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Use of Natural Fibres for Construction of Structure

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Abstract—*The materials chosen for addition to functional efficiency of structural upgradation must increase or improve the various other properties of the structures and should fulfill the criteria of better quality and sustainability. For example, these materials will not pollute the environment and endangers bio reserve and helps in recycling of polluting waste into usable materials. They promotes self-reliance and are self sustainance, and make use of locally and easily available materials, utilise local skills, manpower and management systems, resulting benefit in local economy by income generating and accessible to the ordinary people and be low in production and monetary cost. Besides improving the strength, ductility and sustainability of the structure using FRPs as the raw material, it is better to use local materials in construction. So far the work on construction, retrofitting or rehabilitation of structures is confined to using of carbon, glass or aramid fibres etc., very little work is being imparted in improving structures using naturally available fibres. In recent years it cannot be expected that fibre reinforced polymer prices will be less costly, as the consumption is growing day by day. New materials that would be cheaper and provides equal or better properties that to be developed or invented. Enough natural resources are available and looking for more must be taken into consideration. Among the various natural fibres like sisal, bamboo fibres, coir, hemp, kinaf, flax, ramie and jute fibres are the particular interest as these composites have high impact strength, moderate tensile and flexural properties as compared to the other lignocellulosic fibres. Use of natural fibre in civil engineering as well as waste disposal for society can be targeted together. Scientists and engineers are looking for and partially applied different methodologies to utilize these natural fibres effectively and economically with structural upgradation.*

1. INTRODUCTION

A material is composed of two or more physically distinct phases whose combination produces aggregate properties different from its constituents. Composites are hybrid materials made of polymer (i.e. polyester or PP) resin reinforced with fibres (i.e. glass, carbon or natural fibres), combines high mechanical and physical performance of the fibres and the appearance, bonding and physical properties of polymers. Composite products have good mechanical properties per unit weight. They are durable and their technologies allow the manufacture to have complex and large shapes. For these applications the substitutions of industrial fibres with natural fibres have been considered [5]. Many natural fibres traditionally employed in weaving, sacking, making of ropes; these potential elements can be used as reinforcement elements in composites. Retrofitting of flexural concrete elements is traditionally accomplished by externally bonding steel plates to concrete [1]. This technique has proved its effectiveness in increasing strength and stiffness of reinforced concrete elements, it has the disadvantages of being susceptible to corrosion and difficult to install [4]. In the last decade, the development of strong epoxy glue has led to a technique which has great potential in the field of upgrading structures. The technique involves gluing steel plates or Fibre Reinforced Polymer (FRP) plates to the surface of the concrete. The plates then act compositely with the concrete and help to carry the loads. Recent development in the field of composite materials, together with their inherent properties, which include high specific tensile strength good fatigue and corrosion resistance and ease of use, make them an attractive alternative to any other retrofitting technique in the field of repair and strengthening of concrete elements. FRP can be compared with steel for a number of reasons. 1. These materials have higher ultimate strength and lower density than steel. 2. The installation is easier and temporary support until the adhesive gains its strength is not required due to the low weight.

Usage of natural fibre in present day's construction is cost effective and can be combined with latest technology drivers. Latest development of composites is to use them for protection of man against fire and impact, and a tendency to more environment friendly design, leading to the reintroduction of natural fibres in the composite technology. They can be formed on site into complicated shapes and can also be easily cut to required length. These include wood fibres, jute, sisal, coconut, bamboo and banana leaves. Such fibres are added alone or in hybrid composites, for partial substitution of industrial fibres. Natural fibres such as hem, kinaf, flax and ramie, sisal, bamboo, coir and jute can be used successfully in composite components in order to release the weight and cost of the material. These fibres are renewable, non-abrasive to process equipment, and can be incinerated at the end of their life cycle for energy recovery as they possess high calorific value. They are safe to handle, process and use. The distinctive properties of natural fibre reinforced polymers have improved tensile and bending strength, greater ductility and greater resistance to cracking and improved impact strength and toughness. By changing the direction of the fibres in the resin, the material properties can be tailored to the external loads. For instance, composites combine high stiffness and strength with low weight and their corrosion resistance is excellent [17]. These composites are way better than wood and metal with respect to price and durability. The use of residues from the processing of vegetable fibre in construction could contribute to the increase of income in the agricultural industry [9]. Research is going on to establish the durability of vegetable fibre reinforcement that is normally demolished with time by the alkaline surrounded of Portland cement matrix. The improvement of composites reinforced by vegetable rejects lead to sustainable development in predominantly agricultural regions. The study on sugar cane bagasse shows the viability of composites as a substitute of wood chip board. Jute, curaua, sisal, coconut and banana fibres are the most studied reinforcement in cementitious composites [14]. Natural fibres are generally lignocellulosic in nature, consisting of helically wound cellulose micro fibrils in a matrix of lignin and hemicellulose. According to Food and Agricultural Organization survey, Tanzania and Brazil produces largest amount of sisal. Henequen grows in Mexico. Abaca and hemp grows in Philippines. The largest producers of jute are India, China, and Bangladesh. Presently, the annual production of natural fibres in India is about 6 million tons as compared to worldwide production of about 25 million tons. A good interfacial bond is required for effective stress transfer from the matrix to the fibre where maximum utilization of the fibre strength in the composite is achieved. Modification to the fibre also improves resistance to moisture induced degradation of the interface and the composite properties. Additionally, factors like processing conditions/techniques have significant influence on the mechanical properties of fibre reinforced composites.

