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An experimental analysis on mechanical properties of nature fibre composites

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ABSTRACT

Composites play significant role as engineering material and their use has been increasing day by day due to their specific properties such as high strength to weight ratios, high modulus to weight ratio, corrosion resistance, and wear resistance. In present work, an attempt is made to hybridize the material using synthetic (glass) as well as natural fibres (Banana & Sisal), such that to reduce the overall use of synthetic reinforcement, to reduce the overall cost, and to enhance the mechanical properties. All composite specimens with different weight percentages of fibres were manufactured using hand lay-up process and testing was done by using ASTM standards. Experimental results revealed that hybridization of composite with natural and synthetic fibres shows enhanced tensile strength, flexural strength, and impact strength. Sisal and Banana with Glass fibre composites are performing better for tensile strength (65.5 MPa). And this type of composite material are better for impact strength. Bamboo as stems have been widely manufactured for composite. However, fiber as the smallest constituent component of bamboo stems supporting the strength and flexibility of the plant has not been widely employed as raw material. These strong and flexible properties, coupled with easy planting treatment and fast harvesting, apparently make bamboo highly potential developed as sustainable raw material for composite. Unfortunately, the current manufacturing process of bamboo for composite by using chemical substances would have ended bamboo up as no longer environmentally friendly. By utilizing lignocellulose content within its fiber, this research studied fabrication of a novel composite boards from bamboo fibers through biologically binding mechanism by using fungal mycelium. Gigantochloa apus bamboo stems are extracted into three types: long fibers, short fibers, and powder. Then, the bamboo fibers are added with water and some additional nutritions then sterilized together. These substrates are then inoculated with mycelium seed of Ganoderma lucidum. The fibers bound together along with the growth of mycelium. The result shows that this board is potential to be used for interior purpose in building especially high rise building with high need of light-weight insulation and partition board and expected to replace the need for building components that have been made from unsustainable raw materials and methods.

Keywords: Natural fibres, Finite element analysis, mechanical properties, Material properties.

INTRODUCTION

Composite material is a material made from two or more materials with different physical and chemical properties but the individual components remain separate and distinct in final product. Fibre Reinforced Polymer is a composite material made of a polymer matrix imbedded with high strength fibres such as glass, basalt, aramid, etc. The polymers are usually vinyl ester, polyethylene, epoxy and polyester resins (Aniber Benin et al., 2015). The use of natural fibres as a substitute for synthetic fibres in composites has gained an escalating importance in the recent years due to environmental concerns and growing cost of synthetic materials (Rakshit Agarwal et al., 2015). The centre of study on natural fibres as substitute reinforcement in polymeric composites has created a vast attention of many researchers and scientists. The various advantages of natural fibres such as biodegradability, renewable, low cost, eco-friendly and comparable high mechanical properties make it more noticeable (Bino Prince Raja et al., 2015). Bamboo fibre, banana fibre and linen fibre are some of the natural fibres that have high profitable potential and are extensively cultivated. Bamboo fibre is a regenerated cellulose fibre made from the starchy pulp of bamboo plants processed from bamboo culms (Stanly Johns Retnam and Ramachandran, 2015). It is found to have outstanding properties like high specific strength,

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high tensile strength, very resilient, durable, low cost, recyclable, etc. Banana plant not only gives the appetising fruit but also provides banana fibre. It is a multiple celled lingo cellulosic fibre obtained from the pseudo stems of banana plant (Musa sepientum). The lumens are large in relation to the wall thickness, cross markings are rare and fibre tips either pointed or flat. Banana fibre is a natural fibre with high mechanical properties which can be blended easily with various other fibres or materials (Ramachandran et al., 2015). Linen is a long vegetable fibre which falls into the bast fibre category (fibre collected from bast, the phloem of the plant, sometimes called the skin) derived from the stems of flax plant, Linum usitatissimum. The fibres are mostly yellowish to grey and are 18−30 inches in length. Linen fibre is in great demand due to its high tensile strength, lustre, specific gravity, evenness and length. Natural fibre reinforced polymeric composites are found in countless products including aerospace, civil, automotive, marine and textile applications (Caprino et al., 2015). As a result, increasing attention has been devoted to research on Natural Fibre Polymeric Composites (NFPC).

