybrid polyester composite," Mater Today Proc, vol. 4, no. 8, pp. 7171–7176, 2017, doi: 10.1016/j.matpr.2017.07.043.

[17]. J. Flynn, A. Amiri, and C. Ulven, "Hybridized carbon and flax fiber composites for tailored performance," Mater Des, vol. 102, pp. 21–29, Jul. 2016, doi: 10.1016/j.matdes.2016.03.164.

[18]. M. W. Tham et al., "Tensile properties prediction of natural fibre composites using rule of mixtures: A review," Journal of Reinforced Plastics and Composites, vol. 38, no. 5, pp. 211–248, Mar. 2019, doi: 10.1177/0731684418813650.

[19]. A. K. Sinha, H. K. Narang, and S. Bhattacharya, "Mechanical properties of natural fibre polymer composites," Journal of Polymer Engineering, vol. 37, no. 9, pp. 879–895, Nov. 2017, doi: 10.1515/polyeng-2016-0362.

[20]. M. Ramesh, K. Palanikumar, and K. H. Reddy, "Mechanical property evaluation of sisal–jute–glass fiber reinforced polyester composites," Compos B Eng, vol. 48, pp. 1–9, May 2013, doi: 10.1016/j.compositesb.2012.12.004.

[21]. N. Venkateshwaran, A. ElayaPerumal, A. Alavudeen, and M. Thiruchitrambalam, "Mechanical and water absorption

behaviour of banana/sisal reinforced hybrid composites," Mater Des, vol. 32, no. 7, pp. 4017–4021, Aug. 2011, doi: 10.1016/j.matdes.2011.03.002.

[22]. A. Memon and A. Nakai, "Fabrication and Mechanical Properties of Jute Spun Yarn/PLA Unidirection Composite by Compression Molding," Energy Procedia, vol. 34, pp. 830–838, Jan. 2013, doi: 10.1016/J.EGYPRO.2013.06.819.

[23]. A. K. Sinha, H. K. Narang, and S. Bhattacharya, "Mechanical properties of natural fibre polymer composites," Journal of Polymer Engineering, vol. 37, no. 9, pp. 879–895, Nov. 2017, doi: 10.1515/polyeng-2016-0362.

[24]. S. Chakraborty, S. P. Kundu, A. Roy, R. K. Basak, B. Adhikari, and S. B. Majumder, "Improvement of the mechanical properties of jute fibre reinforced cement mortar: A statistical approach," Constr Build Mater, vol. 38, pp. 776–784, Jan. 2013, doi: 10.1016/j.conbuildmat.2012.09.067.

[25]. S. S. Munawar, K. Umemura, and S. Kawai, "Characterization of the morphological, physical, and mechanical properties of seven nonwood plant fiber bundles," Journal of Wood Science, vol. 53, no. 2, pp. 108–113, Apr. 2007, doi: 10.1007/S10086-006-0836-X.

[26]. M. Ali, A. Liu, H. Sou, and N. Chouw, "Mechanical and dynamic properties of coconut fibre reinforced concrete," Constr Build Mater, vol. 30, pp. 814–825, May 2012, doi: 10.1016/J.CONBUILDMAT.2011.12.068.

[27]. S. Shibata, Y. Cao, and I. Fukumoto, "Flexural modulus of the unidirectional and random composites made from biodegradable resin and bamboo and kenaf fibres," Compos Part A Appl Sci Manuf, vol. 39, no. 4, pp. 640–646, Apr. 2008, doi: 10.1016/j.compositesa.2007.10.021.

[28]. M. Ramesh, K. Palanikumar, and K. H. Reddy, "Mechanical property evaluation of sisal–jute–glass fiber reinforced polyester composites," Compos B Eng, vol. 48, pp. 1–9, May 2013, doi: 10.1016/j.compositesb.2012.12.004.