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A Review on Development of Natural Fibre Composites for Construction Applications

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Abstract

This paper is a review of the past researcher of feasibility of the usage of natural fibre composites in various civil engineering applications and also the advantages and limitations of natural fibres reinforced composites. As the world is gathering attention towards the renewable resources for environmental purposes, studies of natural fibre have been increasing further due to the application of natural fibre throughout various industries such as aerospace, automobiles and construction sectors. This paper is started with brief information regarding the natural fibre composite materials, the natural fibre composite for structural and infrastructure applications, its advantages and also its limitations. With their unique and wide range of variability, natural fibre composites could emerge as a new alternative engineering material that can substitute the use of synthetic fibre composites.

Keywords

Natural Fibre, Natural Fibre Composites, Construction, Infrastructure

1. Introduction

Fibre composites provide many advantages, such as high strength, light weight, resistance to water, chemical resistance, high durability, electrical resistance, resistance to fire and corrosion. In addition, according to the specifications, the properties and performance of fibre composites can be engineered and thus prove cost-effective in most applications. Composite fiber components such as glass fibre, carbon fibre and aramid have been extensively used in the automobile and aerospace industry and are also used in structural and construction applications.

People are now starting to focus on composite materials and are continuing to use different composite material elements. Composite materials made of natural fibre are environmentally friendly, lightweight, strong, organic, inexpensive, biodegradable and sustainable. Compared to synthetic fibre [1], natural fibre has good properties. Natural fibres have increasingly been used as an alternate reinforcement in polymer composites, and many academics and scientists have drawn interest because of their benefits over traditional synthetic materials [2]. These natural fibres include jute, hemp, sisal, kenaf, coir, banana, bam-boo, sugarcane, flax, and many others [3] which, compared to man-made fibres, have strong mechanical properties and reasonable prices, are recyclable and reusable, minimize energy consumption, decrease the risk of health and non-abrasive equipment, and do not irritate the skin [4].

Natural fibres have seen a surge in popularity in recent years as a result of their eco-friendly and renewable nature. Plant, animal, and agricultural by product fibres are examples of natural fibres. Wood, for example, is used to make shelter, cook food, construct tools, and make weapons, and can be traced back to the prehistoric era. Furthermore, when compared to synthetic fibre, the advantages of using such resources include their widespread availability in all parts of the world such as low cost, strength, aesthetics, and biodegradability [5].

Though natural fibre has several advantages (*i.e.* low density, low cost, biodegradability, etc.), it has some disadvantages as well such as high moisture absorption. Therefore, chemical treatments are necessary to control high moisture absorption. After chemical treatment, the mechanical properties of the natural fibres are greatly affected by many factors such as fibre length, fibre aspect ratio, fibre-matrix adhesion, etc. Hence, this paper reviews the past researchers' perspectives on the feasibility of the usage of natural fibre composites in various civil engineering applications and also the advantages and limitations of natural fibres reinforced composites. This paper is expected to provide an insight for future researchers as a reference on natural fibres honeycomb sandwich structures applications that could potentially replace synthetic fiber composites, particularly in the construction industry.

2. Natural Fibre

Natural fibres are basic fibres that are either manmade or not synthetic. It can be found in plants and animals [2]. The use of natural fibre from both resources is renewable and non-renewable. There are many sorts of natural cellulose fibre like flax, hemp, sisal, banana, kenaf, jute, and oil palm fruit bunch cellulose fibre as shown in **Figure 1** where the applications off these fibres are listed in **Table 1** below. Composite materials made up of jute fibre gained considerably more attention within the previous couple of decades, so far. The plants, which produce cellulose fibres will be classified into bast fibres (jute, flax, ramie, hemp, and kenaf), seed fibres (cotton, coir, and kapok), leaf fibres (sisal, pineapple, and abaca), grass and reed fibres (rice, corn, and wheat), and core fibres (hemp, kenaf, and jute) likewise as all different kinds (wood and roots) [3] [4]. The plants, which produce cellulose fibres are often classified into bast fibres (jute, flax, ramie, hemp, and kenaf), seed fibres (cotton, coir, and kapok), leaf fibres (sisal,

Figure 1. Natural Fibres from source [3] [4].