2. DIFFERENT TYPES OF NATURAL FIBRES

2.1 Sisal

Sisal fibre is very sturdy and strong fibres. It is one of the prospective reinforcing materials; its use is more experiential than technical for recent purpose. Presently, Sisal is the first natural fibre in commercial applications. It is estimated from recent literature, that more than half of the total of all natural fibres are used already [19]. Agave Sisalana Perrini is a native species to the Yucatan peninsula is known worldwide for its fibres. Sisal, belongs to the class of natural hard fibres. The plants look like giant pineapples, and during harvestation the leaves are cut closer to the ground. The soft tissue is scraped from the fibres by hand or machine. The fibres are dried and using brushes remaining dirt is removed, results a clean fibre. The leaves of Sisal are an example of natural composite with lignocellulosic material presenting in 75% - 80% of the total weight of the leaves, reinforced by helical micro fibres of cellulose, which presents about 9% - 12% of the total weight. The composition of Sisal fibre is basically of cellulose, lignin and hemicelluloses. The failure strength and the modulus of elasticity, besides the lengthening of rupture, depends on the amount of cellulose and the orientation of the micro-fibres. The use of 0.2% volume fraction of 25mm sisal fibres leads to free plastic shrinkage reduction.

Table 1: Properties of sisal fibre [19].

Specific gravity [Kg/m^3]	1370
Water absorption [%]	10
Tensile strength [M Pa]	347-378
Modulus of elasticity [G Pa]	15

Available countries:-

East Africa, Bahamas, Antiqua, Kenya, Tanzania, India

Advantages:-

a) They are very well resistant against moisture and heat.

b) These fibres have a good tension resistance or tensile strength.

c) Sisal short fibres delay restrained plastic shrinkage controlling crack development at early ages.

d) Sisal fibres conditioned in a sodium hydroxide solution retained 72.7% of their initial strength.

Disadvantages:-

a) Decomposes in alkaline environment or in biological attack.

Applications:-

a) It is mainly used for ropes, mats, carpets and cement reinforcement.

b) In developing countries, sisal fibres are used for reinforcement in houses.

Fig. 1: Sisal Fibre

2.2 Bamboo

Bamboo is one of the common materials in pre-industrial architecture of Asia and South American countries as structural elements. The utilization of bamboo as construction component is motivated by its widespread availability in the tropical and subtropical climatic regions, its rapid growth and the combination of elevated mechanical strength and low specific weight [12], [15]. At the present time, even the most modern construction where bamboo is used rely on a craft approach, with the know-how of construction techniques restricted to a small group of researchers, engineers and architects. Although bamboo has an immense potential, standardization and a definition of a correct construction practice still faces some difficulties. It is well accomplished that bamboo is a composite material of cellulose fibres, with an average tensile resistance of about 700 MPa. These cellulose fibres are immersed in a lignin matrix. Studies narrated that bamboo is a material with the variation of its physical and mechanical properties in an optimized form, according to the stresses generated due to wind load and its own weight [20, 25].

Table 2: Properties of bamboo fibre [18].

Specific gravity [Kg/m^3]	1158
Water absorption [%]	45
Tensile strength [MPa]	73-505
Modulus of elasticity [GPa]	10-40

Available countries:-

India, Sri Lanka, Egypt, Guyana, Jamaica, Philippines, Malaysia

Advantages:-

a) It has elevated mechanical strength.

b) Low specific weight and high tensile strength.

c) It has better modulus of elasticity than any other natural material.

d) Easily and locally available material.

Disadvantages:-

a) It is very much bad in torsion when it becomes mature.

*b)*Have probability of decomposition in biological attack.

Applications:-

a) Bamboo segments are used as reinforcement of concrete beams, circular columns and pillars in quadratic form of concrete, double–layer spatial and plane truss bamboo structure and special joints between the bamboo elements, that can be easily used for plane and double-layer spatial structures [13].

b) Bamboo frame structures commonly used by local people for improvement of the concrete permanent bamboo shutter slabs and reinforced concrete beams and columns [22].