The ever-increasing demand and popularity of the environment-friendly natural resources have caused a major movement in the automotive industry. The usage of natural fibre bio-composite has been increasing in the automotive industry for a long time. The high-strength fibres having high tensile strength such as Kevlar, glass fibre, carbon, and so on are difficult to recycle and are very costly to manufacture. Hence, the environmental impact of synthetic material and the rising prices of the such artificially developed materials are also the causes of the growing demand of the natural fibre composite materials. The industry research found out that the industrial use of natural fibre reinforced polymer composite was nearly 2.1 billion USD in 2010. This market size is currently on the growing trend and is predicted to grow to 6.50 billion USD in 2021. Around 80000–160000 tons of natural fibres are used every year in the automotive industry across the globe. Natural fibres or green fibres are obtained from plants and animals. They are hence readily available throughout the world. Some of the natural fibres that have been in use are flax, sisal, coconut, bamboo, coir, jute, feather, leather, wool, etc. Natural fibre polymer composites are made by using natural fibres with various polymer matrices or resins. The polymers or resins can be thermoplastic or thermoset. The thermoplastic matrix becomes softer material when the heat is applied to the surface of the material. Reshaping of thermoplastic resin can be done with the application of heat and pressure. Some of the examples of the thermoplastics are polyethene, PVC, PP, etc. Thermosets, on the other hand, cannot be moulded and melted into the final shape. They can become soft under the application of heat and have superior mechanical properties compared to the thermoplastics. This is why they are very difficult to be easily recycled and reused. But few of the research studies show that recycling and reusing of thermosets are possible. Thermosets are in low melting solids and liquids for and are difficult to cure. Some of the thermoset polymers include polyester, acrylics, epoxies, phenolic resins, vinyl esters, polyurethanes, etc.

Composite materials most commonly have a continuous bulk phase, called a matrix, and one scattered, contiguous phase, which is considered a tougher and stronger refurbishment. Strengthening content may contain fibres, fragments, or flakes. The principle of composites is that in the bulk process, the load is borne on a broad surface and moved to the reinforcement, which, being more solid, increases composite strength. The interface bonding of the natural fibre and the polymer matrix dictates the physical properties of the natural fibre reinforced polymer composites. The interface bonding tests such as single fibre compression, pull out, and compression tests are commonly used to test the bonding effectiveness in the fibre reinforced composites.

The effectiveness of the natural fibre composites is dependent upon the number of the fibre strands, shapes, and lengths as well as the fibre orientation and adhesion quality of the matrix. The properties of natural fibres can vary due to some factors such as maturity, size, and processing methods. Fibre reinforced composites have woven and non-woven arrangements where the woven fabric has the characteristics of the interlacing of the yarns which are perpendicularly interlocked fibres. The twist angle of the yarn also plays a role in the fibre cohesion and woven strength. However, the twist angle can be effective up to certain limit after which it is shown to have reduction in the bonding strength of fibre and polymer resins. The natural fibres, when embedded with the resin matrix, can impart high strength, less density, high stiffness, and better damping characteristics onto the NFRP composites. Even though natural fibres have bit lesser strength compared to glass fibres, they are twice as light compared to glass fibres and have similar stiffness, which is a great advantage. The utilization of the natural fibre composites provides 20% of cost reduction and 30% of reduction of the weight of automotive parts. The natural fibre materials are also shown to have better cost-effectiveness and better energy recovery compared to glass and carbon fibres.

