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Reviewing the Development of Natural Fiber Polymer Composite: A case study of Sisal and Jute

Gbenga Ekundayo[1] & Sam. Adejuyigbe[2]

1.Mechanical Eng'g Department, Rufus Giwa Polytechnic, Owo,Nigeria
2.Mechatronics Eng'g Department, Federal University, Oye Ekiti, Nigeria

Abstract: Natural fibers that are mainly from plants, animals and regenerated sources are degradable and environmentally friendly as they absorb carbon dioxide and release oxygen, they are cost effective when compare to the synthetic fibers. These materials mainly from plant are used initially for domestics' purposes. They have recently been introduced to some industries, such as automotive, aircraft, marine and buildings, arising from their excellent mechanical, physical and chemical properties. The common natural fibers used for Natural Fiber Reinforced Polymer Composites(NFRPC) are, cotton, sisal, coir, jute, hemp, flax, banana, bamboo etc. Several researches and publications on natural fibers and its composite show that despite the properties of these fibers, their applications were limited to non-structural applications either for interior or exterior applications just for their environmental and low-cost benefit with less concern for their strength capabilities. Sisal and jute are fibers from vegetable and bast plants that had been proved to have exhibited excellent tensile and flexural properties (bast composite) and best impact properties (vegetable composite), were also restricted to non-structural applications only. This paper reviewed the present status and future expectations of natural fiber reinforced compositesin structural applications using sisal and jute fiber reinforced polymer composites as a case.

Keywords: *Natural composites, natural fibers, matrices, sisal and jute fibers, application of sisal&jute fibers in structural composites.*

I. Introduction

Natural Fiber Reinforced Polymer Composite.

The geometric increase of the world population demands that efforts be intensified to meet their material needs socially and economically. If in 1997, Rowell et al forecast that by the year 2000, twenty-five percent of China population would be their "middle class" and that the middle class would be more than the entire population of United State of America, then there is need to show more concern for the development of a new materials that can replace the conventional metals that are costly beyond the reach of the poor masses. There is need for the replacement ofmetal and synthetic materials in order to reduce earth loads, prevent the use of the Petro-chemical by- products and reduce their environmental impact and guide against the prediction that in less than fifty years (50), petroleum (fossil fuel) may go into extinction(Daniel, 2010).Hence, the reason(s) while on the recent attentions is now on natural fiber reinforced composites as the only alternative to both metal and the synthetic composites.

Materials are processed into useful shapes with their structures and properties optimized for the purpose of meeting their end users need using the knowledge of science and technology to arrive at a definite shape. For over thirty years, composite materials, ceramic and plastic had been said to have taken over and dominate the emerging materials (Prakash, 2009).

The volume and number of its applications have grown steadily, relentlessly, penetrating and conquering new markets as the use of composite materials today are applicable to all engineering materials, most especially the sensitive areas such as aircraft, marine, sport, medical, automotive and building industries. Composite materials (composite), according to Mohini et al (2010) is a combination of two or more than two materials in which one of the materials in reinforcing phase (fibre, sheet, or particulate) and the other in matrix phase (polymer, ceramics or metals). It is a hybrid material made of a polymer resin reinforced by fibers, hence combining the high mechanical and physical performance of the fibers and the appearance, bonding and physical properties of the polymer.

Composite materials are expected to have good mechanical properties per unit weight and durable. Their technology allows for the manufacturing of complex and large shapes. The various benefits offered by composite materials make them a reliable source of engineering materialsfor designers in all branches of engineering such as: high strength, light weight, water resistance, corrosion resistance, chemical resistance, high durability, electrical resistance, fire resistance, cost effectiveness and flexibility for design purposes (Bryan, 199; Ticoalu, Aravinthan and Cardona, 2010; Tara and Jagannatha, 2011).

Although, uses of the PFRC and the results from their areas of applications shows that they are reliable due to their well-defined properties. However, recently they have constituted waste management problems, littering everywhere since they are non- degradable and often not recyclable. This is coupled with their methods of production from petroleum which releases carbon gas to the atmosphere causing global warmingthat is injurious to ecological system and human existence.

The demand for renewable and environmentally friendly materials such as NFRC to replace the PFRCthat are not renewable, not environmentally friendly, not degradable and very costly had been the reason of shifting attention to natural fiber reinforced composites. This can be attested to by the number of the various publications and investigations on the structure and properties of natural fiber reinforced composite (NFRPC) (Tara and Jagannatha, 2011; Ticoatu, Aravintha and Cardona, 2010; Joseph et al, 1999; Faruk et at, 2012; Karlia, Kaith and Kaur, 2009).

