STUDY ON MECHANICAL AND MOISTURE ASSIMILATION PROPERTIES OF NATURAL FIBER REINFORCED WITH EPOXY RESIN: A REVIEW

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Abstract: *The advancement of superior designing materials attracts analysts, engineers, and researchers towards the utilization of organic strands in the assembling of the composites as a result of their minimal expense, availability, less weight, biodegradability, recyclability, high mechanical properties, better formability, and eco-friendly characteristics. With the concept of an eco-material, this paper reviews previous research in the mechanical and physical properties of natural fibers reinforced composite. Composite prepared with thermosetting polymer reinforced with strands has high mechanical and physical properties and is less expensive. This paper reviewed the literature on the effects of mechanical processes on fiber matrix and studied the various properties of natural fibers, and also discussed the applications, advantages, and disadvantages of natural fiber polymers.*

Key Points: Plant fibers, composites, treatment, mechanical properties, water assimilation.

I. INTRODUCTION

Composite material is a mixture of at least two materials, and they are mixed in order to make the resulting material having superior properties from its parental materials. [1]. These are hybrid materials made of a polymer resin reinforced by fibers, consolidating the strand's mechanical and physical performances, bonding, and actual properties of polymers [2]. It is a light, strong and durable material that can be produced in complex forms with different production techniques. Composite material's main points of interest are their high strength and firmness, low density, contrast with bulk materials, and a weight decrease in the completed part. Most composites comprise two stages, a matrix, and reinforcement. Reinforcement is a generic term for fibers or particles dispersed within the matrix. It has superior physical/mechanical properties compared to the matrix. Their selection will decide firmness, electrical and thermal conductivity strength, and other numerous properties of composites. The reinforcing phase gives strength and stiffness [3].

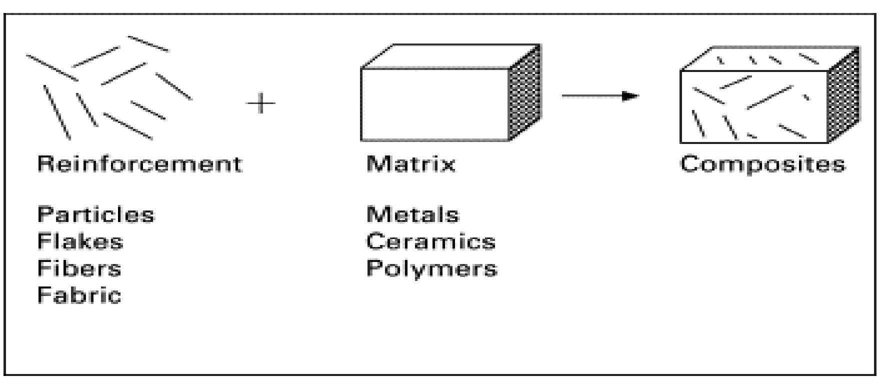

Fig. 1: Schematic represtentation of composites [1].

Fiber is an organic or artificial substance that has a greater length than it is wide. It is a kind of sugar that the body can't absorb. Although most carbohydrates are separated into sugar atoms, fiber can't be separated into sugar particles, and instead, it goes through the body undigested [4]. Natural strand/fiber generally has abundant and endless sources on the earth. The word "natural fiber" covers an extensive scope of vegetable, creature, and mineral strands. However, it is typically limited to wood fiber and agro-based bast, leaf, seed, and stem strands in composites applications [5]. Fiber crops have existed in human culture since the emergence of time. History shows that people gathered crude materials from nature to use as ropes or fabric. In the later period, man-kind figured out how to develop such crops [6]. The continuous improvement of organic fiber has raised interest because of the benefits of organic strands like cost-effectiveness, low density, accessibility, low wear of handling hardware, and bio-degradability [7]. Industries are generally utilizing plant strands for various applications from numerous assets [8]. The utilization of natural strands lessens weight by 10%. It reduces the energy required for manufacturing by 80%, while the part's expense is 5% lower than the similar fiberglass-reinforcement segment [7]. The year 2009 is considered an international year of natural fiber (IYNF) for advancing natural strand and material, supporting farmers, horticulture, climate, and market requests [8].

