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Natural Fiber for Application in Concrete Pavement and Reinforced Polymer Composite

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Abstract

Natural fibers are getting attention from researchers and academicians to utilize in polymer composites due to their ecofriendly nature and sustainability. The widely used natural fiber reinforced polymer composites (NPCs) and their applications. The properties of NFPCs vary with fiber type and fiber source as well as fiber structure. Concrete crack is one of the main problems observed in concrete technology due to drying shrinkage. Incorporating fibers in concrete production is one of the mechanisms implemented to mitigate cracks. The investigators concentrate on different techniques to replace human-made fiber with existing natural fibers for fiber-reinforced composite material. Utilization of natural fiber has initiated the development of eco-friendly materials by reducing damages caused by human-made materials and saving nonrenewable resources. Natural fibers are readily and abundantly available, sustainable, and biodegradable, with low cost and low density, and have superior specific properties. Nevertheless, there are some limitations of natural fiber compared to human-made fiber. Consequently, significant energy was applied to alter the natural fiber's surface and morphology using physical, chemical, and biological treatment techniques to overcome the limitation.

Keywords: *Natural fibres, NFPCs, Concrete, Application.*

1. Introduction

The increase in environmental consciousness and community interest, the new environmental regulations, and the unsustainable consumption of petroleum led to thinking of the use of environmentally friendly materials. The natural fiber is considered one of the environmentally friendly materials which have good properties compared to synthetic fiber. Current pointers are that interest in the NPCs industry will keep on growing quickly around the world. The utilization of NFPCs has expanded considerably in the shopper merchandise as developing industry sectors throughout the last few years. The NPCs industry is estimated to grow by 10% worldwide [1].

Natural fibers in the simple definition are fibers that are not synthetic or manmade. They can be sourced from plants or animals. The use of natural fiber from both resources, renewable and nonrenewable such as oil palm, sisal, flax, and jute to produce composite materials, gained considerable attention in the last decades, so far. The plants, which produce cellulose fibers can be classified into bast fibers (jute, flax, ramie, hemp, and kenaf), seed fibers (cotton, coir, and kapok), leaf fibers (sisal, pineapple, and abaca), grass and reed fibers (rice, corn, and wheat), and core fibers (hemp, kenaf, and jute) as well as all other kinds (wood and roots) [2]. The most

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common and commercially natural fibers in the world and world production have been shown in Table 1.

Table 1: Natural fibers in the world production

Fiber source	World production (10^3 tons)
Bamboo	30.000
Sugar cane bagasse	75.000
Jute	2300
Kenaf	970
Flax	830
Grass	700
Sisal	375
Hemp	214
Coir	100
Ramie	100
Abaca	70

Fiber-reinforced polymer matrix got considerable attention in numerous applications because of the good properties and superior advantages of natural fiber over synthetic fibers in terms of its relatively low weight, low cost, less damage to processing equipment, good relative mechanical properties such as tensile modulus and flexural modulus, the improved surface finish of molded parts composite, renewable resources, being abundant [2], flexibility during processing, biodegradability, and minimal health hazards. NPCs with high specific stiffness and strength can be produced by adding tough and lightweight natural fiber into the polymer (thermoplastic and thermoset) [3]. On the other hand, natural fibers are not free from problems and they have notable deficits in properties. The natural fibers structure consists of (cellulose, hemicelluloses, lignin, pectin, and waxy substances) and permits moisture absorption from the surroundings which causes weak bindings between the fiber and polymer. Furthermore, the couplings between natural fiber and polymer are considered a challenge because the chemical structures of both fibers and matrix are various. These reasons for ineffectual stress transfer during the interface of the produced composites. Accordingly, natural fiber modifications using specific treatments are certainly necessary. These modifications are generally centered on the utilization of reagent functional groups which have the ability for responding to the fiber structures and changing their composition. As a result, fiber modifications cause a reduction of moisture absorption of the natural fibers which leads to an excellent enhancement incompatibility between the fiber and polymer matrix [4].

