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A REVIEW ON NATURAL FIBER COMPOSITES

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Abstract: The best intended uses, such as high-quality bio-composite raw material, can be determined by understanding the fundamental characteristics of natural fibres. In order to increase the sustainability and economic value of natural fibres, this article explains their properties and potential applications. Natural fibres are potential light weight composite and reinforcement materials because of their low density, high strength to weight ratio, and reduction. Any manufacturing sector's ability to survive depends heavily on its materials. Due to their high specific strength, great damping capability, and high specific modulus, composite materials have largely replaced conventional materials. Due to the promising qualities of natural fibres, such as their low weight, water resistance, high impact strength, and environmental friendliness, natural fibre reinforced polymer composites have gained attention in the modern period. Various natural fibre types that can be employed as reinforcement in polymer composites are covered in this study. The mechanical characteristics of fibres are influenced by their microstructure and chemical makeup, with the fibre cross-sectional area having the greatest degree of variation. Natural fibres readily absorb water because they include hemicellulose, which gives them hydrophilic qualities. This makes them less suitable with a matrix that has hydrophobic properties. The production processes and steps for natural fibre reinforced composite are offered in several forms. Then, these composites' mechanical and tribological properties are reviewed.

***Index Terms* – Composites, Natural Fibers, Natural Fiber Composites.**

I. INTRODUCTION

Composite materials came to prominence a few decades ago due to their improved specific mechanical properties, as an outcome of rising consumer and industry demand for high-performance materials and constructions. The combination of fibres and an aggregating substance or matrix, however, greatly heightens the complexity of the design process, frequently creates difficulties for composite engineers, and consequently results in more conservative solutions for a given application. Although the effectiveness of these materials is clear, there has recently been a global agreement regarding the adverse impact of humans on global warming and the environment. On a large scale, composites are thought to be mixtures of materials that differ in composition or form. Although the concept of a composite material is not a novel or recent one, the constituents maintain their identities in the composite, i.e., they do not entirely dissolve or otherwise melt into one another. Many composite materials can be found in nature; for instance, wood is a fibrous natural composite (cellulose fibre in lignin matrix). Another example of a natural composite is bone. In order to create bricks, our forefathers invented composite by combining straw and clay. Clay is the matrix, and straw provides the fibre reinforcement. In 1940, the first glass fibre reinforced polymer was created.

Fiber is a type of material that is intact, long, thin, and simple to bend to form an elongated tissue. Natural fibre composites are used in various industries, including building construction, furniture, aerospace, automotive, and packaging, due to the benefits they provide. These promising fibres do, however, have some drawbacks, including being highly hydrophilic and having a wide range of properties due to the influence of their growing conditions, fibre processing method, fineness of the fibre, and sample test-length, which makes it challenging to predict the specific composite properties. All polymer composites absorb moisture when exposed to a humid environment or submerged in water. Moisture absorption causes the fiber-matrix interface region to deteriorate, which results in poor stress transfer efficiency and a loss of mechanical and dimensional qualities. To make the composites lighter, natural fibres are used in place of synthetic fibres. Natural fibres have a density between 1.2 and 1.6 g/cm3, which is lower than glass fiber's 2.4 g/cm3 density and allows for the creation of lightweight composites. As a result, natural fibre-based composites are increasingly in demand for commercial use across a range of industrial industries. In order to produce the lightweight composites, natural fibres including hemp, jute, sisal, banana, coir, and kenaf are frequently employed.

II. Types of Natural Fibers

Natural fibres are typically categorised according to their botanical types, which include five distinct categories: bast fibres like jute, flax, cannabis, ramie, and kenaf; leaf fibres like banana, sisal, agave, and pineapple; seed fibres like coir, cotton, and kapok; grass and reeds like wheat, maize, and rice; and all other types like roots and wood.

Certain plants can produce multiple types of fibre. Jute, flax, hemp, and kenaf are found in both bast and core fibres, for instance, while agave, coconut, and oil palm have both fruit and stem fibres. Furthermore, stem and hull fibres can be found in cereal grains. Few types of fibers used as fibers are given in Table 1