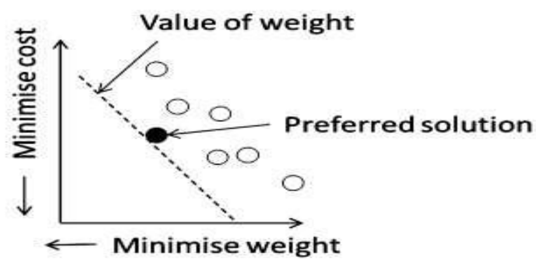

Fig. 2: Weight reduction is inversely proportional to cost reduction [9].

Organic strands are utilized to create the composites based on phenolic, epoxy, polyester, vinyl ester, and thermoplastics resins [9]. Organic strands are progressively used in auto and bundling material. The most significant sector of ongoing development in organic fiber plastic composites is the car industry, especially in Europe, where natural strands favorably utilize their low density and expanding ecological pressure factors [5]. Being one of the fastest-growing nations on the planet, many global considerations are centered on India. India is the world's second-biggest producer and shopper of natural strand materials and fabricated items close to China. In India, increasingly, more examination works are proceeding to use organic strands for designing applications. Table 1 shows the annual production of different fibers and their producers [5].

Table 1: Annual natural fiber production of various fibers and their producer countries [10].

Fiber Type	Origin	Largest Producer Countries	World Production (10^3 tons)
Coir	Fruit	India, Vietnam, Sri Lanka	100
Kenaf	Steam	India, Bangladesh, U.S.A	970
Flax	Steam	Canada, France, Belgium	830
Bamboo	Steam	China, India, Indonesia	30,000
Jute	Steam	India , Bangladesh	2,500
Sisal	Leaf	Tanzania, Brazil, Philippines	378
Cotton	Seed	China, India, United States	25,000
Banana	Leaf	Brazil, India	200
Silk	Animal	China, India, Europe	202
Wool	Animal	Australia, New Zealand, China	2000
Hemp	Steam	China, France, Philippines	215
Bagasse	Steam	Brazil, India, China	75,000

Fiber is classified as natural fiber and synthetic fiber. Synthetic fibers are those fibers made by humans through chemical synthesis, derived from living animals and petroleum-based sources. These materials are polymerized into an extended, linear substance with various synthetic mixes and can create different sorts of strands [11]. Natural strands, any hair-like material extracted from an animal, vegetable, or mineral source. Some of the aspects that separate organic and engineered strands are tabulated in table 1[5].

Table 2: Comparison between Natural and synthetic fiber [5]

Aspects	Property	Natural fibers	Synthetic fiber
Technical	Mechanical property	Moderate	High
	Moisture sensitivity	High	Low
	Thermal sensitivity	High	Low
Environmental	Resource	Infinite	Limited
	Production	Low	High
	Recyclability	Good	Moderate

Natural strands are distinguished, depending on their extraction methods, such as animal fiber, plant strands, and mineral fibers. A significant distinction among animal and plant strands is that the former comprises protein as a substantial constituent while the latter is made out of cellulose. Plant fiber constituents commonly incorporate cellulose (60-80%), hemicelluloses, and lignin (5–20%), while the rest comprises waxes, gelatin, humidity (up to 20%), and water-dissolvable natural segments, which are found to differ generally depends on their birth [12]. These plant fibers are classified into seed, leaf, bast fiber/stem, fruit, and stalk strands [13].