The wide applications of NFPCs are growing rapidly in numerous engineering fields. The different kinds of natural fibers reinforced polymer composite have received great importance in different automotive applications by many automotive companies such as German auto companies (BMW, Audi Group, Ford, Opel, Volkswagen, Daimler Chrysler, and Mercedes), Proton company (Malaysian national carmaker), and Cambridge industry (an auto industry in the USA). Besides the auto industry, the applications of natural fiber composites have also been

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found in the building and construction industry, sports, aerospace, and others, for example, panels, window frame, decking, and bicycle frames.

Regarding the chemical treatments of natural fibers, Kabir and coworkers [5] concurred that treatment is an important factor that has to be considered when processing natural fibers. They observed that fibers lose hydroxyl groups due to different chemical treatments, thereby reducing the hydrophilic behavior of the fibers and causing an enhancement in mechanical strength as well as dimensional stability of natural fiber reinforced polymer composites. Their general conclusion was that chemical treatment of natural fibers results in a remarkable improvement of the NPCs.

2. Literature review

Natural fiber polymer composites (NFPC) are a composite material consisting of a polymer matrix embedded with high-strength natural fibers, like jute, oil palm, sisal, knife, and flax [6]. Usually, polymers can be categorized into two categories, thermoplastics and thermosets. The structure of thermoplastic matrix materials consists of one or two-dimensional molecules, so these polymers tend to make softer at a raised heat range and roll back their properties throughout cooling. On the other hand, thermosets polymer can be defined as highly cross-linked polymers which cured using only heat, or using heat and pressure, and/or light irradiation. This structure gives thermoset polymers good properties such as high flexibility for tailoring desired ultimate properties, great strength, and modulus. Thermoplastics widely used for bio fibers are polyethylene [7], polypropylene (PP) [8], and polyvinyl chloride (PVC); here phenolic, polyester, and epoxy resins are mostly utilized in thermosetting matrices. Different factors can affect the characteristics and performance of NPCs. The hydrophilic nature of the natural fiber and the fiber loading also have impacts on the composite properties. Usually, high fiber loading is needed to attain good properties of NPCs [9]. Generally, notice that the rise in fiber content causes improving in the tensile properties of the composites. Another vital factor that considerably impacts the properties and surface characteristics of the composites is the process parameters utilized. For that reason, appropriate process techniques and parameters should be rigorously chosen to get the best characteristics for producing composite. The chemical composition of natural fibers also has a big effect on the characteristics of the composite represented by the percentage of cellulose, hemicellulose, lignin, and waxes. Table 2 shows the chemical composition of some common natural fibers.

The couplings between natural fiber and polymer matrix are a problem taken into consideration, as a result of the difference in chemical structure between these two phases. This leads to ineffective stress transfer during the interface of the NPCs. Thus, the chemical treatments for the natural fiber are necessary to achieve good interface properties. The reagent functional groups in the chemical treatments can react to the fiber structures and alter the fiber composition [10]. Natural fibers include a functional group named as hydroxyl group which makes the fibers hydrophilic. During the manufacturing of NFPCs, weaker interfacial bonding occurs between hydrophilic natural fibre and hydrophobic polymer matrices due to the hydroxyl group in natural fibres. This could produce NFPCs with a pure biodegradable polymer (Biopol), the mechanical properties of the resulted composites, impact strength, tensile strength, and bending strength, showed an increase when compared with pure Biopol. The

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tensile strength of jute Biopol was enhanced by 50% while bending strength and impact strength of the composites were enhanced by 30% and 90% in comparison to pure Biopol.