Though natural fibres offer a lot of advantages, they also have many more shortcomings on their own. The natural fibres are found to be hydrophilic because of the polarity of hydroxyl groups present in the lignin and cellulose material. Hydrogen bonding of hydroxyl groups helps to retain water in the natural fibres, and this is the reason why the humidity sensitizes the composite materials and can cause swelling of the natural fibres and resins. Also, the plant fibres have bigger oscillations due to the growth of the plant fibres. The binding of the fibre and polymer composites can be difficult to execute because of variations of fibre and matrix chemical structure. From the research, it is determined that the natural fibre modulus can reduce with the increase in its diameter. Hence, the bonding capability of the fibre and resin can be greatly improved by the surface modification processes of fibres such as plasma treatment, chemical treatment, and biological treatment methods. Fahim et al. carried out the tensile behavior study of dried plant and animal fibre composites, and they found out that the rice straw showed the downward trend with the increase in fibre loading volume proportion till 40% of rice straw volume and increased further on fibre loading at 50%. The tensile strength of hybrid fibre (i.e., combination of chicken feather and rice straw) was found to be higher than rice straw and chicken feather at 50% fibre loading. Fibre length can also impact the bonding of matrix and fibre, causing clamping.

Natural fibre composites are in growing use in the automotive industry since the 1990s. Since the popularity of natural fibre, Germany has been the leader in using natural fibre composite materials.

Fiber Reinforced Polymeric (FRP) composites are prone to impact damage. Therefore, impact testing has been performed to study the effect of impact as a little impact can lead to catastrophic failure in various industrial applications where these composites are being used. Impact testing is used to determine Toughness (Tara Sen et al., 2013). Toughness is the ability of a substance to absorb energy without breaking. It is considered as one of the most significant mechanical property of thermoplastics because it relates to lifetime of materials, product safety and legal responsibility. Impact test consists of various tests out of which Izod and Charpy are the ones (Pothan et al., 2002). Izod test is used for determining the impact resistance of materials whereas Charpy test is a standardised high strain rate test which determines the amount of energy absorbed by a substance during fracture.

LITERATURE SURVEY

Sustainable Material: Development Experiment of Bamboo Composite Through Biologically Binding Mechanism

Year- 2020. Bamboo as stems have been widely manufactured for composite. However, fiber as the smallest constituent component of bamboo stems supporting the strength and flexibility of the plant has not been widely employed as raw material. These strong and flexible properties, coupled with easy planting treatment and fast harvesting, apparently make bamboo highly potential developed as sustainable raw material for composite. Unfortunately, the current manufacturing process of bamboo for composite by using chemical substances would have ended bamboo up as no longer environmentally friendly. By utilizing lignocellulose content within its fiber, this research studied fabrication of a novel composite boards from bamboo fibers through biologically binding mechanism by using fungal mycelium. Gigantochloa apus bamboo stems are extracted into three types: long fibers, short fibers, and powder. Then, the bamboo fibers are added with water and some additional nutritions then sterilized together. These substrates are then inoculated with mycelium seed of Ganoderma lucidum. The fibers bound together along with the growth of mycelium. The result shows that this board is potential to be used for interior purpose in building especially high rise building with high need of light-weight insulation and partition board and expected to replace the need for building components that have been made from unsustainable raw materials and methods.

Experimental study of bamboo using banana and linen fibre reinforced polymeric composites

The application of natural fibres such as bamboo, jute, banana, coir, linen and the like in Fibre Reinforced Polymeric (FRP) composites have become so vital due to their high effective stiffness and strength, availability, low cost, specific strength, better dimensional stability and mechanical properties, eco-friendly and biodegradable as compared with synthetic fibres. The interest in natural fibre reinforced polymeric composites is rapidly springing up in terms of research and industrial applications. The increased applications of these natural fibres in such composites are a proof to this claim. The paper deals with the detailed study of bamboo fibre, banana fibre and linen fibre cut into 2−4 mm of length with epoxy resin having random orientations.