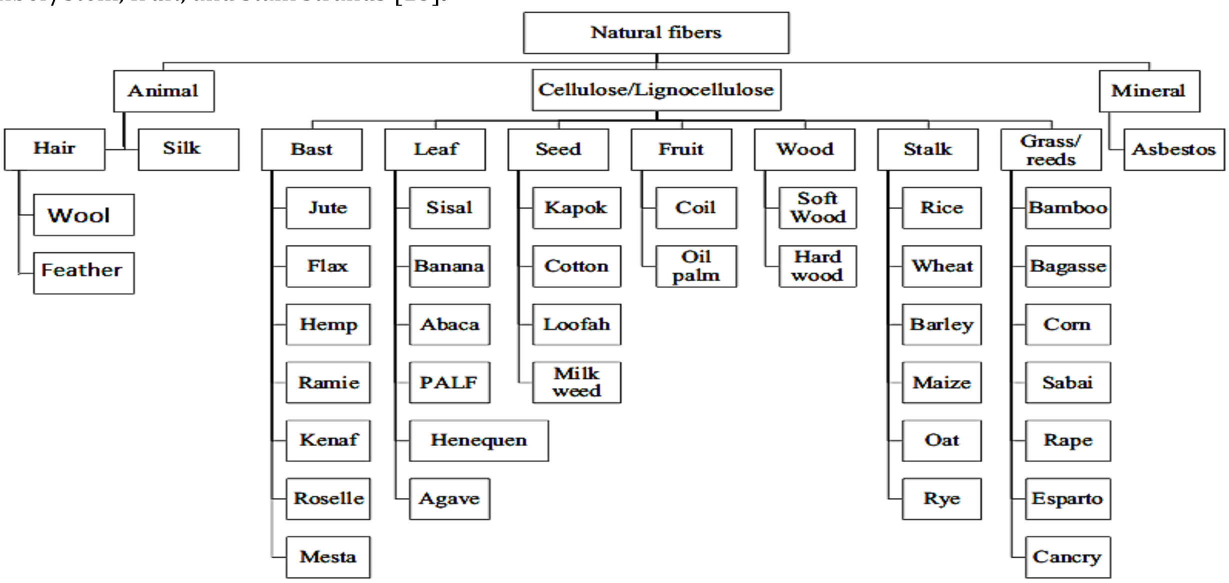

Fig. 3: Classifications of Natural Fibers [14]

Table 3: Characteristic values for physical and mechanical properties of the natural and synthetic fibers [15].

Sr. No.	Fibers	Density (g/cm^3)	Diameter (μm)	Tensile Strength (MPa)	Young's Modulus (GPa)	Elongation at Break
i.	Flax	1.5	40-600	345-1500	27.6	2.7-3.2
ii.	Hemp	1.47	25-500	690	70	1.6
iii.	Jute	1.3-1.49	25-200	393-800	13-26.5	1.16-1.5
iv.	Kenaf	1.2	75-90	930	53	1.6
v.	Ramie	1.55	25-30	400-938	61.4-128	1.2-3.8
vi.	Palf	0.9533	20-80	413-1627	34.5—82.5	1.6
vii.	Oil Palm	0.7-1.55	150-500	248	3.2	25
viii.	Cotton	1.5-1.6	12-38	287-800	5.5-12.6	7-8
ix.	Coir	1.15-1.46	100-460	131-220	4-6	15-40
x.	Carbon	1.78	5-7	3400[a]-4800[b]	240[b]-425[a]	1.4-1.8

[a] - Ultra high modulus carbon fibers.
[b] - Ultra-high tenacity carbon fibers.

1.2 Natural Fiber Composites

Natural strand/fiber polymer composites (NFPC) are a composite material comprising of polymer matrix implanted with high-strength natural strands, similar to jute, oil palm, sisal, kenaf, and flax. Fiber Reinforced Composite (FRC) is a material establishing a matrix along with high-strength reinforcing strands. The selection models of the frameworks are restricted by the user requirement of composites and the temperature at which strands are to be used. Most strands (organic or synthetic) utilized as filler in FRCs are thermally insecure over 200^{o}C. Accordingly, the preparing temperature is restricted, although, in certain conditions, it is likely for them to be utilized at higher temperatures [10].

Advantages of Organic Strand Reinforced Composites

1. Natural strand is sensitive (soft), and there is a steady growth of most parts of natural strand during their whole life.
2. The natural fiber is an ideal alternative rather than E-glass fiber as the discard issue.
3. These are light in weight. Likewise, they give enormous weight saving, eco-friendliness for automotive industries.
4. Effective utilization of agrarian squanders helps to create jobs and income to farmers.
5. The natural strand products require less heat and temperature for their formation.
6. NFRCs also show excellent resistance to noise.
7. The main advantage of organic strand composite is that after completing their lifespan they degrade into H_2O and CO_2 by the action of microorganism, and these H_2O and CO_2 are absorbed by the plant system.
8. As natural strand composites are cheap, they help to reduce the overall cost of the various products.