Table 2: Chemical composition of some common natural fibers

Fiber	Cellulose (wt%)	Hemicellulose (wt%)	Ligning (wt%)	Waxes (wt%)
Bagasse	55.2	16.8	25.3	—
Bamboo	26–43	30	21–31	—
Flax	71	18.6–20.6	2.2	1.5
Kenaf	72	20.3	9	—
Jute	61–71	14–20	12-13	0.5
Hemp	68	15	10	0.8
Ramie	68.6–76.2	13–16	0.6–0.7	0.3
Abaca	56–63	20–25	7–9	3
Sisal	65	12	9.9	2
Coir	32–43	0.15–0.25	40–45	
Oil palm	65	—	29	—
Pineapple	81	—	12.7	—
Curaua	73.6	9.9	7.5	—
Wheat straw	38–45	15–31	12–20	—
Rice husk	35–45	19–25	20	—
Rice straw	41–57	33	8–19	8–38

3. Natural Fiber

Fibers are small-short, distinct strengthening materials prepared by various materials such as steel, plastic, glass, carbon, and natural constituents in several shapes and sizes for different applications [11] such as composite parts for automobiles and aerospace. Natural fibers were grouped based on their sources into subsequent clusters: animal, mineral, and plant, as illustrated in Table 3. Among these, plant fibers are the utmost usually admitted fiber by the manufacturing for different applications and a current crucial research area for scholars worldwide to replace synthetic materials and nonrenewable resources. This is mostly because they have insignificant growth age, low cost, illimitability, eco-friendly materials to the environment, and broader availability [12]. This specific review mainly focuses on the plant fibers (Cellulose/Lignocellulose), but the others have been restricted to the industrial application due to toxic or health problems for human beings and limited usage or resources. Natural fibers in nature have numerous paybacks over artificial fibers such as accessibility, low cost, low density, good modulus-weight ratio, high acoustic damping, lower industrial energy expenditure, low carbon footprint, and being decomposable [13]. Other researchers give more striking pieces of evidence for clear benefits such that their cost is much less when compared to other materials during composite production, and it requires fewer energy requirements than traditional reinforcing fibers such as glass and carbon [14]. Conversely, natural fibers have some limitations due to the lower reliability of properties in nature and their excellence. This fiber has a radical inconsistency of physical and mechanical properties, more excellent humidity absorption, less stability, lower strength, and lower processing temperature [15–16].

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Table 3: Natural fiber classification

Natural fiber	Cellulose/ lignocellulose	Bast Leaf Seed Fruit Wood Stalk	Flax, hemp, jute, kenaf, ramie Abaca, banana, pineapple, sisal Cotton, kapok Coir Hardwood, softwood (e.g., eucalyptus) Wheat, maize, oat, rice
		Grass/reed	Bamboo, corn
	Animal	Wool/hair Silk	Cashmere, goat hair, horsehair, lamb wool Mulberry
	Mineral	—	Asbestos, ceramic fiber, metal fiber

3.1. Advantages and Disadvantages of Natural Fibre

Advantages

1. Comfortable
   Clothes made with natural fibres are more comfortable than those made with synthetic fibres.
2. Environment
   Producing materials from natural fibres is less harmful to our environment.
3. Fire resistant
   Natural fibres are resistant to fire but polymer-based fibres will melt.

Disadvantages

1. Expensive
   Materials produced by natural fibres are generally expensive as synthetic fibres can be made easily by manufacturing.
2. Shrink
   Natural fibres might shrink due to aggressive washing.

4. General Characteristics of NPCs

The properties of natural fiber composite are different from each other according to previous studies, because of different kinds of fibers, sources, and moisture conditions. The performance of NFPCs relies on some factors, like mechanical composition, microfibrillar angle [17], structure, defects [18], cell dimensions [19], physical properties, chemical properties [20], and also the interaction of a fiber with the matrix [21]. Since every product in the market has drawbacks, similarly, natural fiber reinforced polymer composites also have drawbacks. The couplings between natural fiber and polymer matrix are a problem taken into consideration, as a result of the difference in chemical structure between these two phases. This leads to ineffective stress transfer during the interface of the NPCs. Thus, the chemical treatments for the natural fiber are necessary to achieve good interface properties. The reagent functional groups in the chemical treatments can react to the fiber structures and alter the fiber composition. Natural fibers include a functional group named as hydroxyl group which makes the fibers hydrophilic. During the manufacturing of NFPCs, weaker interfacial bonding occurs between hydrophilic natural fibre and hydrophobic polymer matrices due to the hydroxyl group in natural fibres. This could produce NFPCs with weak mechanical and physical properties.