The various advantages and properties of NFRPC allow the opportunity for NFRPC to serve as alternative to the PFRC. The advantages include their availability in different varieties of forms throughout the world, CO_2 sequesterization, low cost, low density, acceptable specific properties, recyclable, biodegradable, surface reactivity and enhance energy recovery, non- abrasiveness and the pressure to reduce dependence on petroleum products (Deepa et al, 2011).

NFRPC like PFRC is a combination of the fibers from the natural sources such as: plant, animal and mineral-based resources (fig.1). The matrices can either be thermosetting or thermoplastic (Christopher et al, 2013; Roger et al, 2012; FAO, 2009). Fibers consist of thousands of filaments each with diameter ranging from 5 to 15micrometer.

Natural fibers, after being extracted and processed, appear in many forms such as: particulate, discontinuous, or continuous. Fibers provide the mechanical properties (stiffness and strength) required for the composite while the matrix (resin) act as a binder that holds the fiber in their aligned positions of applied stress, continues to keep them away from each other so that they can act as entities, protects the reinforcing filament from mechanical damages and transfer loads to the fibers as the principal load-bearing of the structure. Hence, it enables the composite to withstand compression, flexural and shear stress (Bryan, 1999).

In this review, the limitation shall be on plant fiber reinforced composite (PFRC) only. The plant fiber (cellulose fiber) such as: sisal, jute, flax, bamboo, coir etc., comprises of mainly cellulose, hemicellulose, lignin, pectin, wax and some other water soluble substance were from bast stem, seed, wood and grass stem (Xue et al, 2007; Rowell, 2008).

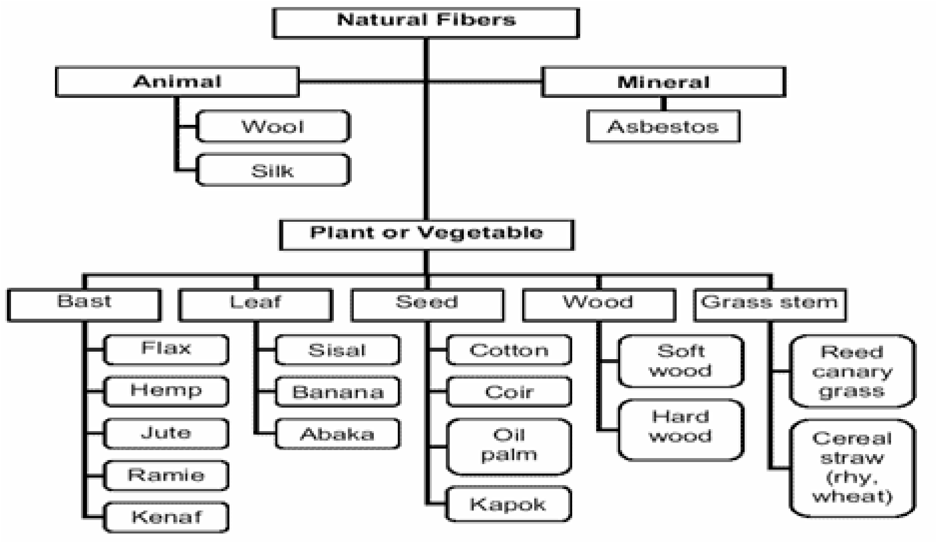

Figure 1: Classification of natural fibers according to their origin together with several examples (Adopted from: Janarthanan et al, 2014)

According Tamrat (2013), the potential properties of the plant fibers are inherent in their cellulose contents and literatures had shown that they are more in bast and vegetable fibers (Table1).