Fig. 2: Bamboo Fibre

2.3 Coir (Coconut Fibre)

Coconut fibre is obtained from the husk of the fruit of coconut palm. The fruits are de-husked with a spike and after retting, the fibres are subtracted from the husk with beating and washing. The fibres are strong, light and easy to withstand heat and salt water. After twelve months of growth, the fibres are brown and can be used for brushes and mattresses. The combined use of coconut and sisal short fibres seems to be delayed restrained plastic shrinkage controlling crack development at early ages. Coir is an abundant, versatile, renewable, cheap, and biodegradable lignocellulosic fibre used for making wide variety of products. Coir has also been tested as filler or reinforcement in different composite materials. Coconut coir is the most interesting products as it has the lowest thermal conductivity and bulk density which reduces the thermal conductivity of the composite specimens and yields a lightweight product [2]. Coir fibre–polyester composites were tested as helmets, roofing and postboxes. These composites, with coir loading ranging from 9%- 15% wt, have a flexural strength of about 38 MPa. Coir–polyester composites with untreated and treated coir fibres, and with fibre loading of 17% wt, were tested in tension, flexure and notched Izod impact. The results obtained with the untreated fibres show clear signs of the presence of a weak interface long pulled-out fibres without any resin adhered to the fibres—and low mechanical properties were obtained. But they show better mechanical performance, when they are treated. Alkali treatment is also reported for coir fibres. Treated fibre–polyester composites, with volume fraction ranging from 10% -30%, shows better properties than composites with untreated fibres. Acetylation of coir fibres increases the hydrophobic behaviour, increases the resistance to fungi attack and also increases the tensile strength of coir–polyester composites. However, the fibre loading have to be fairly high, 45 wt% or even higher, to attain a significant reinforcing effect when the composite is tested in tension. Moreover, even with high coir fibre loading fractions, there is no improvement in the flexural strength. From these results, it can be apparently concluded that the usual fibre treatments reported so far did not significantly change the mechanical performance of coir–polyester composites. Although there are several reports in the literature which discuss the mechanical behavior of natural fibres reinforced polymer composites.

However, very limited work has been done on effect of fibre length on mechanical behavior of coir fibre reinforced epoxy composites.

Table 3: Properties of coir fibre[2,3,6,16]

Specific gravity [Kg/m3]	1177
Water absorption [%]	12
Tensile strength [MPa]	95-118
Modulus of elasticity [GPa]	8

Available countries:-

India, Sri Lanka, Philippines, Malaysia

Advantages:-

a) The fibres are strong, light by weight.

b) The use of coconut fibres seems to be delayed restrained plastic shrinkage controlling crack development at early ages.

c) The fibres can withstand salt water and heat.

d) Coir is an abundant, versatile, renewable, cheap, and lignocellulosic fibre.

*e)*The addition of coconut coir reduces the thermal conductivity of the composite specimens.

Disadvantages:-

a) The fibres are biodegradable.

Applications:-

a) It is used for the production of yarn.

b) It is used for manufacturing of rope and fishing nets.

c) It can be used for the production of brushes and mattresses.

d) Coir has also been tested as filler or reinforcement in different composite materials [23].

Figure 3. Coir Fibre

2.4 Jute

The fibres are extracted from the ribbon of the stem. When harvested the plants are cut near the ground. The small fibres, 5 mm, are obtained by successively retting in water, beating, stripping the fibre from the core and drying. A single jute fibre is a three dimensional composite composed mainly of cellulose, hemicelluloses, and lignin with minor amounts of protein, extractives and inorganics. These fibres were designed, after millions of years of evolution, to perform, in nature, in a wet environment [7]. Nature is programmed to recycle jute, in a timely way, back to basic building blocks of carbon dioxide, and water through biological, thermal, aqueous, photochemical, chemical, and mechanical degradations. To achieve better wet ability of jute with resin and to improve strength properties, fibre pre-treatment is necessary. Simple pre-treatment is done with low-condensed resins like melamine resin, phenolic resin and CNSL modified phenol formaldehyde resin. To improve the interface adhesion between the non polar matrices and hydrophilic fibre, coupling agent or compatibiliser can be used. By cyanoethylation and acetylation of jute fibre the reduction of –OH content can be done. The both processes are effective for dimensional stability. Cyanoethylation also improves the bonding between jute and non polar matrix like unsaturated polyester resin.

Table 4: Properties of jute fibre.

Specific gravity [kg/m^3]	1460
Water absorption [%]	13
Tensile strength [MPa]	400-800
Stiffness [KN/mm^2]	10-30

Available countries:-

India, Egypt, Guyana, Jamaica, Ghana, Malawi, Sudan, Tanzania

Advantages:-

a) Lignocellulosic fibres are favorably bonded with phenolic resin to have better water resistance.

b) It has high tensile strength.

c) The fibres can easily withstand heat.

d) It can withstand rotting very easily.