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Mechanical Properties of the NPCs. There are considerable enhancements and suggestions for the natural fibers that can be implemented to enhance their mechanical properties resulting in high strength and structure. Once the base structures are made strong, the polymers can be easily strengthened and improved [22]. There are some aspects that effects the composite are performance level or activities, of which to name a few are the following;

1. Orientation of fiber.
2. Strength of fibers.
3. Physical properties of fibers.,
4. Interfacial adhesion property of fibers, and more.

NPCs are composites whose mechanical efficiency is dependent upon the interface provided by the fiber-matrix along with the stress transfer function in which stress is transferred to fiber from the matrix. This has been reported by many investigators [23], Characteristic components of natural fibers such as orientation [24], moisture absorption [25], impurities [26], physical properties [27], and volume fraction [28] are such features that play a constitutive role in the determination of NFPCs mechanical properties. Mechanical properties of PLA, epoxy, PP, and polyester matrices can be affected by many types of natural fibers, and to show some of them, Figure 1 is included. NPCs show even better mechanical properties than a pure matrix in cases where jute fibers are added to PLA (polylactic acid); in this case, 75.8% of PLA's tensile strength was improved; however, introduction or incorporation of flax fibers showed a negative impact on this addition. The addition of flax fibers resulted in a 16% reduced tensile strength of the composites. Conversely, composites of PP were improved with the incorporation of hemp, kenaf, and cotton. By far, maximum improvement is only seen in such composites where jute or polyester has been incorporated where a total of 121% improvement is evident compared to pure polyester.

However, due to the rubber phase present in gum compound, a greater range of flexibility is present in such materials which result in reduced stiffness and storage modulus. It is also known that stiffness and stress transfer in composites increases with increased or excessive addition of fiber which provides a better loss modulus and also a better storage modulus. The loss modulus is also considered to be increased with fiber addition up to 756 MPa at 50 phr fiber loading compared to the loss modulus of gum which is 415 MP. The effect of size and filler content on fiber characteristics that cures a wound or any part of the body. Along with this, mechanical properties of Oil Palm Wood Flour (OPWF) were also examined which is reinforced with (ENR) epoxidase natural rubber composites. When the fiber content is increased, the torque of the fibers is also increased and with the smallest possible particle size of OPWF, the highest torque was noticed. However, increasing the factor of OPWF in ENR compounds showed reduced tensile strength and while reaching the breakpoint a considerable elongation is evident.

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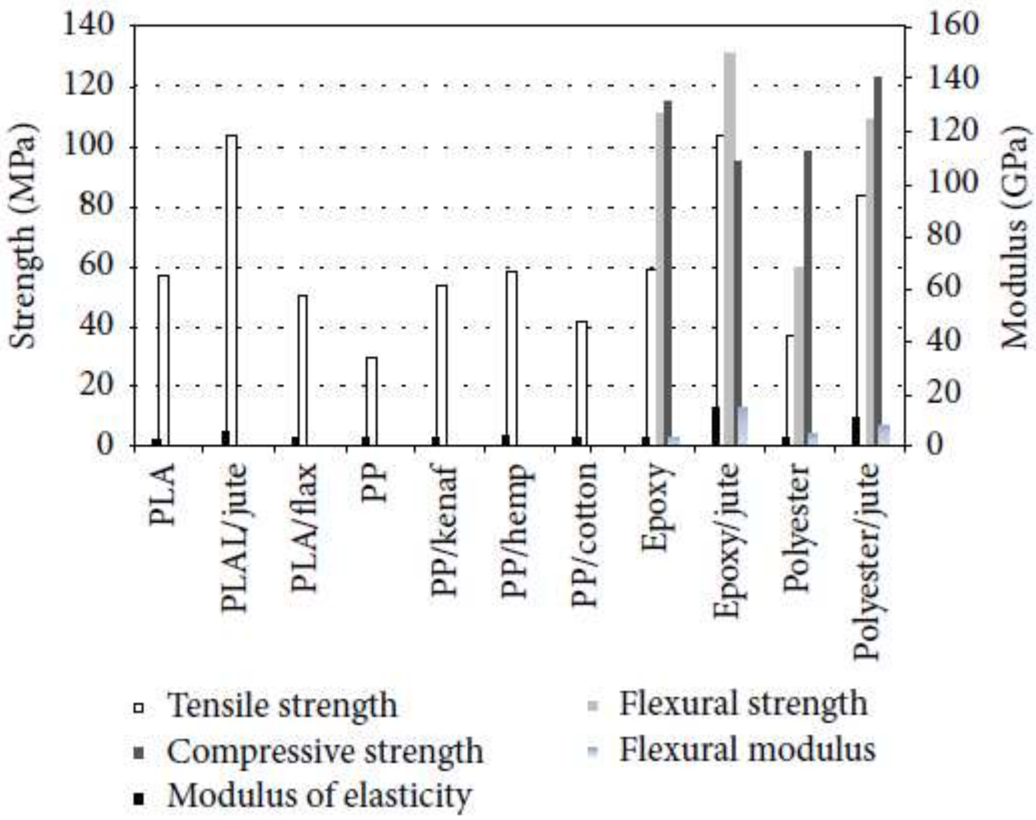