Table1: % Chemical contents of some plant fibers

Fiber type	Cellulose	Hemicellulose	Lignin	Pectin
*Abaca	61-64	21	12	0.8
Bagasse	32-48	21	19.9-24	10
*Banana	60-65	6-19	5-10	3-5
Bamboo	26-43	15-26	21-31	
Coir	46	0.3	45	4
Cotton	82-96	2-6	0.5-1	5-7
*Flax	60-81	14-19	2-3	0.9
*Hemp	70-92	18-22	3-5	0.9
*Jute	51-84	12-20	5-13	0.2
Kapok	13-16			
Kenaf	44-57	21	15-19	2
Phormium	67	30	11	
Pineapple	80-81	16-19	4-6-12	2-3
*Ramie	68-76	13-15	0.6-1	1.9-2
*Sisal	43-78	10-13	4-12	0.8-2
Wood	45-50	23-30	27	2-2.5

Source: (Adopted from: Tamrat, 2013)

Although Tara and Jagannatha (2011), believe that researches on PFRC has just started, they however opined that among the various fibers used for the NFRC sisal, coir, bamboo and jute are the mostly used, due to their high impact strength alongside with moderate tensile and flexural properties, which are very important factors when selecting materials for structural applications. According to Drzal (2014), the bast fibers have excellent tensile and flexural and the vegetable fibers have the best impact properties. If combined or blended, they can be used to achieve a balance of flexural and impact properties which are best used for the development of structural components.

Although, as provided from the various publications PFRPC are used in the automobiles, buildings, sports, everyday appliances(lampshades), Toys etc., their involvement in these areas of applications are due to their environmental and low-cost benefits playing little or no structural role (like the dash board of a car) Ticoalu, Aravinthan and Cardona (2011).

Darshil (2013) explained that despite the promising technical properties of cellulose based fibers and the historic uses of PRFPC, the industrial use of PFRPC in structural application are still limited.

Developing PFRPC for structural application requires that some key factors be considered: (a) the type of fiber, (b) the fiber extraction process, (c) the fibers surface modification techniques, (d) the reinforcement geometry and interfacial properties, (e) the reinforcement packing arrangement and orientation and (f) type of matrix and the manufacturing techniques (Angelo, Mark and Ning, 2005; Christopher, Christian and Chris, 2013; Yan, Yiu-Wing and Lin, 2000; Joseph et al, 1993).

Load-bearing structures such as: beams, columns and panel plates are the basic components of buildings, bridges and other structures. Beams are structural elements that are mostly in bending or flexural manner. It can be in square cross-section or rectangular depending on design and requirement.

Hence, the following models with regard to the properties of individual component of the composites can be used for the prediction of composite properties to be manufactured: Rule of Mixture (ROM), Inverse rule of mixtures (IROM), Halpin-Tsai equation, Narin's generalized shear-lag analysis and Mendel et al (1999) stress transfer model for single fiber and platelet composite (Angelo, Mark and Ning, 2005).

Natural fibers are associated with the problems of wettability and weak interfacial bonding (due to their polar properties) with polymer when used as reinforcement in non-polar matrix, thus pre-treatment of the fibers is required in order to reduce the hydrophilic nature of the fiber and improve their adhesion properties (Min et al, 2001; Fuentes et al, 2013; Farsi, 2012; Kabir et al, 2012; Favaro et al, 2010; Zhong, Lv and Wei, 2007; Xue et al, 2007; Yan, Yiu-Wing and Lin, 2000).

Design and manufacturing of composites for structural applications is different from non- structural composite, the latter is aesthetics in nature. Load-bearing structures are designed and produced not only to support external loads but to maintain their structures when in service example is the shear web of a wind turbine or airframe of an aircraft or building roofing frame. The principle for composite production is similar to the conventional materials production and researchers have observed that the techniques for the manufacturing of natural fiber reinforced composites are similar to that of the synthetic fiber reinforced composite (Mohini et al, 2010).

The use of mathematical modeling for the prediction of macromechanical behavior of structural composites is very important since load-bearing structures are considered as structural elements under constant bending and flexural mode. Therefore, the primary design criteria are bending strength, bending stiffness, tensile strength and tensile stiffness.

The design of composite for structural applications relies on proper selection of materials based on the components function, objectives and constrain; for example, the design of a beam and plate loaded in pure tension need maximum specific stiffness (E/ρ) and specific tensile (σ/ρ). Composites designs and manufacturing for structural application put a lot of emphases on: (1) the volumetric composition (V_f, V_m and V_p), (2) the reinforcement forms (short, continuous or particulate) and the matrix. It has been said and investigated that the type of manufacturing method used for composite manufacturing also affects the variations in the properties of the composite.

The various methods of manufacturing composite based on the factors mentioned above coupled with the shape of the final product(s) are: Open moulding processes (filament winding, hand lay-up, spray-up etc.), Close moulding processes (Vacuum bag, pressure bag, autoclave, injection moulding, Resin transfer moulding (RTM), Reinforced reaction injection moulding etc.) and Continuous moulding processes (Pultrusion, braiding etc.).