Table 1. Applications of natural fiber from Source [3] [4].

Natural Fibres	Applications
Jute	Building panels, door frames, chipboards, geotextiles, door shutters, packaging, transport and roofing sheets
Flax	Tennis racket, bicycle frames, snowboarding, panels, doors, laptop cases
Hemp	Textiles, geotextiles, paper and packaging, electrical, furniture, cordage, construction items, producing banknotes and manufacturing pipes
Sisal	Panels, doors, paper and pulp
Kenaf	Mobile cases, insulation materials, animal bedding and packaging materials
Jute	Building panels, door frames, chipboards, geotextiles, door shutters, packaging, transport and roofing sheets
Oil palm	Building and construction materials

pineapple, and abaca), grass and reed fibres (rice, corn, and wheat), and core fibres (hemp, kenaf, and jute) additionally as all other forms (wood and roots). South East Asia, Indonesia, and Malaysia, specifically, being top producers of oil, having problems in eliminating the empty fruit bunch cellulose fibres and so, it's of interest to convert the waste into useful reinforcement. Advantages of natural fibre as plastic reinforcement are thanks to its low density, renewability, biodegradability, non-toxicity, good insulation property and machine wear.

Natural Fibre Composites (NFC)

The purpose of fabrication of NFC for example sisal fibre used as reinforcement in various polymeric matrices and the production of roofing sheets. Other than that, jute-coir composite is an economic alternative to wood for the construction industry as it involves in the production of coir-ply boards with oriented jute as face veneer and coir plus waste rubber wood inside. The applications continues on and on with different type of fibres [6] [7]. A mixture of either natural fibres/synthetic resin or natural fibres/bio-resin can be natural fibre composites. Bio-resin means resin that is bio-degradable. Synthetic and bio-resin are also in the shape of thermoset resin or thermoplastic resin. In automotive applications, natural fibres/thermoplastic composites are used [8]. Most infrastructure composites, however, are produced out of thermoset resins. NFC has also been used for bone and tissue restoration and regeneration in biomedical applications [9]. In an attempt to examine the properties of fibre composites, numerous experiments have been performed. A summary of some fibre composites that are published in the literature is shown in **Table 2**. The property (tensile strength) of fiber composites differed according to the form of fibers, type of resin and manufacturing method, as will be inferred from the **Table 2** below.

3. NFC for Structural and Infrastructure Applications

Natural fibre composites have been used in structural applications and engineering applications to build load-bearing structures such as beams, roofs, multipurpose panels, water tanks and pedestrian bridges. One of the fundamental components of buildings, bridges and other systems is the beam. As a structural feature that is in bending or flexural mode, a beam is taken into consideration. Depending on the specification and specifications, beams may have a square cross section or a rectangle. Structural beams are tested with a three-point or four-point bending test for their flexural capacity, which can yield load capacity, flexural tension, pressure, deflection and elasticity modulus effects.

Beams are typically made of wood, reinforced concrete, laminated veneer lumber (LVL) or glulam, and steel profiles. The potential cost, weight, construction and time advantages of using fibre composite beams have been demonstrated by recent advances. Therefore, in the construction of structural beams and pedestrian bridge girders that involve low to moderate design loads, there is a potential for NFC applications. The lower density of natural fibres, lower costs and environmental benefits are driving the concept of using natural fibre composites in beam production.

Table 2. Natural fibres and its tensile strength and manufacturing process from source [6].

Type of fibres	Resin	Manufacturing process	Tensile Strength (MPa)
Flax	Polyester	Vacuum infusion	61.00
Jute	Polyester	Hand lay-up	60.00
Hemp	Polypropylene	Extrusion & Inj. mold.	50.50
Hemp	Polypropylene	Compression moulding	52.00
Hemp	Polypropylene	Resin transfer moulding	32.90
Coir	Epoxy	-	17.86
Coir	Polypropylene	Extrusion-compr. mold.	26.20
Coir	Polypropylene	Compression moulding	10.00
Sisal	Low density polypropylene	-	16.50
Sisal	Polyester	-	47.10
Sugar-palm fibre	Epoxy	Hand lay-up	51.73
Sugar-palm fibre	Polyester	Hand lay-up	24.49