Figure 1: Some of the mechanical properties of natural fiber

It is also evident an increase in elongation, tear strength, tensile modulus, and hardness due to higher loading of OPWF. A higher tensile strength and tear strength as tensile modulus were identified in composites that were filled with even the smallest proportion of OPWF. The fracture behavior of composites is also affected due to the nonlinear mechanical behavior of natural fibers, under the influence of tensile shear loads. Table 3 shows the mechanical properties of common types of natural fiber in the world [27].

The bonding strength between fiber and polymer matrix in the composite is considered a major factor to get superior fiber reinforcement composites properties. Because of pendant hydroxyl and polar groups in fiber, this leads to extremely high moisture absorption of fiber, resulting in weak interfacial bonding between the fiber and the hydrophobic matrix polymers. To develop composites with good mechanical properties, chemical modification of fibre is carried out to reduce the hydrophilic behavior of fibers and the absorption of moisture [28].

The different surface treatments of advanced composites applications were reviewed by several researchers [29]. The effects of different chemical treatments on cellulosic fibers that were employed as reinforcements for thermoplastics and thermosets were also examined. For the treatments, the different kinds of chemical treatment include saline [30], alkali [31], acylation [32], benzoylation [33], maleate coupling agents [34], permanganate [35], acrylonitrile and acetylation grafting [36], stearic acid [37], peroxide [38], isocyanate [39], thiazine [40], fatty acid derivate (oleo chloride), sodium chloride, and fungal. The main purpose of surface

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treatments of natural fibers is to enhance fibre/matrix interfacial bonding and stress transferability of the composites.

The impact of alkaline treatment on surface properties of Iranian cultivated natural fibers was revealed that alkaline treatment gets rid of some chemical components on the surface of the fibers, comprising uranic acid (hemicellulose), aromatic moieties (extractives), and nonpolar molecules from the partial lignin depolymerization. There is a stronger effect on the chemical components of non-wood fibers. Improving the crystallinity of non-wood fibers, in the softwood fibers results in only a minor increase. Hence, alkaline treatment can result in a remarkable improvement in the specific interaction of the fibers as well as improving the fibers' wettability.

5. Natural Fibres in construction

Concrete was the most extensively used building material worldwide among the materials utilized in all types of civil engineering works [41] such as concrete pavement, concrete domes, apartments, and bridges. One of the applications of concrete is to be utilized in the construction of a rigid pavement due to its several advantages when compared to flexible pavement such as its durability, ability to resist unexpected traffic load, serving a long time with low repairing cost, and favorability in different environmental conditions [42], but there was some drawback of concrete such as a little tensile strength, limited ductility, and little resistance to early cracking; there is also structural crack build-up particularly before loading due to drying shrinkage or other causes of volume change [43].