There are reports on hand lay-up, spray-up, compression, RTM, compression injection, pressure bag, however, cold press molding, filament winding, Pultrusion, reinforced reaction injection molding and vacuum forming are rarely reported (Deepa et al, 2011).

These are manufacturing processes where unidirectional fibers and thermosetting matrix are mostly used for the development of structural reinforced composites such as beams and columns used for bridges and building constructions as applicable to the synthetic composites.The matrices used for plant fiber reinforced polymer composite development are from two major sources, thermosetting and thermoplastic matrices.

Resins (Matrices) are chosen for composite development based on their properties, the composite manufacturing process(es) and areas at which the product(s) will be used (Ekundayo, 2012). Thermosetting matrices are synthetic matrix formed from chemical reaction and when mixed with hardener or catalyst, they become irreversible, hard and infusible resin. The most commonly used are: polyester, Vinyl ester and Epoxy while thermoplastic matrices mostly appeared solid and softened when heat is applied. They can be reversed by heating after used and re-used again without much effect on their initial properties.

Notable among other thermoplastic matrices used in composite are: polypropylene (PP), Low density polyethylene (LDPE), High density polyethylene (HDPE) and Nylon (6 and 6, 6). A good matrix to be used for composite development must have good mechanical and environmental properties. Plant fiber composites can be combinations of plant and bio-based resin or plant and pro-chemical-based resin that is, it could be made of plant fiber and epoxy or plant fiber and poly(lactic acid) (Mohanty, 2000; Ticoalu, Aravintha and Cardona, 2010).In the Plant fiber reinforced polymer composite, the combination of plant fiber and bio-based resins is called bio-composite (Ku et al, S.a.).

The choiceof thermosetting resins,that ispetro-chemically based matrix for PFRPC, aside the facts that it is non-degradable and cannot be easily recycled, it has been known to have good resistance to solvent, tough and creep resistant, coupled with its low viscosity and low curing temperature. They also provide strong interfacial bonding between the polar fibers and it can be used to maintain balance between economy and environmental impact. Hence, they are commonly used for composite production where structural applications are needed due to their chemical reaction after solidification.

Filament winding is used to process continuous reinforcing fibers. A barrel is required in the shape of the final product, the resin-wetted roving is them wound around the mandrel taking into consideration the designer fiber orientation distribution and number of layers, while the wound barrel is placed inside an oven for curing to a solid form.

Fibers are very effective when used as continuous reinforcement in a matrix and their properties can be tailored to meet the objective of the designer. Pultrusion have been proved to be very good in the production of highly mechanical property composites that can be used for structural application (Darshil, 2013).

Although, the use of sisal and jute fibers for PFRPC are well reported than other plant fibers in many literature and journals, however their involvement in the structural composite production and applications were scantlyreported as an individual composite material but most often as hybrids with synthetic fibers and cement.

Can Sisal and Jute fibers be used for load-bearing structural composite

Among other numerous available natural fibers, sisal, coir, bamboo and jute fibers are mostly used, due to their high impact strength alongside moderate tensile and flexural properties when compared to other lignocellulosic fibers and glass fiber. Drzal (2014) reported that, bast fiber (jute) reinforced composites exhibit excellent tensile and flexural properties and leaf fiber (sisal) reinforced composites give best impact properties and that a blend of bast and leaf fibers can be used to achieve a balance of flexural and impact properties of structural composites.

They can easily be wet-spun into silver and roving or dry-spun to yarn with controlled anisotropy and reduced surface defects (Ekundayo, 2012). They have high aspect ratio and they can best be utilized as continuous fibers benefitting from their excellent properties such as high specific strength, stiffness and impact strength.

They are biodegradable, low cost, low density, widely available; environmentally friendly with some specific properties which can be tailored using the mathematical modeling for fiber reinforced composite design in order to meet the requirement for load-bearing structure with proportionate results similar to the use of glass and carbon fibers. They serve as balance between low cost, low density and environmental impact when used as reinforcement in a thermosetting matrix,hence reducing their reaction to wettability and quick degradation when used in moist environment.

Sisal and jute fibers have been used in different geometries, both singly and in combination with glass fiber that can be employed for the fabrication of uniaxial, biaxial and randomly oriented composites (Myvizhirajeswar and Saravanna, 2011).

