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Review on Properties of Natural Hybrid Composites

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Abstract— **Due to environment and sustainability issues, there has been remarkable development in the natural fibre-based composites. There is increased in utilization of natural fibre to obtain high performance composite material. The challenge of working with the natural fibre-based composites is that they have large variation of physical as well as chemical properties by introducing synthetic fibre along with the natural fibre and by chemical treating the natural fibre there is been increment in the performance and characteristic of the natural hybrid composites. Also factors like fibre type, environmental condition, type of reinforcement used, source, type, structure, composition of the ply effects on the hybrid composite properties. Further the mechanical properties of natural hybrid composite have been discussed.**

Index Terms—natural fibre, hybrid composite, chemical treatment, tensile strength

I. Introduction

Composite materials can be identified differently on a macroscopic level. The main objective is to make a composite with superior properties. The two materials may be termed as discontinuous phases which is strong and hard, while the continuous phase provides reinforcement and also called as reinforcing material. They are chemically and physically separated by boundaries [1].

Awareness towards the environment and the concept of sustainability attracts many researchers towards the use of natural fibres as reinforcement in polymer matrix composites. It is due to natural fibers-based composites have high strength to weight ratio, low cost, renewability, lower density and light weight [2]. However, due to certain drawback like incompatibility between the natural fibre and thermoplastic based matrix, surface modification of natural fibre by chemical treatment became necessary. This improves the bonding between fibre and the matrix [3].

The aim of the paper is to explore the research gap of hybridization of natural fibre composites. Many researchers have focused on the natural fibre composites due to various advantages of the natural fibre along with the view of eco-friendly and sustainable environment. This paper focuses on various effect of hybridization on natural fibre composites with respect to mechanical properties, chemical properties and advantages of synthetic fibre in hybrid composites.

II. Constituents of Composites

A. Matrix

Even though, the basic function of the matrix is to keep the fibres together, they also have several other important functions as such, it keeps the fibres at preferred orientations. It separates the fibres from each other so as to avoid the mechanical abrasion between them. It transfers the load from one fibre to another fibre. It protects fibres from environmental effects. It offers good surface finish to the composites. It improves the mechanical properties like impact resistance and transverse strength. The polymeric matrix materials are divided into thermoplastic polymer and thermoset polymer. The thermoplastic polymers can be softened, melted and reshaped by heating, but the thermoset polymers cannot be reshaped by applying the heat or pressure. Although thermoplastic polymers have the good fracture toughness and also available at less costly than thermoset polymer, they can be used only at ambient temperature. Hence, they are normally not used in Polymer based composites.

B. Fibre

Fibres are the primary constituents in the FRP composites and they occupy the major volume fraction. The fibre material, volume fraction and fibre orientation are to be carefully selected, as these factors influence the density, strength, modulus and cost of the composite.

The natural fibre are vaguely classified into three types. They are classified on the source of organ as: vegetable, animal and mineral. Among the vegetable ,these fibres are available in different forms like Bast fibres (ramie ,hemp, jute, kenaf), leaf fibres (sisal ,abaca, banana), fruit fibres (coir, oil palm), seed fibres (kapok, milkweed), stalks (rice, wheat, maize), grass/reeds (bamboo, bagasse), and wood fibres (softwood and hardwood).we would concentrate on vegetable section for study of natural fibre.

Classification of the various fibres in polymer matrix composites are:

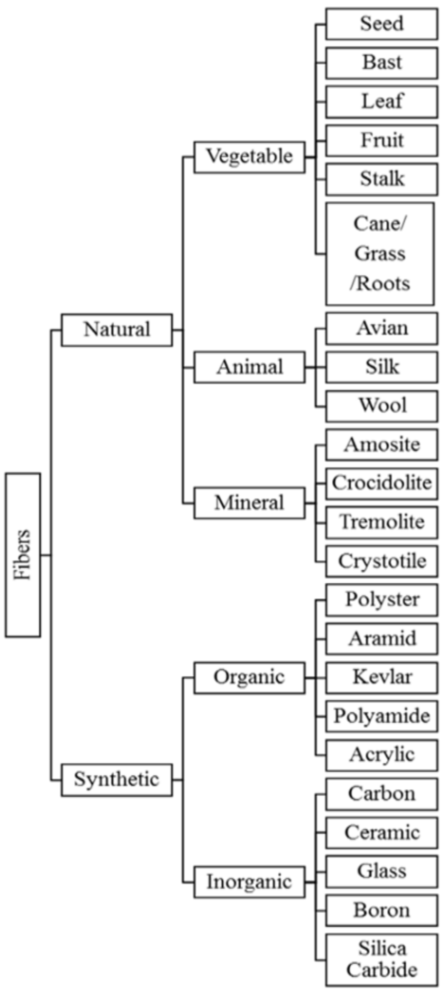

Figure 1: Classification of fibres in composites [4]

TABLE.1.
PLANT FIBRE PRODUCTION AND THEIR PRODUCERS [5]

Fibre	World production (1000 ton)	Producers
Flax	830	France, Canada, Belgium
Hemp	214	France, China, Philippines
Jute	2300	China, India, Bangladesh
Kenaf	970	USA, India, Bangladesh
Abaca	70	Ecuador, Philippines, Costa Rica
Sisal	378	Brazil, Tanzania

C. Jute

Jute fibre which is take out from the Bast section of plant and is of genus Corchorus, has more than 100 species. It is mainly produced in high volume in countries like India, China and other south Asian countries due to suitable climate conditions.