Disadvantages of Natural Strand Reinforced Composites

1. organic strand fibers show a high absorption rate of moisture (depends upon the organic strand type), resulting in swelling of different parts, affecting the quality of the product
2. Massive difference in strands characteristics contributes clearly towards enormous scatter in NFRCs attributes.
3. Vulnerable to parasitic, creepy crawlies' attacks.
4. The organic strand composites have a lesser thermal conductivity in contrast with the E glass synthetic composites.
5. There is variation in price and supply due to weather and harvest yield.
6. As the service temperature of organic strand fiber is low (<200), these are confined to non-auxiliary segments [9, 16].

Application of Natural Fiber

Many industries, such as construction, auto, energy, and aviation, are being forced by the general public and governments to make items made of organic-based materials [17]. In this situation, organic strands are the best alternative for ventures to meet financial and ecological difficulties [18]. Moreover, the utilization of organic strands would create jobs in villages and less developed districts, reducing unemployment in several countries like India [17].

- Organic composites are used to build military warrior airplanes, helicopters, general public transport airplanes, satellites, launch vehicles, cockpits, and rockets.
- In the auto sector, organic strands are used to make headliner boards, door panels, boot lining, noise insulation boards, seatbacks, cap racks, tire lining, wheel boxes, etc. [2].
- They are utilized in clinical practice to reestablish foremost and back teeth, intraocular lenses, vascular unions, pacemakers, heart valves, and artificial hearts, etc. [19]
- Composite materials are broadly utilized in making athletic products [20].
- Organic strands, such as bamboo and wood strand-based composite materials, have been utilized to make in a few melodic applications [21].
- Composite materials have been utilized in manufacturing areas, e.g., tanks, factories, elevated structures and windows, lightweight structures, furniture, bridge parts, etc. [3].
- Natural fiber-based packaging materials utilized as bundling material are bags, yarns, ropes, packets [22].

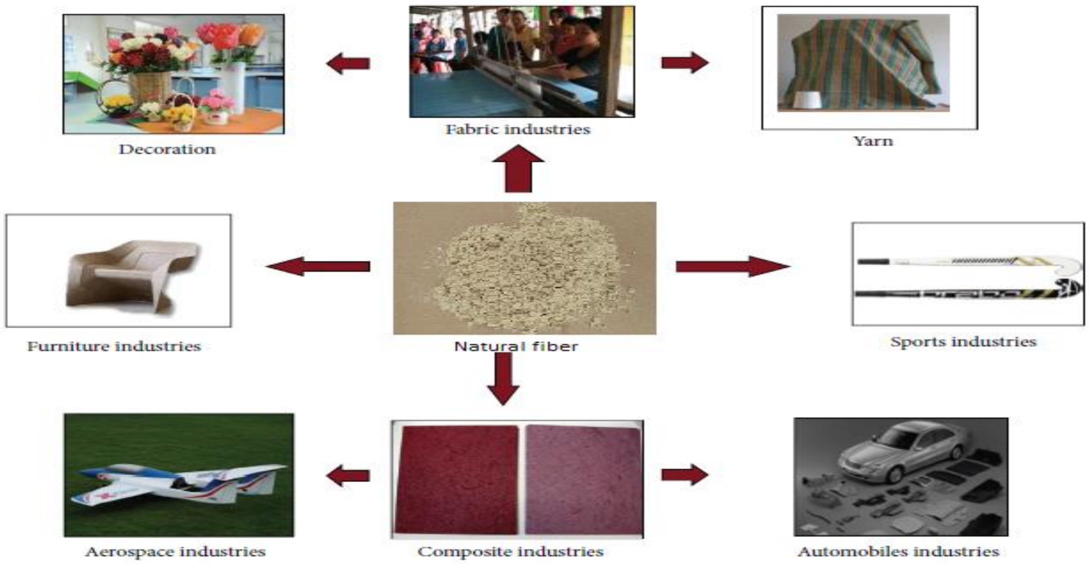

Fig. 4: Application of Natural Fibers [8]

2. LITERATURE REVIEW

Girijappa Y.G.T. et al. [4] explored natural fibers as a sustainable and renewable resource to develop eco-friendly composites. The outcomes demonstrate that change of material properties has been done through substance treatment of organic strands that improve the bond between the strands and matrix and upgrade the composites' mechanical properties.