According to [44], most of the new concrete cracks observed after five days of placing the concrete as a structure and its early full crack recognize up to 60 days of the age of concrete on the face of casted concrete mainly by variation of moisture, temperature, and poor mix design. Therefore, taking a slab as a counterexample to observe a crack, it takes more than a week to observe a visible crack on the bottom. In general, even by considering all the parameters required during the production of concrete for different applications worldwide, a different defect was observed, starting from a few days of the casting of concrete up to a structure's design life. This is why researchers are looking for an alternative mechanism to solve concrete problems by dispersing fibers in concrete production for different applications. Nowadays, natural fibers are utilized for different industrial applications for self-weight reduction for automotive aerospace due to their advantages such as being cheaply available; in abundance, it controls the ecosystem of the environment, being biodegradable and sustainable with low density and high specific properties [45]. Therefore, this review mainly emphasizes the utilization of surface treatment techniques to enhance the mechanical property of natural fibers and their applicability in concrete, especially in civil infrastructure construction as a crack arresting mechanism of concrete during a structure's intended life.

One of the significant reasons for cracking in early-age concrete is the volume changes due to the temperature difference and stress growth throughout the toughening of concrete or moisture variations during the hardening process [46]; this makes the concrete structure unsafe for its intended purpose. Researchers worldwide categorize the cause of concrete cracks based on drying shrinkage cracks and settlement cracks [47] by exothermic hydration process of cement during hardening as well as with moisture exchange with the environment, while other

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researchers clustered the concrete cracks based on the appearance of cracking to be observed such as random cracking due to excess water in the mix, map cracking by drying shrinkage, and concrete over finishing, transverse cracking caused by contraction or shrinkage as the concrete cures and gives up its moisture content, corner cracking by unequal drying shrinkage, and reentrant crack mainly by high-stress concentration around a joint [48]. In addition to this, for further understanding the crack characteristics which were shown mostly on the face of concrete structure not only restricted to early-age concrete but also incorporated into the rigid concrete during its design life due to different factors of environment and loading conditions, therefore, it is important to understand types of crack, crack patterns or characteristics, their causes, and the preventive measures to control the cracks.

Researchers have studied increasing concrete's toughness by integrating a dispersed fiber in the concrete matrix to overcome the cracks and defects observed in a concrete structure. The experimental results have been accepted as the best remedial for improving energy absorption, stiffness, and mechanical property compared to usual concrete. Also, it is one mechanism of crack resistance or cracks arrest in concrete during its design life [49]. This technique has been used at an earlier time for strengthening the inelastic composite for the construction material. Spread fibers can avert cracks and their propagation differently as a crack arrester mechanism in brick production for house construction. Therefore, the use of dispersed fiber in the concrete matrix as a construction material utilized on various occasions shows that its results have improved mechanical properties compared to ordinary concrete properties such as flexural strength and compressive strength.

5.1. Chemical Composition of Natural Fibers.

The chemical composition of natural fibers consists of cellulose microfibrils in amorphous lignin and hemicellulose composition matrix. The lignocellulose cell wall looked up as naturally happening as a compound structure of spirally oriented form with numerous biochemical mixtures [50]. The fundamental chemical conformation of plant fibers is lignocellulose (cellulose, hemicellulose, and lignin), and the quantity of these constituents vary from plant to plant because of age, species, and also being somewhat dissimilar from portions of the same plant [51]. The topographic nature and climate discrepancy affect the chemical composition of cellulose fibers [52]. Cellulose is a linear macromolecule comprising D-a hydro glucose iterating items linked by b−1, four glycosidic linkages. It delivers strength, toughness, and structural constancy to the plant. Hemicelluloses are branched polymers holding five- and six-carbon sugars of several chemical structures; lignin is an amorphous, cross-linked polymer network containing an asymmetrical group of differently joined hydroxyl- and methoxide-substituted phenyl propane parts [53]. Lignin is not as much cellulose but a chemical epoxy resin within and between the fibers. Pectin is a multifaceted polysaccharide; the principal chains contain an improved polymer of glucuronic acid and ramose residues. Their side chains are plentiful in ramose, galactose, and arabinose sugars. Calcium ions often cross-link the chains; they recover structural honesty in pectin-rich zones. Lignin, hemicellulose, and pectin together gather as matrix and epoxy resin to grasp the cellulosic framework structure of the most common chemical composition of natural fiber composite [54].

