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A Review On Natural Composites

Tushar Kumbhar[1], Dr. S.S.Chavan[2] , Dr.S.M.Shendokar[3]
[1]Research Scholar, Bharati Vidyapeeth Deemed University College of Engineering, Pune-Satara Road, Pune,
[2]Professor, Mechanical Department Bharati Vidyapeeth Deemed University College of Engineering, Pune-Satara Road, Pune.
[3]Principal, Bharati Vidyapeeth College of Engineering, Lavale Pune.

Abstract: *Recently, there has been a rapid growth in research and innovation in the natural fibre composite (NFC) area. Interest is warranted due to the advantages of these materials compared to others, such as synthetic fibre composites, including low environmental impact and low cost and support their potential across a wide range of applications. Low cost, low density, low energy input and comparable mechanical properties, natural fibres now dominate the automotive, construction and sporting industries. The aim of this review article is to provide a comprehensive review of the foremost appropriate as well as widely used natural fibre reinforced polymer composites (NFPCs) and their applications.*
Keywords*: Natural fibre, Mechanical properties*

I. Introduction

Overview of composites

Over the last thirty years composite materials, plastics and ceramics have been thedominant emerging materials. The volume and number of applications of composite materialshave grown steadily, penetrating and conquering new markets relentlessly. Modern compositematerials constitute a significant proportion of the engineered materials market ranging fromeveryday products to sophisticated niche applications. While composites have already proventheir worth as weight-saving materials, the current challenge is to make them cost effective.The efforts to produce economically attractive composite components have resulted in severalinnovative manufacturing techniques currently being used in the composites industry. Fibre-reinforced polymer composite material have been developed or under development for anumber of products in transportation industry for roadside structures, Major structure of thistype include sign support, guardrail system and lightning poles [1]. It is obvious, especially forcomposites, that the improvement in manufacturing technology alone is not enough to overcome the cost hurdle. The composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry. Thus the shift of composite applications from aircraft to other commercial uses has become prominent in recent years. Increasingly enabled by the introduction of newer polymer resin matrix materials and high performance reinforcement fibres of glass, carbon and aramid, the penetration of these advanced materials has witnessed a steady expansion in uses and volume. The increased volume has resulted in an expected reduction in costs. High performance FRP can now be found in such diverse applications as composite are designed to resist explosive impacts, fuel cylinders for natural gas vehicles, windmill blades, industrial drive shafts, support beams of highway bridges and even paper making rollers. For certain applications, the use of composites rather than metals has in fact resulted in savings of both cost and weight.

Natural fibre composites

In recent times there is increase in research related work in natural fibre composite (NFC). Natural fibres have been used by humans for thousands of years, with early records of flax dating back at least 7000 years in Egypt [2]. But in recent few years time span the use of natural fibres in composite material has gained rapid interest, where these fibres may be combined with thermoset or thermoplastic polymers to create natural fibre composites, which have been particularly identified for their sustainability attributes [3]. This is because of the advantages of natural fibre such as light in weight, low cost, biodegradable etc. So the growing awareness of environmental concerns the natural fibres have become attractive topic recently.

Despite the fact that advanced composites bring advantages to many engineering applications, there are three major issues commonly criticized by the public: [4]

1. Advanced composites are hardly to be recycled, which may cause serious environmental problems after disposal.

2. The structures made of advanced composites may be over-strength in particular using carbon fibre reinforced polymer (CFRP) composites and

3. There is relatively high materials cost of advanced composites for domestic products.

Therefore, fibres extracted from the nature have emerged in the past decades aiming at replacing traditional high strength synthetic fibres to form a new class of natural fibre reinforced polymer (NFRP) composite. The growing awareness of environmental concerns is also another element to force the engineering sectors to develop new materials from natural resources that are either reusable or renewable.

II. Types of natural fibres

Fibres are a class of hair-like material that are continuous filaments or are in discrete elongated pieces, similar to pieces of thread. They can be spun into filaments, thread, or rope. They can be used as a component of composites materials. They can also be matted into sheets to make products such as paper or felt. Fibres are of two types: natural fibre and man made or synthetic fibre.

There are broadly two types of natural fibres : animal based and plant based. Along with these two there is one more type that is mineral based natural fibres. Commonly used animal based natural fibres are wool, hair, silk, chicken feather etc. In plant based fibres jute, banana, bamboo, hemp, sisal, flax etc. these are commonly mixed with polymers to form NFRP composites. Such fibres are extracted from the nature without damaging the environment.