Akil H.M. et al. [6] present an outline of the advancements made in kenaf fiber reinforced composites' territory regarding their market, fabricating strategies, and properties. From this investigation, the author examined that Kenaf has superior tensile properties over sisal and coir, great flexural strength than hemp, sisal, and coir; also, kenaf fiber has high specific modulus properties. Due to this, it can help produce jobs in rural and urban regions, decreasing waste and, consequently, contributing to a healthier environment.

Karthikeyan A. et al. [7] found ways to improve the impact properties of coconut fiber-supported epoxy composites utilizing sodium lauryl sulfate (SLS) treatment. The modified coconut fibers were assessed by utilizing Scanning Electron Microscopy (SEM). The SLS treated epoxy composites improved the impact strength by about 6% when contrasted with NaOH treatment.

M. Asim et al. [8] present a study on pineapple leaves fiber and its composites. The outcomes demonstrate that Young's modulus of pineapple fiber was high. Also, the tensile strength and elasticity of the pineapple fiber are highest among the related natural strands.

Chauhan A. et al. [9] discussed the impacts of mechanical properties and water absorption of natural fiber reinforced with epoxy resin. The author establishes that parameters like reinforcement proportion, curing temperature, and curing time influence this investigation's mechanical properties and water digestion. He also found an increment in mechanical properties like elasticity, flexural strength, and impact strength. And with an increment in the raw natural fiber reinforcement composite, water absorption also increases; however, when treated natural strand utilized as a reinforcement, the water digestion diminishes.

Balla V.K. et al. [12] had researched additive manufacturing of natural fiber reinforced polymer composites. These treated composites showed rigidity and modulus, which was 134% and 157% higher than untreated polylactic acid (PLA). Nonetheless, the tensile strain of treated PLA was low compared to treated PLA.

Wang H. et al. [16] investigate the critical factors on manufacturing processes of natural fiber composites. The author found that the inter-laminar shear strength increased with the use of nano clay as nano-reinforcement, and increasing the fiber content results in the decrease of the degradation temperature.

Ahmad F. et al. [17] studied natural fiber composites selection in view of mechanical, lightweight, and economic properties. The author founds that the water absorption of natural fibers can be significantly reduced by alkali (KOH, NaOH) treatment. He also demonstrates that the addition of the fiber content to the composite will increase its flammability.

Peças P. et al. [18] discussed the natural fiber composites and their applications. The author from this investigation concluded that natural fiber material properties are highly dependent on region, cultivation method, harvesting method, and how the treatment is made. He found that cotton had the lowest tensile strength vibration value among the different fibers, while pineapple was the strongest one in this property. Also, the young's modulus of the ramie fiber was highest, but its elongation at break is the lowest one.

Nguong C.W. et al. [22] presents an investigation on the renewable organic strands, such as flax, oil palm, and pineapple leaf, for their utilization in new polymer materials. The examination found that adding nanomaterials, for example, Nano Silica Carbide (n-SiC) and Nano Clay; polymer composites can enhance its elastic and wears properties, fracture toughness, and flexural stress-strain behavior, and crack strength in wet and dry conditions.

Shah D.U. [23] presents a study on the development of plant fiber composites for structural applications by optimizing composite parameters. The outcomes of this examination showed that bast strands are generally appropriate for reinforced composites because of their high mechanical properties. Natural strands with high cellulose content, high-cellulose crystallinity, low micro-fibril inclination, and a high-aspect-ratio are beneficial.

Koronis G. et al. [24] present a study to find adequate materials for automotive applications. The author found that green composites in automobile body panels are feasible because green composites have a similar mechanical performance to synthetic ones. The green composites are cheaper than synthetic ones and provide good mechanical properties like tensile strength, shear modulus, impact strength, etc.