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Currently, researchers' awareness increases of effective and economical utilization of the entire plant fibers as the possibility of making better quality fiber-reinforced polymer composites for structural and construction material and other purposes. Due to the abundance of natural resources in a wide range globally, this leads to the development of unusual materials instead of human-made materials [55]. Some researchers have been exploring the opportunity to utilize natural fibers to replace human-made fibers in fiber-reinforced composites. Natural fibers have numerous properties such as low density, low cost, sustainability, high specific properties, and biodegradability. Nevertheless, they have some shortcomings while operating in compound materials such as low compatibility with various matrices, high moisture absorption, and swelling property that indicates the establishment of cracks in brittle matrices. Natural fibers provide a remarkable property during the last formation of composite output, significantly when associated with the atmosphere's protection, such as their capability to be biodegradable, renewable, and small abrasive and harmful [56]. Therefore, some benefits related to natural fibers' usage as strengthening in plastics are their nonabrasive nature, biodegradability, low energy consumption, and low cost.

Furthermore, natural fibers have low density and high specific properties. The specific mechanical properties of natural fibers are like the traditional reinforcements. Hence, the inherent properties of natural fibers can fulfill the requirement of the international market [57]; specifically, manufacturing has a concern of a self-weight reduction (i.e., automotive, aerospace) for industrial products. That is why scholars are looking to potentially replace nonrenewable human-made fibers with natural fibers. Still, the hydrophilic nature of natural fibers is a foremost disadvantage for their application as reinforcement for composite manufacture; in addition to this, the weak moisture resistance of natural fibers leads to incompatibility with different matrix fibers and poor wettability with hydrophobic polymers, and this natural property reduced the interaction bonding at the fiber-matrix interface [58].

Therefore, to utilize natural fibers for different applications for structural and nonstructural composite materials, their inherent properties should be modified to accelerate adhesion to other matrices as composite and avoid their limitation for the required application.

6. The Natural Fiber Applications in the Industry.

Other than the car industry, the applications of NPCs are found in building and construction, aerospace, sports, and more, such as partition boards, ceilings, boats, office products, and machinery. Most applications of NFPCs are concentrated on no-load bearing indoor components in civil engineering because of their vulnerability to environmental attack [59]. Green buildings are wanted to be ecologically mindful, suitable, and healthy places to live and work. Biocomposites are considered one of the major materials utilized as a part of green materials at this time. It could be categorized, concerning their application in the building market, into two principal products: firstly, structural bio-composites, which include bridge as well as roof structures, and secondly, nonstructural bio-composites which include windows, exterior construction, composites panels, and door frame.

The wide advantages of natural fibers reinforced composites such as high stiffness to weight ratio, lightweight, and biodegradability give them suitability for different applications in building industries [60]. The good properties of thin-walled elements such as high strength in

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tension and compression, made of sisal fiber-reinforced composite, give it a wide area of application, for instance, structural building members, permanent formwork, tanks, facades, long span roofing elements, and pipes strengthening of existing structures. On the other hand, bamboo fiber can be used in structural concrete elements as reinforcement, while sisal fiber and coir fiber composites have been used in roofing components to replace asbestos. Natural fiber reinforced concrete products in construction applications like sheets (both plain and corrugated) and boards are light in weight and are ideal for use in roofing, ceiling, and walling for the construction of low-cost houses [61].