The classification of natural fibres is presented in fig. 1 and annual productions of natural fibres are tabulated in Table 1.

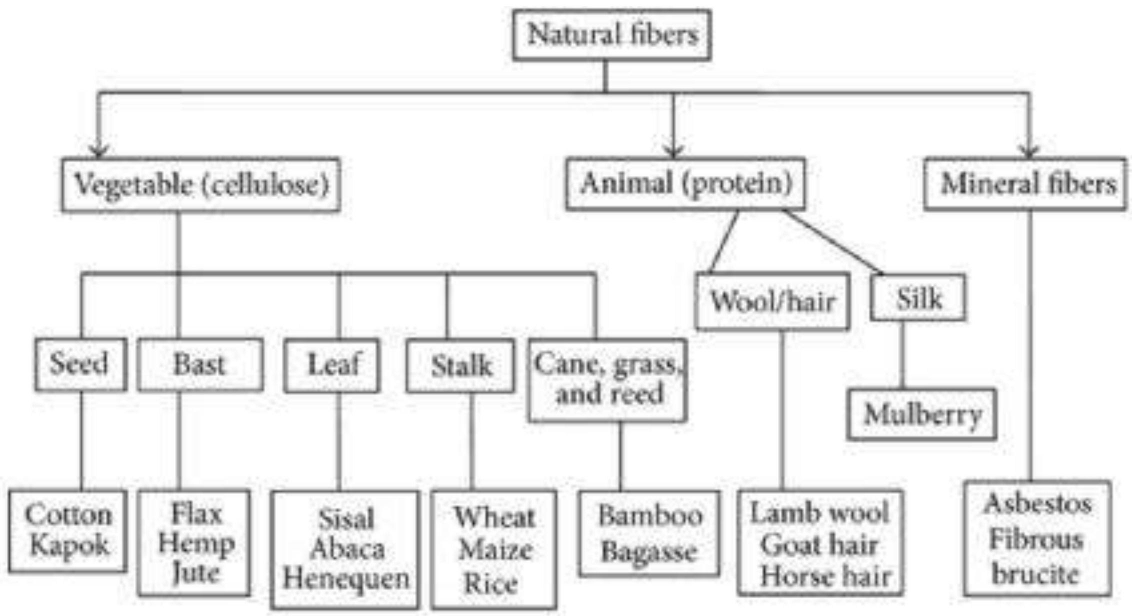

Fig. 1. Classification of natural fibres [Akil et al., 2011; Sanjay et al., 2015][5].

Natural Fibre	Origin	World production (x 10^3 Tons)
Abaca	Leaf	70
Banana	Stem	200
Bamboo	Stem	10,000
Broom	Stem	Abundant

Coir	Fruit	100
Cotton lint	Fruit	18,500
Elephant Grass	Stem	Abundant
Flax	Stem	810
Hemp	Stem	215
Jute	Stem	2500
Kenaf	Stem	770
Linseed	Fruit	Abundant
Oil Palm Fruit	Fruit	Abundant
Ramie	Stem	100
Rice Husk	Fruit/Grain	Abundant
Roselle	Stem	250
Sisal	Leaf	380
Sun hemp	Stem	70
Wood	Stem	1,750,000

Table 1. Annual production of natural fibres [Athijayamani et al., 2010] [6].

III. Constituents of natural fibre reinforced composites

Composites constitute of two parts namely- reinforcing material and matrix. Generally, reinforcing materials are strong with low density and matrix material is ductile and tough so that the composite can get a combination of both the properties [7]. Natural fibres are used for reinforcing material. These have complicated structure, with crystalline cellulose micro fibril- reinforced amorphous lignin or/and hemi-cellulose matrix. Natural fibres are constitutes of cellulose, hemi-cellulose, lignin, waxes and some water-soluble compounds [8].

In microscopic view the natural fibres have complicated structures. As shown in Fig.2, if we grind a kenaf bark fibre, a core lumen is wrapped by different layers of cell wall with different microfibril orientations, these orientations give the strength to the fibre subject to different loads [9]. Similar to other layer systems, the microfibrillar angle governs the tensile strength of nature fibres. The elongation at break increases with microfibrillar angle. The internal structure of natural fibres in contingent upon the age and origin of the plants and climate conditions. Ho et al.[9].