Yousif B.F. and Ku H. [25] examined the utilization of the coir fiber/polymeric composite for the design of liquid storage tanks. Scanning electron microscopy (SEM) was utilized to analyze the damage of various samples. The outcomes showed that the highest ingested liquid was water, followed by saltwater. He also founds that the interfacial adhesion properties of coir fiber were high as compared to the polyester. But the fiber strength deteriorates during the aging technique.

Verma D. et al. [26] done an investigation on coir fiber reinforcement and its application in polymer composites. The author observed that tensile and flexural properties of hybrid, i.e., treated composites are higher than that of the untreated composites. Also, untreated coir composites showed a rough surface as compared to that of treated ones.

Tajuddin M. et al. [27] researched the natural fibers and processes for producing binder-less boards. This research concluded that the modulus of rupture (MOR) value of the Miscanthus Sinensis board is highest, followed by wood. He also found that palm fiber has the highest swelling thickness and water absorption. In addition, he found that the hot press technique and steam process provide the best quality boards.

Zhu J. et al. [28] examined the development of flax fibers and their reinforced composites based on different polymeric matrices. He found that flax strands with excellent mechanical properties (e.g., high elasticity up to 1000 MPa) and found anhydride treatment is an effective method to improve the flax/PP bond and, consequently, the mechanical properties.

Lu N. et al. [29] present a study on hemp strand-reinforced composite's composition, mechanical and structural properties with reused high-density polyethylene matrix. This investigation showed that hemp strand-reused high-density polyethylene (HDPE) composites with 40% of fiber volume portions exhibited the best mechanical properties, including flexural strength, elastic modulus, rigidity, and modulus.

Leao A.L. et al. [30] researched the utilization of the pineapple leaf fibers as reinforcement in the natural fiber composites. The author of this investigation concluded that Pineapple Leaf Fiber (PALF) treated with NaOH and coupling agent (polystyrene-co-maleic anhydride) have better adhesion with the matrix of high impact polystyrene in comparison to the untreated one. He found that the composite with long PALF fiber possesses higher tensile strength than short fiber composites; he also demonstrates that its impact energy is lower than that of pure epoxy.

Shah A.U.M. et al. [31] researched the tensile properties of bamboo fiber reinforced polymer composites (BFRP). The author concluded that coupling specialists, such as maleic anhydride polypropylene (MAPP), improve bamboo strand's bond in the polypropylene (PP) matrix. A high level of lignin content in bamboo strands limits partition, which prompts minor adhesion between fibers. With the expansion of Micro/nano-sized bamboo fibrils into the carbon fiber composites, the author also found improvement in composite strength.

Kumar P.S.S. and Allamraju K.V. [32] investigated organic strands composite's mechanical behavior and structural properties made from the Sisal, Jute, and Kenaf fiber. The outcomes of this investigation are discussed below:

1. Natural strands display bio-degradable and eco-friendly properties.
2. Natural fiber composites exhibit excellent mechanical properties; they improve whenever treated with epoxy polymers.
3. Natural Fiber composite Materials with no additional covering of epoxy resins will probably be affected or exposed to oxidative deterioration, water ingestion, and thermal degradation enormously.

Rohan T. et al. [33] discussed the benefits of new alternative materials based on natural fiber to the current alloys, conventional metals, and synthetic materials. This study concluded that the organic strand reinforcement materials have some favorable properties, for example, better sound absorbing properties because of their porous construction. Certain inconveniences, such as low mechanical, heat, moisture resistance, and imperviousness to fire properties, can be overwhelmed by adjusting suitably with chemical treatment or adding appropriate substances.

Khandanlou R. et al. [34] examined modified rice straw fiber blend's mechanical and thermal stability properties with polycaprolactone composite. In the outcomes of this investigation, the tensile modulus was increased, but tensile strength and elongation were reduced as we increase the content of modified rice straw in the composite. In addition, thermal stability was also decreased with an increase in the modified rice straw.

Mohamed M.S. et al. [35] discussed the utilization and properties of rice straw as a cementitious composite material. From this investigation, the author concluded that the rice straw fly debris cement-based composite lessens the thickness, compressive strength, and thermal conductivity. Also, incorporating 10mm, 20 mm, and 30 mm straw particles strands into the cementitious matrix increases the flexural strength.