These two fibers from bast stem and leaf of jute and sisal plants, when treated with alkali solution and compounded with epoxy have shown better mechanical properties (Boopalan, Umapathy and Jenyfer, 2012). Especially Jute/epoxy recorded up to 104.0MN/m^2 tensile strength when treated using hand lay-up molding (Myvizhirajeswar and Saravanna, 2011). These coupled with other properties as revealed in this paperwhich shows that jute and sisal fibers can be designed and structured to load-bearing composite materials that can be used for building and bridge construction similar to the use of synthetic composites.

Sisal fiber: Structure and Properties

Sisal from the Agave plant called Agave Sisalana was first known and called sisal from Yucatan, Mexico from where it was believed to have moved to other parts of the world e.g. Tanzania, Kenya, Brazil, Haiti, Angola, China, Indonesia, Madagascar, Mozambique, South Africa etc.

The major producer of sisal today is Brazil producing about 60, 000 tons annually (Wigglesworth, 2014). The vegetable fiber of Sisal is coarse and hard.

Figure2: Showing example of sisal leaf plant and the fiber after decortications (Adapted from: Tara and Jagannatha, 2011)

Sisal plant consist of rosette of sword- shaped leaves of between 1.5-2-meter-long with young leaves having few minutes' teeth which they lose as they mature. It's grown well in hot climate and arid region, harvesting takes place 2 years after planting and it can live up to 12 years, producing 180 to 240 leaves. It is environmentally-friendly; it does absorb more carbon dioxide than it produces. It residues can be used as bio-energy, animal feeds, fertilizer and ecological housing material and it is100% biodegradable.

The fiber from the sisal leaves are obtained after decortications when they are crushed and beaten by a rotating wheel set with blunt knives. The fiber is then washed and dried either mechanically or naturally. The dried fiber from a100kg of sisal leaf represents 4% of the total weight of the leaf. Once it is dried the fiber is mechanically double brushed. The fiber which usually appears creamy white in color has an average length of 100centimeter and diameter ranging from 0.2 to 0.4 mm. It is traditionally used as twine, ropes, string, yarn and it can be woven to carpet, mats and various handicrafts (FAO, 2009).

There are many varieties of the Agave plant throughout the tropical and sub-tropical world especially in the central American region, but the most important varieties for fiber production on commercial scale are: Agave Sisalana (commercially refers to as 11648) and the Agave fourcroydes (called Henequen)

Figure 3: Sisal fiber (Adapted from: online image, 2014)

Properties of Sisal Fibers

The favourable properties of sisal fiber are listed thus:

- It's a biodegradable fiber. It can be recycled
- The fiber is from the outer leaf skin, hence removing the inner pulp yields the sisal fiber
- It is available in plaid, herringbone and twill forms
- They are ant-static. It does not attract or trap dust particles and does not absorb moisture or water easily
- It can be dyed to change its colored. The fine textures embedded in it, absorb dyes easily.
- It exhibits good sound and impact absorbing properties.
- Its leaves can be treated with natural borax for it to have good fire resistance properties.

Table 2: % chemical contents of sisal fiber

Contents	
Cellulose (wt. %)	67-78
Hemicellulose (wt. %)	10-14.2
Lignin (wt. %)	8-11
Pectin (wt. %)	10
Wax (wt. %)	2.0
Moisture (wt. %)	20
Micro-fibril/spiral angle (^{O})	11.0

Source: (Adapted from: Majeed et al, 2012; Kabir, Wang and Cardona, 2012; Textile learner, 2014).

Flavio (2010), explained that sisal fiber microstructure was formed by numerous individual fibers of between 6-30µm thick with the individual fiber-cell linked together by means of the middle lamella, which consist of hemicelluloses and lignin. Sisal fibre is a promising reinforcement used in composites on account of its low cost, low density, high specific strength and modulus, no health risk, easily available in some countries and renewable (Yan, Yin-Wing and Ye, 2000). Sisal reinforced polymer composite became interesting due to the fact that it can be produced abundantly and its plant can be grown in all kinds of environment (Joseph et al, 1999).

Many experiments have been performed on sisal fibers treatment in order to improve its mechanical properties and compatibility with hydrophobic polymer matrices. The presence of hydroxyl and other polar groups in sisal fiber make it hydrophilic in nature, hence its incompatibility with hydrophobic polymer matrix.