S. No	Fiber	Uses
1	**Abaca**	Textiles, apparel, useful papers including currency, journals, and premium papers, and even composite materials
2	**Banana/Musa**	Place mats, cardboard, string yarn, tea bags, fine textiles and fabrics, money note paper, mushrooms, handicrafts, cordage, cushion covers, tablecloths, curtains, natural absorbents in coloured wastewater, oil absorbers, light weight composites and bio-fertilizer are just a few examples of the items that fall under this category.
3	**Bamboo**	The fabric is used in making different products such as sanitary towels, gauze, bandages, absorbent pads, surgical wear, medical masks, doctor's coat, etc.
4	**Coir**	Filler, reinforcement in composite materials, light weight composites
5	**Cotton**	As coating materials, the furniture, clothing, and textile industries
6	**Eucalyptus**	Eucalyptus pulps are recommended for papermaking due to specific properties they impart to paper
7	**Hemp**	Bags, tarpaulins, carpets, rope, furniture materials, fabric, textile, garden mulch, fleeces and needle felts, light weight composites, composites, geotextiles/geotextile insulation industry
8	**Jute**	Furniture materials, cloth, light weight composites, tarpaulins, bags, sacks, carpets, carpet upholstery, geotextile for transportation, electrical insulation and ropes.
9	**Kenaf**	Pulp and paper product
10	**Pineapple**	items for interior design, livestock, and agriculture, as well as bags, tablecloths, mats, ropes, pulping material, handbags, composites, lightweight duck cloth, conveyor belt cable, and coasters.
11	**Ramie**	Textiles, papers, pulp, yarn, fabrics, biofuels, seed foods, resins, waxes, composites, livestock, and agriculture
12	**Sisal**	The sisal fibres are employed in the automotive sector, shipping industry (for tying small craft and handling cargo), civil constructions, utilised as the fibre core of the steel wire cables of lifts, agricultural twine or baler twine, etc. The fibres have a wide variety of mechanical qualities.

Table 1

III. Properties of Natural Fibers

Studies on the mechanical and physical characteristics of natural fibres are included in this area. Additionally, the mechanical properties of plant fibres are influenced by their physical, chemical, and morphological characteristics. While the characteristics of a single fibre are influenced by the size, crystallite concentration, orientation, and thickness of the cell walls. Natural fibres typically have properties like low energy usage, low density, non-abrasive nature, low cost, renewability, biodegradability, easy availability, and global abundance. Environmental factors include growth, location, nutrient, temperature, season, and local climatic condition all have an impact on the size and quality of fibres. Additionally, these fibers' characteristics are influenced by the stage of harvest, thickness, and stickiness between them. Their properties are also influenced by the supply phase, which includes the mode of transportation, the duration of storage, and the storage environment.

In order to produce the best fibre characteristics, all the elements must be optimized. In addition, the plant component from which these fibres are harvested also influences the differences in their properties. The tensile strength of natural fibres is lower than that of synthetic fibres, yet they have more benefits overall. Additionally, they are typically robust, do not shatter during processing, and have similar stiffness and specific strength to glass fibres. They are less elastic and have a competitive Young's modulus. Some of them are rigid, have high strain, and have high stiffness and tensile strength. Asim et al.'s comparison of the characteristics of natural and synthetic fibres is summarized in. The density, cost, and energy consumption of natural fibre were lower than those of synthetic and glass fibre. In contrast to glass fibre, natural fibres are naturally renewable, recyclable, and CO_2 neutral. Both glass and natural fibre are widely available. Natural fibres do not possess the abrasion to the machine and health risk that glass fibres do when inhale. Natural fibre can be degraded from a disposal standpoint, but glass fibre has non-biodegradable qualities. Both glass and natural fibre are widely available. Natural fibres do not possess the abrasion to the machine and health risk that glass fibres do when inhale. Natural fibre can be degraded from a disposal standpoint, but glass fibre has non-biodegradable qualities.

The porous structure of fibres makes it extremely difficult to determine its density with accuracy. The densities of ramie bast and sisal leaf fibres are high (1.38 g/cm3) and low (0.76 g/cm3), respectively. Natural fibers' specific gravity (1.2–1.6 g/cm3) is lower than glass fiber's (2.4 g/cm3), hence this results in the creation of lightweight composites.

It's crucial to comprehend natural fiber's fundamental physical-mechanical characteristics in order to ensure its proper use.

Additionally, a particular quantity must be used to analyses the relationship between their weight and the rise in tensile strength. Natural fibers such as sisal and jute fiber could be used to replace the glass and carbon fibers due to their easy availability and low cost. Natural fibres include flax, hemp, jute, sisal, kenaf, coir and many others are inexpensive, abundant and renewable, lightweight, with low density, high toughness. Furthermore, they are biodegradable and have the potency of being used as a replacement for traditional reinforcement materials in composites for applications which require high strength to weight ratio and reduction.

IV. Composite Materials and its types

Over 6000 years ago, the earliest composite material, wattle, and daub, was used as a building material for walls, beginning the human race's production and usage of composite materials. In the past, composite materials have mainly been made of two different substances: a matrix that functions as a binder and a fibre that serves as reinforcement. Each of these substances has its own mechanical characteristics, such as stiffness and strength. When a reinforcement and matrix are combined to create a composite, the mechanical properties of the composite also depend on the relative amounts of each material, the size and shape of the reinforcement, and the orientation of the reinforcement with respect to the loads that will be applied to the composite. In fiber-reinforced composite materials, fibres, whether natural or synthetic, serve as reinforcement and add strength and stiffness. In the end, the intrinsic characteristics of these fibres determine the characteristics of the composite material. The term "matrix material" refers to a continuous phase made up of various matrix materials, such as polymer matrix composites, metal matrix composites, and inorganic non-metallic matrix composites. A composite has a matrix that is polymeric, metallic, and ceramic. In a nutshell, a composite material is a multi-phase system made up of a matrix material and reinforcing material. The reinforcement is often stiffer, stronger, and harder than the matrix. The shape and size of the reinforcements have a significant impact on the mechanical properties of composite materials.