Atoyebi O.D. et al. [36] researched the evaluation of particle board from sugarcane bagasse (SB) and corn Cobb (CC). The result showed that the board's mechanical properties improved as the CC substitution level expanded but had poor physical properties. 50% CC and 50% SB panels are the most liked since they had the best physical and mechanical properties execution.

Labintan C.A. et al. [37] studied rice straw's influence on banco's physical and mechanical properties, an adobe (a combination of sandy earth and rice straw) reinforced with rice straw. The author of this investigation found that adding 25% rice straw in the clay matrix provides the best compressive and tensile strength. He also found that the adobe provides better adhesion between rice straw and the clay matrix, which increases the tensile strength. In addition, the flexural strength increases continually with straw content increment, which shows that straw carries malleability to the clay.

Mohdy F.A.A. et al. [38] studied rice straw as a new resource for some beneficial uses. The author of this study concluded that with the liquefaction temperature from 140^0C to 200^0C, the liquefaction process accelerates, resulting in decreased residue content. He also found that the solubility of rice straw increase with an increase in the time of liquefaction. The X-ray diffraction examination showed that about 69% silica content remained after the liquefaction process.

Nunes L.J.R. et al. [39] studied the recovery of sugarcane industry waste using thermo-chemical conversion technologies to increase sustainability. He found that roasted bagasse has high energy content in comparison to the dried bagasse. In addition, the author also found a high amount of mass loss in the production of energy from dried bagasse than that of roasted bagasse.

Samariha A. and Khakifirooz A. [40] discussed the application of the Neutral Sulfite Semi-Chemical (NSSC) pulping method to obtain mash from bagasse. This investigation showed that paper obtained from the sugar cane bagasse has high strength compared to the paper obtained from hardwood pulp. He also found that paper quality obtained from sugar cane bagasse is higher than that obtained from hardwood.

Ferreira A.M. et al. [41] studied manufacturing conditions and stability of particleboards produced from the low-cost natural binder. He found that particleboard pressed for 10 minutes at 200°C obtained from recycled wood has the highest internal bond strength compared to pine and beech particle boards. Also, the author concluded that the stability of the boards obtained from the thick spent sulfite liquor (TSSL) with wheat flour was highest in contrast to the other boards.

Prasad A.V. and Rao K.M. [42] examined the tensile and impact strength of rice straw-polyester composites. The outcomes showed that rice straw strands extensively improve the epoxy's elasticity, firmness, and strength alone and decrease its thickness with the expansion in fiber rate volume in the composite. He also demonstrates that the impact strength of polyester rice straw is highest compared to wheat straw polyester composite and softwood.

Halvarsson S. et al. [43] researched on manufacturing of high-performance rice-straw fiberboards. In the outcomes of this investigation, various mechanical properties of rice straw boards such as modulus of rupture, modulus of elasticity, and internal bonding were improved as the resin content, and fibreboard density increased. He also observed improvement in water absorption and thickness swelling with an increment of density and resin levels.

Hussein Z. et al. [44] examined the technical properties (elastic and compressive strength, modulus of rupture (MOR), flexibility, thermal conductivity, etc.) of rice straw and flax fiber particleboards made from agriculture waste. This investigation showed that particleboards produced using flax shives had better properties than the rice straw particles. The sheet's mechanical properties improve with an expanding epoxy content, aside from the MOR and modulus of elasticity (MOE), declining with an expanding epoxy percentage.

Alebiosu S.O. et al. [45] investigated the mechanical properties of Sugar Cane/Banana fiber paper blend. He found that sugarcane/banana paper mix with a high portion of banana fiber has maximum tensile and tear strength. He also demonstrates that a high portion of banana fiber in the blend improves the abrasion resistance of paper compared to the other specimens.

Pan M. et al. [46] researched the water-resistance and mechanical properties of rice straw fiberboards affected by the thermal modification. This examination showed that, after the heat treatment, thickness inflammation was remarkably diminished because of the reduction in the free activated hydroxyl groups of rice straw fiber. It was additionally deduced that some mechanical properties of the fiberboards, like the internal bonding strength, modulus of rupture (MOR), and modulus of elasticity (MOE), were drastically decreased with an increment in temperature from 120^{o}c to 210^{o}c.