One of the possible ideas is the composite sandwich beam. This kind of beam requires the use of many material layers. For the thin top and bottom part, the same material is typically used and hence the thick core material is put in between. Usually, the cloth for the top and bottom (skins) has greater strength than the core. Reinforced Acrylated Epoxidized Soybean Oil (AESO) and foam core sandwich beams made of cellulose fibres (from recycled paper) were developed and researched by Dweib *et al.*, [10]. Another concept of natural fibre composite beam was an "I"-shaped beam. A composite of woven jute fabric (burlap) and soybean oil based resin system has been successfully accustomed develop an "I"-shaped beam using vacuum assisted resin transfer molding (VARTM) method [11].

Bending strength, bending stiffness, tensile strength and tensile stiffness are the most widely used key principles of structural architecture. However, the impact resistance of 1.96 J is to be noted in the Australian standard (AS 4253.3-2006) for glass fibre reinforced polyester to be used as roof materials and has a tensile strength of not less than 50 MPa with no noticeable splitting or cracking after inspection. To maintain loading, live load, wind load and, in some situations, snow load, the roof material should be constructed. The fabric should be light, resistant to fire, resistant to water and resistant to weather (such as resistant from ultraviolet light). The roofing industry has the second highest percentage (after electricity) of the use of glass fibre in building and construction in Europe, while the third percentage is used for industrial infrastructure, including corrosion resistance, pipes and tanks [12].

These sectors, where moderate strength is required and high demand is demonstrated, provide considerable opportunities for the easy adoption of fibre composites. As an example, woven mat sisal fiber/cashew nut shell liquid (CNSL) and recycled paper reinforced AESO with a foam core are roof materials manufactured from natural fiber composites that are made. In the shape of a sandwich panel, the recycled paper reinforced AESO composite was used to create a monolithic roof for a single story A-frame building [13] [14]. Usually, a composite panel is a flat surface part on either side, while corrugated panels are also possible. It is typically of uniform thickness and can be manufactured in various dimensions. A panel can consist of a homogeneous material, a laminate composite or a sandwich panel. A fibre composite sandwich panel using plant-based polymers has been developed and manufactured by LOC Composites Pty Ltd, which will be used in various applications such as balcony building, walls, roofs, floors and fire doors [15]. Using recycled paper/AESO composites [8], a natural fibre composite panel suitable for housing building materials, furniture and automobile parts was also made.

Jute mats of reinforced composites are used for trenchless reconstruction of underground drain pipes and water pipes in the field of structural rehabilitation. The studies described earlier have shown that natural materials are used effectively for the construction of load bearing materials such as roofs, beams and panels. In addition, natural fibres are an appropriate alternative for infrastructure applications where the use of synthetic fibres is not suitable. In structural and infrastructure applications, the most and present disadvantages of natural fibre composites are often associated with the massive variance in the properties of natural fibres, treatments and optimization of development. In order to create and manufacture better design components that can be used both for structural and infrastructure purposes, these issues have to be resolved.

4. Advantages of Natural Fibre Composites

4.1. High Strength

Metals such as steel or aluminum are used in construction sectors which are provided high strength in all directions. Composite materials can be designed to be stronger than other materials and must be designed in a specific direction. For example, high strength composites are resultant products of natural fiber reinforcement in polymers which also provide extra or improved biodegradability, low cost, light weight, and enhanced properties related to mechanical structure.

4.2. Strength Related to Weight

Strength-to-weight ratio is a material property of the composite material which helps us information about the material and also give us idea how much that material strong, heavy or light. Composite materials are not only strong material but also light material. For example, composite materials can be used in aerospace design and automotive industries as well.

4.3. Durable

When composites are used to build a structure, they have a long life and need little maintenance. Many composites can serve around half a century. But we do not know how long composite structure can be shown its durability and we do not know when original composites have come to the end.

4.4. Low Thermal Conductivity

Natural fibre composites are used as a good insulator since natural fibre based composites do not easily conduct cold or heat. For example, they are used in buildings for doors, windows, and panels to protect the buildings from the weather.