Despite the green message is straightforward, product manufacturers hesitate to use these kind of composites due to several aspects, such as geometrical and mechanical properties, consistent and stable supply chain of natural fibres, bonding properties between the natural fibres and matrix, and the durability of NFRP composites served in different harsh environment[10].

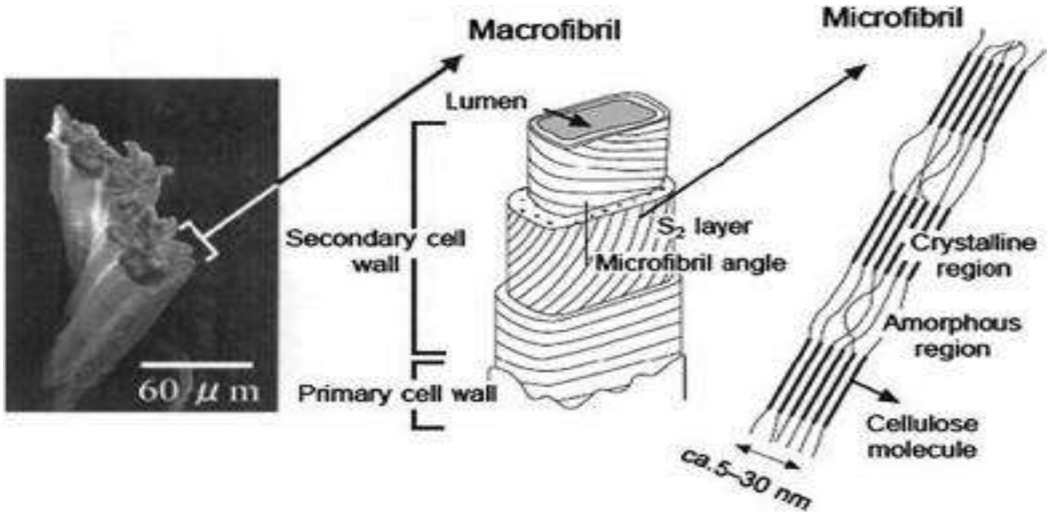

Fig. 2. SEM of a kenaf bark fibre, and schematic representations of macro- fibril of natural plant [9]

Mechanical properties of natural fibres

Researchers have begun to focus attention on natural fibre composites (i.e., biocomposites), which are composed of natural or synthetic resins, reinforced with natural fibres. Natural fibre exhibit many advantageous properties, they are a low-density material yielding relatively lightweight composites with high specific properties. These fibres also offer significant cost advantages and ease of processing along with being a highly renewable resource, in turn reducing the dependency on foreign and domestic petroleum oil. Recent advances in the use of natural fibres (e.g., flax, cellulose, jute, hemp, straw, kenaf, coir and bamboo) in composites have been reviewed by several authors [11-13]. Nilza et al. [14] use three Jamaican natural cellulosic fibers for the design and manufacture of composite material. They took bagasse from sugar cane, banana trunk from banana plant and coconut coir from the coconut husk. Samples were subjected to standardized tests such as ash and carbon content, water absorption, moisture content, tensile strength, elemental analysis and chemical analysis.

Tensile Properties

In general, natural fibre reinforced composites are reported to exhibit comparable mechanical properties with those of synthetic fibre ones. For example, Van et al., 2002[15], established that the mechanical properties of flax, hemp, jute and sisal fibres are very good, which makes them capable of competing with glass fibre as regards strength and modulus. Srinivasan et al., 2014[16], carried out research on the ultimate tensile strength of banana/flax and glass fibre reinforced polymer (GFRP) composites. The results showed that the flax-banana-GFRP hybrid composite had higher ultimate tensile strength of 39 N/mm2, compared to the flax-GFRP composite and the banana-GFRP composite, which reached tensile strength values of 32 N/mm2 and 30 N/mm2, respectively. Paul et al., 2003[17], reported on the mechanical behaviour of kenaf reinforced polypropylene composites, among others. The results showed that with increasing fibre weight fraction, the tensile modulus and the ultimate tensile stress of the kenaf reinforced polypropylene composites improved. Table 2 presents an overview of the tensile properties of various natural fibres in comparison with those of synthetic fibres, as reported in the literature discussed above.