Anand G.S. and Jayamohan K.G. [47] examined the mechanical properties of rice straw fiber reinforcement natural rubber composite for various weight percentages of rice straw strands under-treated and non-treated conditions. The outcomes of this investigation showed that 50% fiber with 3mm length is appropriate for lightweight applications. It is deduced from this examination that surface treatment significantly enhances the mechanical properties of rice straw composite materials reinforced with natural rubber.

Srinivasa C.V. and Bharath K.N. [48] researched the impact and hardness properties of areca fiber epoxy reinforced composites. The outcomes showed that, with an increase in the fiber volume percentage and composite post-curing time, the mechanical properties of the composite are also improved. The mechanical properties of composites of treated areca strands showed better outcomes when contrasted with untreated strands.

Abbass O. A. et al. [49] examined the physical and mechanical properties of bio-composite material made of wheat starch and wheat straw strands. This examination showed that with an increment in the fiber content, there is a decline in the impact energy while increasing the flexural stress and the hardness values. The author also concluded that there is a decline in the water take-up by the specimens on increasing the fiber content.

Ganesh B.N. et al. [50] investigate the mechanical properties of rice straw and chicken feather fiber composite supported in unsaturated polyester gum with changing strand volume fraction. The outcomes showed that the composites reinforced with Rice Straw and Chicken Feather (Hybrid mix) have higher mechanical properties than independent fiber composites and uncovered that the ideal fiber content for accomplishing the most noteworthy impact and flexural strength is 40% by volume portion. The flexural strength diminishes, and the impact value increases with increment in volume proportion.

Anni Q. et al. [51] researched the mechanical and physical properties of the rice straw particle board reinforced with various epoxy resin compositions. The outcomes showed that the increase in the rice straw portion density of particleboard is decreased, and it increases with an increase in the resin portion. He also found that water absorption and modulus of rupture also increases with the increased rice straw portion.

Ismail M.R. et al. [52] examined the mechanical properties of rice straw strand composite, reinforced in polyvinyl liquor and polystyrene polymers with various proportions of polymers. The outcome demonstrated that with increment in the polymer proportion in the mix composition, there is an increase in the impact strength, flexural strength, and modulus of elasticity. The author also concluded that rice straw fiber polystyrene composite's thickness swelling and water ingestion rates decline with increment in the polystyrene content.

Ali-Eldin S.S. [53] examined the mechanical properties of rice straw and rice straw-glass strand reinforced epoxy composites. The outcomes showed that with an increase in the content of rice straw modulus of elasticity and modulus of rupture also increased. Also, the compressive strength of the composite enhances with the insertion of rice straw content. The author also concluded that the bending modulus of the [RS/E] composite is lower than the pure epoxy composite by 30 %, while the bending modulus of [G/RS/E] is higher than [G/E] composite by 13 %.

Chauhan A. et al. [54] investigated the mechanical properties of himalayan extract reinforced epoxy composite. The author found that the composite's flexural strength, tensile strength, and hardness increases with an increment in Oak particulate content. He also concluded that the impact strength of composite decreases with increment in Oak particulate content due to their brittle nature.

3. CONCLUSION

The above analysis concluded that environmentally friendly reinforced composite is much more beneficial than commercial materials. The criteria of reinforcement ratio, curing temperature, and curing time utmost affect the mechanical properties and the water assimilation.

1. Mechanical properties such as tensile, flexural, and impact strength increase with natural fiber reinforcement in the composites.
2. Water absorption increases with the addition of the untreated natural fiber to the composite, but when the treated organic strand is employed as reinforcement, water assimilation decreases.
3. Water has a negative impact on the mechanical characteristics, likewise lowering tensile strength, toughness, flexural, and impact strength.

4. FUTURE SCOPE

The experiment may be conducted in the future by using the following parameters- Treatment method, alleviating temperature, different reinforcement ratios of the treated natural strand, or an untreated natural strand.

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