4.5. Light Weight

Composites are lightweight material that is why it is used in aerospace and automotive applications. Composite materials weight is lighter than any other materials such as woods and metals. For example, composite materials are used in building modern airplanes (*i.e.* Boeing 787 Dreamliner, Cockpit) because they are now more concern about fuel efficiency which is only possible if we use lightweight composite material.

4.6. Corrosion Resistance and High-Impact Strength

Composites have good corrosion resistant and high impact strength properties.

It can absorb any things and also it can resist damage from the weather. Composite has good chemical resistance properties. It has ability to severe in any temperature or weather. Composite materials are able to absorb any sudden force because of this property. For example, composites are used to make bulletproof vests and panels, and to shield airplanes, buildings, and military vehicles from explosions.

5. Limitations of Natural Fibres

Natural fibres also have certain drawbacks, among many advantages, until they are used to manufacture composite materials. Natural fibres have certain performance limitations, the behavior is altered as the polymer is inserted for new composite production and manufacturing. The physical properties of the fibre do not seem to be constant, with the harvesting season, harvesting reign, their physical properties differ. Variations in the properties of natural fibres depend on the processing method, location, and maturity of the fabric, woven or unwoven, plant and manufacturing process. These factors determine the properties of the composites of natural fibres [8]. The expense of producing the products provided by natural fibres is typically costly. It also reveals some flaws when natural fibre composites are used as construction materials, such as less toughness due to high humidity, solvent absorption, concrete cracks due to swelling and volume changes, and low consistency with polymeric or cement matrices. Non-uniform effects are demonstrated by their weak consistency with many polymeric matrices. Any modifications of natural fibres are needed to address these drawbacks, such as treatment with alkali, saline, water repelling agents, to enhance adhesion between matrix chemical coupling or compatibility methods [16], and many researchers are already using plasma modification of natural fibres and these methods help to minimize the absorption of water from natural fibres by eliminating them. In treating the surface of the matrix, chemical coupling agents are used. An additional downside is that the composite materials are less stiff. The rigidity of the materials or composites is a critical aspect for developing every technology framework within the building industries. While composites of natural fibre have high strength, their stiffness is below that of any composite. It is necessary to over-design the systems to address the matter. Restricted thermal stability is another key downside to the use of fibres. Natural fibers can withstand temperatures of up to 2000˚C, natural fibres have started to degrade and shrink above this temperature, and natural fiber composites exhibit poorer efficiency than other materials due to poor thermal stability. The number of time intervals and the temperature range must be limited to prevent this problem [17].

6. Conclusions

In a nutshell, the utilization of natural fibre is increasing hurriedly in industrial application. Already much research work is done but still, further research and investigation are required to overcome the restrictions of the natural fibre such as stiffness of composites, moisture effect, an alkaline solution, fatigue, creep and physical degradation, moisture absorption toughness and reduced future stability for outdoor application. Even now, many researchers are highly fascinated by doing their research work on natural fibre and natural fibre based composites. Therefore, due to its durability, renewable, entirely or partly recyclable properties, research on natural fibre-based composite materials has expanded by leaps and bounds over the last few years.

Previous experiments have demonstrated the effectiveness of using natural fibre composites for numerous applications of civil engineering, including roofing and bridges. A critical advancement that demonstrates viability not only for non-load bearing building elements but also for structural elements is the all-natural composites that are composites made of natural fibers and biodegradable resins. Natural fiber composites therefore have important environmental advantages.

Today, the use of composites of natural fibre is based more on the advantages of the environment and low cost rather than their potential for strength. In order to obtain improved strength and modulus properties, further research is therefore required, including the enhancement of the interfacial bond between fibre and resin by fibre treatment. Further research on the use of natural fibre composites in the structural and infrastructure industries is required, in particular with regard to the problems of fibre costs and, subsequently, the availability of fibre for the manufacture of composites.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Keya, K., Kona, N., Koly, F., Maraz, K., Islam, M. and Khan, R. (2019) Natural Fiber Reinforced Polymer Composites: History, Types, Advantages, and Applications. *Materials Engineering Research*, **1**, 69-87. https://doi.org/10.25082/MER.2019.02.006

[2] Saira, T., Munawar, M.A. and Khan, S. (2007) Natural Fiber-Reinforced Polymer Composites. *Proceedings of the Pak-Istan Academy of Sciences*, **44**, 129-144.