The hydrophilicity nature results in high moisture absorption of the fiber, therefore the reason for weak adhesion with matrix and the cause of which composite fail when used in humid environments (Azwa et al, 2012). Consequently, researchers result into chemical treatment of the fiber surface before use as reinforcement in polymer matrix (Doan, Gao and Mader, 2006; Kabri, et al, 2012). Taran and Jagannatha (2011) gave the properties of Sisal fiber to be as stated below:

- Specific gravity [kg/m^3] 1370
- Water absorption [%] 110
- Tensile strength [MPa] 347- 378
- Modulus of elasticity [GPa] 15

Despite the seemingly impressive properties of sisal fibers, sisal fiber reinforced composite (either as a combination with synthetic fibers or resin) are still limited to non-structural applications.

Jute Fiber: Structure and Properties

Jute is a member of the Titiaceae family. Jute fiber (often referred to as Jute) can be obtained from two species **Corchorus Capsularis** cultivated in India, Bangladesh, Thailand, China, and Burma and the **Corchorus Olitorus** cultivated in Egypt in Africa(World Jute. Com2002; Encyclopedia, 2014).

Jute is a member of the family of "soft" vegetable fibers. It is one of the cheapest natural fibers. It falls into the categories of the bast fibers (produced from the skin of the plant) (Wigglesworth, 2014).

Jute fiber, also known as golden fibre is one of the longest fiber (between 1 to 4 m long) and shining. It is best grown in tropical lowland with relative humidity of between 60%-90 % (FAO, 2009). In order to extract the fibre from bast of the bast fibre plant, retting process is required, the stalks are harvested and tied into bundles and submerged in soft running water for about 20 days, after which they are removed from the stem of the bast plant for retting.

The most available retting processes are Mechanical (hammering), Chemical (boiling and applications of chemical), Stem/Vapor/Dew, and Water or Microbial retting. Although, the Water or Microbial retting process

is the oldest, it is still the best method of extracting fine bast fibers. After the removal, they are packaged into bundles and hit with long wooden hammer to make the fiber loose the jute hurd or core.
The fiber is then washed with water, squeezed from dehydration, further washed and dried, then tied into bundles and sold to the primary markets.
Jute, Sisal, banana and coir are the major sources of natural fibers. Jute fiber(s) are extensively used for cordage, sacks, fishnets, matting, ropes and filling mattresses and cushion. Jute like any other natural fibers, is degradable, produces non-toxic gas during combustion. The properties of jute fiber can compete favorably with the properties of glass and some other fibers. Table 3 shows properties of jute fibers as compared with other natural fibers and the synthetic fibers of glass.

Table 3: Comparison of jute properties with other fibers

Fiber	Density (g/cm^3)	Tensile Strength (MPa)	Young Modulus (GPa)	Elongation at break (%)	Specific tensile strength ($MPa/g.cm^{-3}$)	Specific Young's Modulus ($GPa/g.cm^{-3}$)
Jute	1.3-1.45	393-773	13-26.5	1.16-1.5	286-562	9-19
Flax	1.5	345-1100	27.6	2.7-3.2	230-773	18
Ramie	1.5	400-938	61.4-128	1.2-3.8	267-625	41-85
Sisal	1.5	468-640	9.4-22	3-7	323-441	6-15
Coir	1.15	131-175	4-6	15-40	114-152	3-5
E-glass	2.5	2000-3500	70	2.5	800-1400	28
S-glass	2.5	4570	86	2.8	1828	34

Sources (Adapted from: Myvizhirajesweri and Saravanan, 2011)

Figure 4: (a) Jute plant, (b) Retted jute fiber drying and (c) The bundled or coiled jute ready for sales (Adapted from: online image of jute, 2014)

Fashion Textile study (2012), described jute fiber as a renewable fibre that compose of cellulose, hemi-cellulose and lignin saying that the presence of lignin in jute fiber made it harder than cotton fiber but it is weaker than other fibers. The variation in the physical and chemical properties of jute fibers depends on the region, atmospheric conditions and temperature of where it is grown.

Table 4: % chemical ingredients of Jute fiber

Contents	
Cellulose (wt. %)	67-71.5
Hemicellulose (wt. %)	13.6-20.4
Lignin (wt. %)	12-13
Pectin (wt. %)	0.2
Wax (wt. %)	0.5
Moisture (wt.%)	12.6
Micro-fibril/spiral angle (^{O})	8.0

Source: (Adapted from: Kabir et al, 2012; Myvzihirajeswari and Saravanan, 2011).