Khan et. Al [5] mechanical properties of jute/biopal and jute/polyamide composites. There was increase in tensile, impact and bending strength by 50%,30% and 90% respectively in the hybrid composites. Jute FRP composites were studied for properties orientation, volume fraction, weathering, durability, thermal stability, notch strength, elastic properties, water absorption, which were seen to be increased by use of hybrid FRP composites [6-9].

D. Flax

Flax is the oldest fibre plants known, in which the fibre is extracted from Bast section of the plant. It is most commonly used in textile market. Being commonly available, it is used in most of the composites now-a-days.

Benjamin et. al. [10] studied the mechanical properties of Cordenka fibre and flax fiber. The matrix material used is polylactic acid. The Cordenka fibre performed better in the impact strength and tensile strength while the flax fibre had better Young’s modulus. The adhesion at the matrix fibre interface was found out to be poor.

Yan li et. al. [11] studied the tensile failure strain on glass/flax hybrid composite. The tensile stress and strain were seen to be influenced by the stacking sequence, but there was no much change in the value of tensile modulus. Due to hybridization there was increased in the interlaminar shear strain and fracture toughness then compared to the glass FRP.

V foire et. al. [12] studied the hybrid carbon and flax fibre composite for structural applications. There was improvement in the properties like elastic modulus flexural and tensile strength of the hybrid composite. The addition of the carbon fiber enabled us the use of flax fibre in the structural applications

Flax fibre and polyester composites have been evaluated for thermal properties. Also, the effect of surface chemical treatments on fibre surface properties, water absorption and adhesion were studied [13]. The effect of bio fibre modification, toughness and fracture behavior, the effect of alkaline treatment of fibre on composites, the influence of processing parameters retting, hackling and scutching of flax fibres have also been estimated [14-15].

E. Hemp

Hemp is grown mostly in northern hemisphere for its fiber and other product derived from it. It is among the fastest growing plants and, also was one of the first plants which was used to make fibre.

R. Petrucci et. al. [16] have compared different hybrid composite, using glass, basalt, hemp and flax fibre laminates and epoxy as the matrix with symmetrical and balanced configuration and volume fibre fraction of 20%. The tensile and shear strength and their fractures have been studied using SEM.

Asim Shahzad [17] studied glass and hemp fibre based hybrid composite. By replacing 11% of hemp fibre by glass fibre there was seen increased in impact damage tolerance of hybrid composite. Hybrid hemp/glass composite showed increased value of fatigue strength compared to hemp fibre composites.

Hemp FRP composites are recyclable up to great extent. Hemp fibre reinforced composites with epoxy matrix, were used to study effect of fibre properties on weight impact properties, impact load performance of composites. Unrutted hemp was also seen as a source of fibre for bio composites. Also, mechanical properties of hemp fibre reinforced composites with wheat gluten matrix were stuied [18-20].

F. Kenaf

Kenaf belongs to Hibiscus cannabinus, is inherent from southern Asia. Kenaf and jute show similar characteristics. Kenaf is now cultivated in U.S. and shows great potential as raw material in composite products.

A. Atiqah et. al. [21] tested the hybrid composites for Izod impact, tensile and flexural strength. Kenaf and glass fibres reinforced with unsaturated polyester as matrix was used hybrid composite. The process used was sheet molding compound process. Matrix to fibre ratio used is 70%-30%. The chemically treated kenaf fibres were used. Under SEM debonding, fibre cracking and pulled fibre was seen and concluded the key reason for the fracture.

A. Alavudeen et. al. [22] studied the banana fibre and kenaf hybrid composites to evaluate the effect of fibre weaving patterns and orientation of ply on mechanical properties. There was seen improvement in tensile strength of the plain weaved fibre compared to the twill weaved fibre. Mechanical properties were seen improving in the plain weaved fibre composites. Chemical treatment of fibre with sodium lauryl sulfate and alkaline NaOH further improved the properties of hybrid composites.

Xue et. al. [23] studied that kenaf fibre can be made into sheets by thermoforming and compression moulding. Fibre volume fraction of 0.3 improves the tensile and flexural strength of the composites. The hybrid fibre composite had higher specific modulus and modulus/cost ratio than coir, sisal and E-glass fibre .so they could be an option in replacing material with high strength and low cost which are ecofriendly as well.

G. Sisal

Sisal is native to Mexico but now widely cultivated in other countries. It produces a stiff fibre which can be used in making variety products. Also referred as sisal hemp as hemp was primary source of fibre for a long period of time. Sisal is now produced in East Africa and Brazil. the global demand for sisal fibre declined as the other synthetic fibers requires less weaving and twining.