[3] Faruk, O., Bledzki, A.K., Fink, H.P., *et al.* (2012) Biocomposites Rein-Forced with Natural Fibers: 2000-2010. *Progress in Polymer Science*, **37**, 1552-1596. https://doi.org/10.1016/j.progpolymsci.2012.04.003

[4] Nguong, C.W., Lee, S.N.B. and Sujan, D. (2013) A Review on NaturalFibre Reinforced Polymer Composites. *International Journal of Materials and Metallurgical Engineering*, **7**, 52-59.

[5] Karim, A.M., Shah, M.M., Jundam, M. and Abdullah, S. (2020) Investigation of Tensile Properties of the Eco-Board of Hybrid Composite That Consist of Oil Palm Empty Fruit Bunch (OPEFB) Fiber Added with Rice Husk. *IOP Conference Series: Materials Science and Engineering*, **834**, 012012. https://doi.org/10.1088/1757-899X/834/1/012012

[6] Ticoalu, A., Aravinthan, T. and Cardona, T. (2010) A Review of Current Development in Natural Fiber Composites for Structural and Infrastructure Applications. Southern Region Engineering Conference (SREC'10), Toowoomba, Australia, 2010, 113-117.

[7] Akil, H.M., Omar, M.F., Mazuki, A.A.M.,*et al.* (2011) Kenaf Fiber Re-Inforced Composites: A review. *Material and Design*, **32**, 4107-4121. https://doi.org/10.1016/j.matdes.2011.04.008

[8] O'Donnell, A., Dweib, M. and Wool, R. (2004) Natural Fiber Composites with Plant Oil-Based Resin. *Composites Science and Technology*, **64**, 1135-1145. https://doi.org/10.1016/j.compscitech.2003.09.024

[9] Cheung, H.-Y., Ho, M.-P., Lau, K.-T., Cardona, F. and Hui, D. (2009) Natural Fibre-Reinforced Composites for Bioengineering and Environmental Engineering Applications. *Composites Part B: Engineering*, **40**, 655-663. https://doi.org/10.1016/j.compositesb.2009.04.014

[10] Dweib, M.A., Hu, B., O'Donnell, A., Shenton, H.W. and Wool, R.P. (2004) All Natural Composite Sandwich Beams for Structural Applications. *Composite Structures*, **63**, 147-157. https://doi.org/10.1016/S0263-8223(03)00143-0

[11] Alms, B., Yonko, P.J., McDowell, R.C. and Advani, S.G. (2009) Design and Development of an I-Beam from Natural Composites. *Journal of Biobased Materials and Bioenergy*, **3**, 181-187. https://doi.org/10.1166/jbmb.2009.1014

[12] Marsh, E. (2000) Composites in Infrastructure: Building New Markets. Elsevier Advanced Technology, Oxford.

[13] Bisanda, E.T.N. (1993) The Manufacture of Roofing Panels from Sisal Fiber Reinforced Composites. *Journal of Materials Processing Technology*, **38**, 369-379. https://doi.org/10.1016/0924-0136(93)90209-O

[14] Dweib, M.A., Hu, B., ShentonIII, H.W. and Wool, R.P. (2006) Bio-Based Composite Roof Structure: Manufacturing and Processing Issues. *Composite Structures*, **74**, 379-388. https://doi.org/10.1016/j.compstruct.2005.04.018

[15] Erp, G.V. and Rogers, D. (2008) A Highly Sustainable Fibre Composite Building Panel. Presented at the Fibre Composites in Civil Infrastructure—Past, Present and Future, Toowoomba, Australia.

[16] Bismarck, A., Mishra, S. and Lampke, T. (2005) Plant Fibers as Reinforcement for Green Composites. In: Mohanty, A.K., Misra, M., Drzal, T.L., Eds., *Natural Fibers, Biopolymers, and Biocomposites*, CRC Press-Taylor & Francis Group, Boca Raton.

[17] Chadramohan, D. and Marimuthu, K. (2011) Tensile and Hardness Tests on Natural Fiber Reinforced Polymer Composite Material. *International Journal of Advanced Engineering Science and Technologies*, **6**, 97-104.