6.1. Some of the Applications of Fibers in Concrete Technology

Due to various kinds of manufacturing in building engineering, the applications of fiber-reinforced concrete materials incorporated in composites are reliable and expanded worldwide, especially in developed countries [62]. Therefore, one of the reasons to use fiber-reinforced concrete as composite material when compared to plain concrete is the fact that it has many characteristics observed in the experimental investigations of different researchers looking for a positive outcome, such as the following:

1. It acts as a mechanism for crack arresting and crack control as a solution in concrete technology.
2. It increased flexural strength, post cracks loadbearing capacity, toughness, and viscosity in the fresh state.
3. It enhanced excellent mechanical performance and its properties such as strength, toughness (rigidity), permanence, and ductility.
4. It shrinks the specific weight and density in a lightweight invention material that is both energy-efficient and cost-efficient in the application.
5. It avoids the existence of reduction, cracks, spalling, and puffiness in concrete during casting.
6. Reduction of pavement thickness in the rigid pavement as compared to the plain concrete slab and use of natural fibers, as reinforcement of composites (such as cement paste, mortar, and/or concrete), is economical for increasing their certain properties, for example, tensile strength, shear strength, and toughness.
7. Higher energy absorption was observed for fiber-reinforced foamed concrete compared to the plain foamed concrete, which was attributed to the fibers' enhanced toughness and ductility.

The applications of natural fiber composites are found in building and construction, aerospace, sports, and more, such as partition boards, ceilings, boats, office products, and machinery. Most applications of natural fiber composites are concentrated on non-load-bearing indoor components in civil engineering because of their vulnerability to environmental attacks. Green buildings are wanted to be ecologically mindful, suitable, and healthy places to live and work. Biocomposite is considered one of the major materials utilized as a part of green materials at this time. It could be categorized, their application in the building market, into two principal products: firstly, structural biocomposite, which includes bridge as well as roof structure, and

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secondly, nonstructural biocomposite, which includes a window, exterior construction, composite panels, and door frame [63] in table 4.

Table 4: Applications of the biocomposite

Parts	**Panel**	**Material used**
Applications	Door and panels Roof	Sisal jute Sandwich composites Bamboo mat composite Jute coir composite
	Furniture	Jute pultruded door frames, medium-density composites
	Cupboards, wardrobes	Natural fiber-reinforced boards

The wide advantages of natural fibre-reinforced composites such as high stiffness to weight ratio, lightweight, and biodegradability give them suitability in different applications in building industries and also have good properties of thin-walled elements such as high strength in tension and compression, made of sisal fiber-reinforced composites, which give it a wide area of applications, for instance, structural building members, permanent formwork, tanks, facades, long span roofing elements, and pipe strengthening of existing structures. On the other hand, bamboo fiber can be used in structural concrete elements as reinforcement, while sisal fiber and coir fiber composites have been used in roofing components to replace asbestos. Natural fiber-reinforced concrete products in construction applications like sheets (both plain and corrugated) and boards are light in weight and are ideal for use in roofing, ceiling, and walling for the construction of low-cost houses [64]. Fiber-reinforced concrete increases the static and dynamic tensile strength, energy-absorbing characteristics, and good fatigue strength; nowadays, it is used as overlays of the airfield, road pavement, refractory linings, etc. The isotropic properties of concrete are provided by uniform dispersion of fibers compared to conventional reinforced concrete, so, fiber-reinforced concrete is also nowadays used in the fabrication of precast members like pipes, boats, beams, staircase steps, and wall panels, roof panels, and sanitary man-holes covers.

7. Conclusions

Natural fiber-reinforced polymer composites have beneficial properties such as low density, less expensive, and reduced solidity when compared to synthetic composite products, thus providing advantages for utilization in commercial applications (automotive industry, buildings, and constructions). Using natural fibers as reinforcement for polymeric composites introduces a positive effect on the mechanical behavior of polymers. The application of NPCs in automobiles and industry is reported. The effects of chemical treatment of the natural fiber properties were also addressed. The physical and mechanical properties of these NFPCs can be further enhanced through the chemical treatment, while moisture absorption of the NPCs can be reduced through surface modification of fibers such as alkalization and the addition of coupling agents.

The application of natural fibers in the composite material is increasing at the industry level due to several advantages it has over synthetic fibers. Natural fibers' surface treatment is crucial to replace synthetic fiber with natural fibers to mitigate global warming. To entirely avoid

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natural fibers' limitation composites such as weak fiber-matrix interfacial adhesion, water absorption, low wettability, weak interfacial contact between the polymer matrix and the fiber, moisture concentration, and the natural fibers' hydrophilic nature, a chemical treatment was adopted.

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