N. Venkateshwaran et. al. [24] evaluated the water absorption and mechanical properties of the banana and sisal fibre. By adding the sisal fibre there was 50% weight reduction and also water absorption was reduced.

M. Ramesha et. al. [25] studied sisal, jute, glass fibre and epoxy composites. Sisal and glass fibre composites performed better in tensile properties, while the jute and glass fibre composites had better with flexural properties. Sisal and silk fibre with unsaturated polyester composite were tested for chemical properties. They were treated with solvents, alkalis and acids for chemical resistance [26]. Constant-life diagrams of epoxy matrix FRP composite with untreated fibre bundles showed that treated fibers had low cycle fatigue.

H. Abaca

Abaca, which is native to Philippines, now also grown in Costa Rica and Ecuador. The fibre which is extracted from leaves stem has great economic value. It is cellulose fibre and also resistant to sea water.

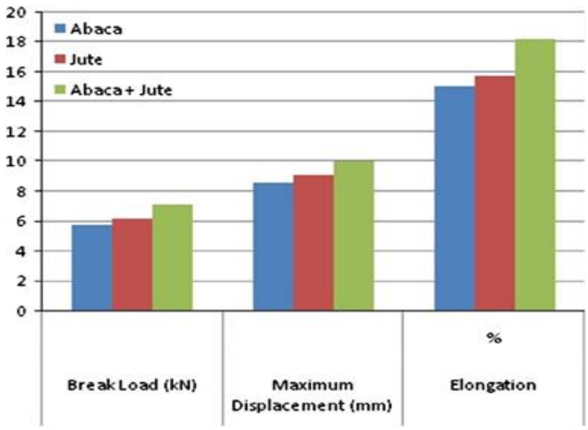

Fig.2-Comparison between different composites: break load, displacement and %elongation [27].

Vijaya Ramnath et. al. [27] Studied jute and abaca fiber as reinforcement in hybrid FRP. It was a sandwich structure with top and bottom of glass fibre, next to it a layer of abaca and jute fibre at the center. The hybrid composite showed better strength and improved surface finish. The hybrid performed better in shear and tensile strength, while the abaca composite was better in impact and flexural strength. Fibre delamination, fracture of the internal structure was studied under SEM.

III. TENSILE PROPERTIES

The tensile strength of hybrid FRP is distinctly improved by increasing fibre content in the hybrid FRP since fibres have much higher stiffness and strength values than the matrix material. In general, higher fibre volume fraction is desired for high performance of SFRP [28]. The strength and modulus of the composites is often increased by addition of fibre to the composites. Therefore, many researchers started taking interest in the fibre content of the matrix, knowing its significance.

TABLE.2

MECHANICAL PROPERTIES OF FIBRES [29]

Fibre	Elongation (%)	Density (g/cm^3)	Tensile strength (MPa)	Young's modulus (GPa)
Flax	2.7-3.2	1.5	345-1035	27.6
Hemp	1.6	1.48	690	70
Jute	1.5-1.8	1.3	393-773	26.5
Kenaf	-	1.3	300-1200	22-60
Abaca	3-10	1.5	400	12
Sisal	2-2.5	1.5	511-635	9.4-22

M. Jawaid et. al. [30] studied jute fibre and EFB composites for tensile properties. Different layering sequence and EFB to jute fibre ratio was 4:1 were used to estimate the properties. These composites were chemical resistant to most chemicals. By varying the stacking sequence there were improvement in the tensile strength.

The natural fibers are not compatible with the polymer matrix due to the hydrophilic nature, which leads to form aggregates. These natural fibers show poor resistance to water absorption which leads to poor tensile strength [31].

The natural fibre also exhibit poor adhesion due to lignin, hemi-cellulose, pectin and waxes are present in it. With the help of chemical surface treatment, the adhesion between matrix and fibre could be improved, which would increase the tensile properties of the hybrid composites [32].

TABLE.3
CHEMICAL COMPOSITION OF FIBRES [33]

Fibre	Cellulose (wt%)	Ligning (wt%)	Hemicellulose (wt%)	Waxes (wt%)
Flax	71	2.2	20.6	1.5
Hemp	68	10	15	0.8
Jute	61-71	12	14-20	0.5
Kenaf	72	9	20.3	-
Abaca	56-63	7-9	20-25	3
Sisal	65	9.9	12	2

IV. CONCLUSION

Hybrid composite with natural fibres have developed over the years significantly because of their advantages such as biodegradability, lower cost, lower density, and recyclable nature. The hybrid composites will find more and more application in the future. Bonding between natural fibres and matrix will have great significance in the properties of the composites. The amount of synthetic fibre added and the fibre volume ratio will be important for improving the overall properties of hybrid composites. Many studies are examined, reviewed and highlighted in this review paper regarding the importance of the synthetic fibre which is added in hybrid composite, the influence of surface modifications, different types of matrices used for the composites, as well as fabrication methods, and the performance of hybrid composites. Researchers around the world are trying to develop hybrid composite with improved performance for global applications like housing, automobile and packaging industry, etc.

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