Disadvantages:-

a) Due to its short fibre length, Jute is the weakest stem fibre than other fibres.

*b)*Jute fibre based composites involve reactions with acetic anhydride.

c) The fibres are biodegradable.

Applications:-

*a)*It is used as packaging material, carpet backing, ropes, and yarns.

b) It can be utilized for wall decoration.

Figure 4: Jute Fibre

2.5 Kenaf

Kenaf [Etymology: Persian] *Hibiscus cannabinus*, is a plant in the Malvaceae family. *Hibiscus cannabinus* is in the genus *Hibiscus* and is probably native to southern Asia [10]. Kenaf is one of the allied fibres of jute and shows similar characteristics. It is also known as Bimli, Ambary, Ambari Hemp, Deccan Hemp, and Bimlipatum Jute. It is labeled as Gongoora in Indian, Korea, and America. Gongoora is from Telugu [24]. It is a high-yielding tropical plant traditionally grown for the long, strong bast fibres that develop in the bark layer of the stem. Cultivation spread internationally in the beginning of mid-twentieth century, but interest waned, particularly in developed counties, as raw materials for cordage and related products, and shifted from biological to petrochemical sources. Concerns over rising costs, unstable supply, and negative environmental impact of fossil fuels are promoting renewed interest in traditional fibre crops. Beyond cordage, bast fibres are expanding into new markets of moldable, nonwoven fabrics, and reinforced composite materials in automotive, aerospace, packaging and other industrial applications [21]. This trend is in part due to the physical properties of fibre like light weight, competitive tensile strength and stiffness, and vibration damping properties, and also due to the fibre being a renewable and biodegradable resource. Nonwoven materials made of kenaf or other natural fibres blended with polyester or polypropylenes are efficient sound absorbers and can meet industry specifications of flammability, and odour and mildew resistance. It is an annual or biennial herbaceous plant growing to 1.5-3.5 m tall with a woody base. The stems are 1–2 cm diameter [11].

Table 5: Properties of kenaf fibre[10,21,24].

Density [kg/m^3]	1320
Tensile strength [N/mm^2]	260
Moist absorption [%]	10-12

Available countries:-

India, Bangladesh, United States of America, Indonesia, Malaysia, South Africa, Viet Nam, Thailand.

Advantages:-

a) It is a bast fibre with good length.

b) Kenaf also yields more fibre per acre than southern pine producing 5-10 tons of dry fibre per acre, or approximately 3 to 5 times as much as southern pine.

c) This fibres are very good in tension.

d) Rapid growth: Kenaf reaches 12-18 feet in 150 days, while southern pine must grow 14 to 17 years before it can be harvested.

e) Less chemicals, heat and time are required to pulp kenaf fibres because they are not as tough as wood pulp and contain less lignin.

f) Easily available and low cost fibres.

g) Bast plants have a relatively low specific gravity of 0.28 – 0.62, yielding an especially high specific strength, i.e. strength to weight ratio[8].

h) Genetic strains have been developed which yield 35% or greater bast portions. This is a relatively high proportion.

Disadvantages:-

a) Rotations at least every other year generally required.

b) Lack of related agricultural infrastructure.

c) Relatively high absorption of moisture in core portion.

d) Diminished board properties when using core for particleboard.

e) Difficulty in handling and applying binder to long fibre bundle lengths for processing.

f) Low productivity in cooler climates.

g) High moisture requirements. 600 mm, (23.6 in) of water is preferable during its growing cycle of 120-150 days,

Applications:-

a) The kenaf leaves are consumed by human and animal.

b) The bast fibre was used for bags, cordage, and the sails for Egyptian boats.

c) The uses of kenaf fibre are rope, twine, coarse cloth.

d) Uses of kenaf fibre include engineered wood, insulation, clothing-grade cloth, soil-less potting mixes, animal bedding, packing material, and material that absorbs oil and liquids.

e) It is also useful as cut bast fibre for blending with resins for plastic composites, as a drilling fluid loss preventative for oil drilling muds, for a seeded hydro mulch for erosion control.

f) Kenaf can be used for environmental mats, such as seeded grass mats for instant lawns and moldable mats for manufactured parts and containers.

g) Kenaf is also used for producing papers.

3. CONCLUSION

The fibres (Sisel, Coir, Jute, Bamboo, Kenaf) can be utilized successfully in construction of composites for retrofitting and rehabilitation of structures. These fibres have effective mechanical properties like low specific weight, corrosion resistivity, high tensile and flexural strength. They are easily available, easy to handle, eco-friendly and less costly than other artificial fibres. Local man power can be utilized and socials benefits in monetary concern are directly involved with the utilization of these fibres. Utilization of natural fibres in our day to day life construction is to be stimulated for betterment of social, economical and environmental longevity.

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