Fibre Name	Density (kg/m^3)	Diameter (µm)	Tensile strength (MPa)	Tensile modulus (GPa)	% Elongation	Reference
Jute	1460	-	393-800	10-30	1.5-1.8	David et al., 2012

Sisal	1450	50-300	227-400	9-20	2-14	[18]
Kenaf	1400	81	250	4.3	-	
E-glass	2.55	<17	3400	73	3.4	Emad et al., 2016 [19]
S-glass	2.5	-	4580	85	4.6	
Carbon (Std. PAN-based)	1.4	-	4000	230-240	1.4-1.8	
Flax	1500	-	345-1500	27.6-80	1.2-3.2	Libo et al., 2014 [20]
Hemp	1480	-	550-900	70	1.6	
Banana	1350	80–250	529–759	8.20	1–3.5	Mei-po et al., 2012 [21]
Coir	1150	100–460	108–252	4–6	15–40	
Bamboo	910	-	503	35.91	1.4	
Cotton	1600	-	287-597	5.5-12.6	3-10	Satyanarayana et al., 1990[22]

Table 2 Comparison of the tensile properties of various natural fibres with synthetic fibres.

Flexural Properties

Flexural properties are one of the major parameters in composite materials and are used mainly to assess the suitability of the material for structural applications by determining its flexural strength, flexural modulus, flexural load and deflection at break. Research on flexural properties of natural fibre composites reports a relationship between flexural strength and fibre content/fibre length. Satyanarayana et al., 1990[22], reported that in bamboo-mesh reinforced cement composites, the reinforcing material enhanced the ductility and toughness of the cement matrix, and significantly increased the tensile, flexural, and impact strengths. Joseph et al., 2002[23], compared the mechanical properties of phenol formaldehyde composites reinforced with banana fibres and glass fibres. The composites were fabricated using banana fibre and glass fibre with varying fibre length and fibre loading. The analysis of flexural properties of these composites revealed that the optimum fibre length required for banana fibre and for glass fibre is different for reinforcing a phenol formaldehyde resole matrix. Aziz et al., 2003[24], observed the effect of fibre alignment and alkalization of long and random hemp and kenaf fibres, which were combined with polyester resin and were hot pressed to form a composite. Their results revealed that alkalized and long fibre composites gave higher flexural modulus and flexural strength compared with the composites made from as-received fibre. The flexure properties decreased due to water absorption by damaging and degrading fibre-matrix interfacial bonding but maximum strain is increased due to it [25-26].

Shibata et al., 2005[27], concluded that kenaf fibres could achieve higher flexural strength in composites, which was due to their densified structure, in comparison with the porous structure of bagasse fibres. Surya et al., 2014[28], studied the hybridizing effect on the mechanical properties of jute/glass reinforced epoxy composites. The results observed revealed that the addition of thin layers of E-glass fabric to the outer layers of composites improved the tensile, bending, and impact properties of the jute-reinforced composites. An overview of specific modulus values achieved for natural fibres and glass fibre is depicted in Fig.

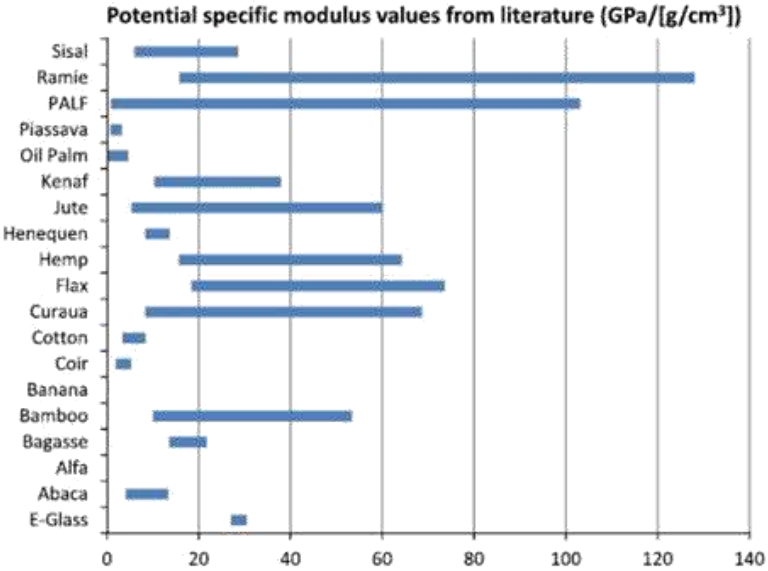

Fig. 3 Comparison of potential specific modulus values and ranges between Natural fibres and glass fibre (Dittenber et al., 2012[18]; Singh et al., 2005[29]).