Apparently, today in the need for environmental friendly materials to replace the non- degradable synthetic composite , jute fiber is the best, it is renewable, environmentally friendly (takes in CO_2 and releases O_2), constituted no harms to both lives and ecological system, non- toxic during combustion coupled with excellent mechanical properties, low density and cost effectiveness which is one of the reasons it is being used in the fabrication of composites for automobile and building constructions.

Although, the presence of hydroxyl and polar groups in jute which make it hydrophilic in nature often result into the incompatibility of the fiber with the hydrophobic polymer matrix due to the presence of high moisture absorption in the fibers. This is the reason for the weak adhesion of fiber to the hydrophobic matrices that causes the composite to fail when used in wet conditions. This is under review as several researchers use chemical treatment to reduce or eliminate this defect (Kabri et al, 2011).

ProblemStatement

Synthetic fiber reinforced polymer composites perform credibly well when they were used to replace the conventional materials(metals) for structural and non-structural applications such as inbuilding, aircraft, automobile, sporting, medical, bridge constructions due to the significant advantages offered by these composites.

The recent increase in domestic and global population requires for more and better housing for both rural and urban development coupled with environment free from danger to both human and ecological system resulting from the production of petroleum and its by-products (synthetic fibers). This is one of the major reasons for further researches and developments on natural fiber reinforced composites to reduce dependency on petroleum and reduce carbon dioxide emission. Hence, using materials that are recyclable, biodegradable, low cost, low weight, high tensile and stiffness, non-toxic with specific tensile and modulus propertiesthat can competefavorably with synthetic composites in both structural and non- structural areas of applications (PTRPC). Jute and sisal fibers which are second and third to the largest natural fibers produced after cotton, are presently been used to replace synthetic fiber reinforced composites in the automobile, building, aircraft, bridges with limitation to interior and non-structural applications due to their drawback of poor mechanical properties and poor moisture resistance since structural composites must resist loads due to tension, compression, impact, fatigue, blast and creep (Azwa et al, 2013).

Recent studies, researches and publications have shown that if sisal and jute fibers are well treated chemically before use, their mechanical and adhesion properties with non-polar matrix would be improved enough to rival glass composites in structural applications (Ticoalu, Aravinthan & Cardona, 2010; Taran and Jagannatha, 2011; Boopalan, Umapathy & Jenyfer, 2012; Darshil, 2013). Other properties of sisal and jute fibers that have been confirmed through researches are:

- Their chemical, physical and mechanical properties are reliable to some extent than glass fiber (table 3)
- They are continuous fibers; hence their properties can be tailored due to their anisotropic properties similar to glass fibers
- They can be grown easily hence, providing economic opportunity to the agricultural sector and employment opportunity
- Since human existence is basically on: food, clothing and shelter, low cost of building and easy accessibility of the rural communities to the urban city for sales of their agricultural goods to promote good standard of living, sisal and jute with low cost, low density with reliable economic and mechanical properties should be developed to meet these needs.

Conclusion

The recent attentions, researches and development of PFRPC to replace synthetic composites have shown that the limit to what can be made of PFRPC would be limited to individual's knowledge about natural fibers, the matrices and their areas of applications.

PFRPC have shown that with their impressive properties mostly when treated chemically, compared to the synthetic composites properties can be tailored to meet the growing global populations need socio-economically and improve their standard of living.

Sisal and jute fibers are continuous with high specific tensile, stiffness and impact strength coupled with their controlled anisotropic properties can be developed and manufactured into structural beams, columns etc. for structural application and replace synthetic composites in building and bridge constructions.

Further Trends

Since jute and sisal fibers have shown some exceptional properties compared to other plant fibers and synthetic fibers, cost-effective designs and fabrications techniques should be developed to manufacture them into load-bearing structures that can be used in building and bridge constructions similar to the synthetic composite.

A well-defined mathematical model should be developed for the designs and manufacturing of natural fiber reinforced polymer composites mostly for structural applications.

Natural fibers marketers should have pre-treated natural fibers and characterized them before supply to reduce design and fabrication time.

Researchers should focus on the possibility of making available theeffective means of maintaining plant fiber reinforced polymer composites when in used as load-bearing structure(s)to avoid unexpected failureduring in service conditions

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