Humans have employed natural fibres like wood and various synthetic composites for thousands of years, but recent years have seen significant advancements in these fields. The three primary cell wall polymers that make up all vegetable fibres, whether they come from non-wood or wood sources, are cellulose, lignin, and matrix polysaccharides (such as pectins and hemicelluloses), which are linked to cellulose and lignin in the cell wall. In addition, there are several extractives that are non-structural in nature, including waxes, nitrogenous materials, and inorganic salts. Vegetable fibres are thought of as minuscule composites made up of millions of tiny fibrous units called microfibrils in terms of fibre structure.

The parameters used to select appropriate fibres are the desired stiffness and tensile strength of a composite. The selection of an appropriate reinforcing fibre for a composite material will also consider factors including elongation at failure, adherence of the fibres to the matrix, thermal stability, dynamic and long-term behavior, cost, and processing expenses. It is obvious that hemp and flax fibres can potentially compete with E-glass fibres when comparing the tensile strength, elasticity, and elongation at break of natural fibres with synthetic fibres. E-glass fibres serve as a reference because of their significant roles in composite technology.

Thermosets, thermoplastics, and polymeric matrices are the fundamental building blocks of industrial composite materials. Typically, these materials are strengthened with aligned ceramic fibres made of glass or carbon. show prominent anisotropy frequently because the matrix is much weaker and less rigid than the fibres. Recent years have seen a rise in interest in metal matrix composites (MMCs), such as aluminum reinforced with short fibres or titanium- and ceramic-particle-containing long, large-diameter fibres. The qualities of the ingredients, the microstructure (which comprises the morphology of the reinforcement and the volume percentage), and the matrix reinforcement interface properties all play a role in determining the important characteristics of composites, which differ noticeably from those of the constituents.

Over time, various authors have developed various classifications for composite materials. These classifications can be grouped into three groups: fiber-reinforced composites, which use fiber-like inclusions, and structural composites, which combine composites and homogenous materials (Table 2). Particle-reinforced composites use inclusions with uni-form axes. The dispersed phase particle geometry is hence the primary distinction between the first two categories. The fiber-type particles have uneven geometries but higher length-to-diameter ratios, just like natural fibres, while the particles in the particle-type are typically spherical in shape. Depending on the type of matrix employed, particle- and fiber-reinforced composites can be divided into different categories. Metal matrix composites, polymer matrix composites, and ceramic matrix composites are the three main groups.

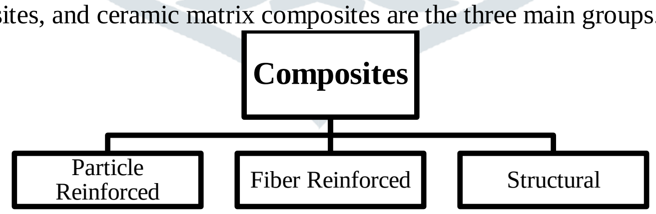

Table 2.

V. FUTURE AND SCOPE OF NATURAL COMPOSITE MATERIALS

Natural fibre reinforced polymers are expanding substantially and have promising futures in the building and automotive industries, according to current market trends. For automotive uses, bast fibres like hemp, kenaf, flax, etc., are chosen. For the construction industry, however, wood plastic composite is the material of choice. Due to the high level of acceptance of environmentally friendly composite materials by the automotive industry, governmental organizations, and the expansion of small-scale environmentally friendly industries, it is predicted that Europe will continue to be the world's largest market for natural fiber-reinforced composites. The development of natural fibre reinforced polymer composites in new potential fields will be fueled by the improvement in material performance. In the fields of electrical, electronics, and sports, natural fibre composites are new.

V. Conclusion

Natural fibre is being employed as an effective reinforcement material in polymer matrix composites as a result of rising environmental awareness. Natural fibres are effective materials that can take the place of synthetic fibres now in use. The main drawback of the fibres, which are typically derived from plants and animals, is that they frequently have a low resistance to moisture. Therefore, natural fibres have been chemically treated to change the material properties by increasing the adherence of the fibres to the matrix and improving the mechanical properties of the composites. Natural fibres will soon replace synthetic fibres in many applications as one of the composite industry's sustainable and renewable resources. These natural resources and fibre, however, will eventually run out as time goes on. Therefore, there is a huge need to care for them and buy them for usage in the future. We should seek for more resourceful ways to harness the full potential of natural fibre and use it to develop science and technology.

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