Impact Properties

Pothan et al., 1997[30], investigated short banana fibre reinforced polyester composites. The aim of the study was to understand the effect of fibre length and fibre content on the impact strength of the composites. The maximum impact strength was observed at 40 mm fibre length. The incorporation of 40% untreated fibres gave a 34% increase in impact strength. Ray et al., 2002[31], carried out an impact behaviour study on 35% jute/vinyl ester composites having both untreated and alkali treated fibres. From the results, it was evident that the alkali treatment removed the hemicellulose, while enhancing the crystallinity and resulting in better fibre dispersion. Sanjay et al., 2016b[32] evaluated the impact behaviour of banana/E-glass fabrics reinforced polyester hybrid composites, by comparing laminates with different composition. The results revealed that the highest impact strength was found in the hybrid laminate, which was 6 J.

Hardness Properties

Zampaloni et al., 2007[33], concluded that Kenaf–maleated polypropylene composites have a higher modulus/cost and higher specific modulus and strength, at a lower cost than those reinforced with sisal, coir, and E-glass, thereby making them good alternatives for various existing materials. Sanjay et al., 2016b[32], measured the hardness values of different laminates prepared from banana/E-glass fabrics reinforced polyester hybrid composites by various stacking sequences. It was found that laminate L1 (pure glass fibre composite) was the hardest (26.72 HV) and laminate L2 (pure banana fibre composites) was the least hard (12.36 HV). The results revealed that an increased number of banana fabric layers reduced the hardness of the composites. (Fig. 4)

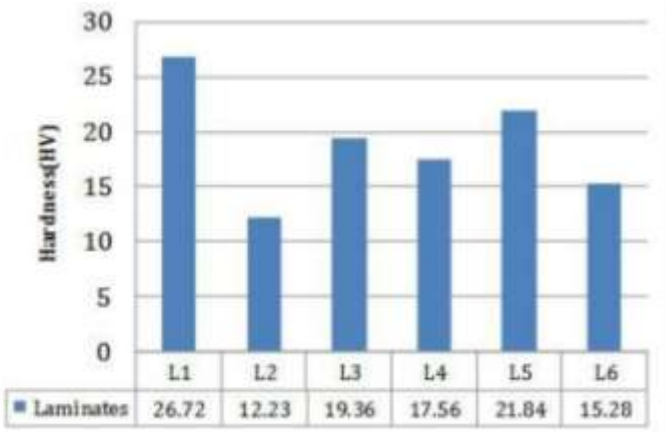

Fig.4. Hardness value for hybrid composites (Sanjay et al., 2016b[32])

IV. Applications of natural fibre composites

As properties discussed above, like low cost, low density, low energy input and comparable mechanical properties, natural fibres now dominate the automotive, construction and sporting industries.

At present, most of the automobile companies of Germany (like Mercedes, Audi, BMW, Ford, Opel etc.) are using natural fibre composites for interiors, door lining and panelling, wood fibres are used to enclose the rear side of seat backrest. Cotton fibres are used as sound proofing material. Coconut fibres are used in cars for interior trim and seat cushioning [34-35]. Also to provide weight reduction door trims are made of polyurethane reinforced with a mixed flax/sisal mat is used. Soya based form filling are used in seats with natural fibres. Improvement in noise reduction is due to use of a cellulose based cargo floor tray [34]. Kenaf fibre is used for making boards with polypropylene [35].

The hemp fibre is used in lightweight lotus designed seats. This fibre when used with polyester forms a hybrid composite. Sisal has been used for the carpet in Eco Elise as it is tough, abrasion resistant material and is obtained from renewable crop [34-36].

V. Conclusions

Natural fibre composites is the better alternate to the synthetic fibre composite due t to its eco-friendly, non-toxic and biodegradable nature. With appropriate attention to fibre and resin design and structural geometry, natural fibre composites may prove a viable alternative to traditional building materials in the future.

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