Experimental Study On Banana And Bamboo Fibre Reinforced Polymeric Composites

Year-2019. Bamboo as stems have been widely manufactured for composite. However, fiber as the smallest constituent component of bamboo stems supporting the strength and flexibility of the plant has not been widely employed as raw material. These strong and flexible properties, coupled with easy planting treatment and fast harvesting, apparently make bamboo highly potential developed as sustainable raw material for composite. Unfortunately, the current manufacturing process of bamboo for composite by using chemical substances would have ended bamboo up as no longer environmentally friendly. By utilizing lignocellulose content within its fiber, this research studied fabrication of a novel composite boards from bamboo fibers through biologically binding mechanism by using fungal mycelium. Gigantochloa apus bamboo stems are extracted into three types: long fibers, short fibers, and powder. Then, the bamboo fibers are added with water and some additional nutritions then sterilized together. These substrates are then inoculated with mycelium seed of Ganoderma lucidum. The fibers bound together along with the growth of mycelium. The result shows that this board is potential to be used for interior purpose in building especially high rise building with high need of light-weight insulation and partition board and expected to replace the need for building components that have been made from unsustainable raw materials and methods

METHODOLOGY

Existing System

A composite material is made by combining two or more dissimilar materials. They are combined in such a way that the resulting composite material or composite possesses superior properties. Which are not obtainable with a single constituent material. The components do not dissolve or completely merge. They maintain an interface between each other and ad in concert to provide improved, specific or synergistic characteristics not obtainable by any of the original components acting singly. Bone is a simple example of a natural composite material having the best properties of its constituents. Bone must be strong and rigid; yet flexible enough to resist breaking under normal use. These requiste properties are contributed by its components. gives the required softness. The inorganic component, made up of calcium phosphate, gives it the required strength and rigidity. The most common synthetic composite material is glass fibre reinforced plastics (GRP) which is made out of plastics and glass fibre.

Proposed System

This paper helps to find the effectiveness of each of the four natural fibre composites that have already been used in the automotive sector. This paper includes the analysis of four different natural fibres with and without the addition of the aluminium as the reinforcement material. This project revolves around the design of the composite fibre sheet and analysis of the mechanical parameters such as equivalent stress, shear stress, strain, deformation, and so on. The studies and observations of the analysis showed that the natural fibre with the aluminium reinforcement proved to be much stronger than that without the reinforcement. The results of finite element analysis showcased lowest total deformation and equivalent strain in the flax as 1.026 m and 0.017 mm/mm, respectively. However, sisal showed the lowest equivalent stress and shear stress which were 68.09 and 38.178 MPa, respectively. A series of experiments are carried out to investigate the mechanical performance of bamboo fiber reinforced concrete, including the cubic compressive strength and splitting tensile strength. The experimental results show that bamboo fibers can enhance the cubic compressive strength and remarkably improve the splitting tensile strength of concrete. In addition, the effects of various bamboo fiber content and length on cubic compressive strength and splitting strength are also discussed respectively.

RELATED WORK

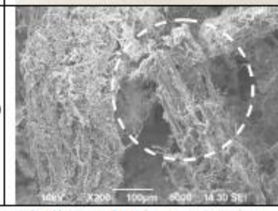
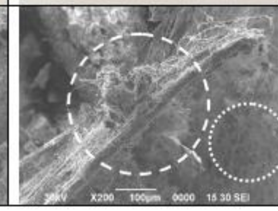
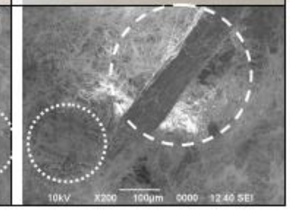
The Experimental Work Details

Fibers and Resins Bamboo fibers were used as reinforcement. The bamboo fibers were made from the starchy pulp of bamboo plants. In order to remove the dirt and other contaminants, these fibres were washed by water. Subsequently, fibres were cut into small length (18 to 20 cm). Cellulose, hemicellulose, lignin and wax are the major constituents of bamboo fibres. The average diameter of the bamboo fibre used was in the range of 100-550 µm. In this experiment, epoxy was used as a resin. Rice husk particulates were used as filler material. The particle size of rice husk fibre used were from 60-100 µm. The rice husk fibre was oven dried at 70 oC for 25 hours to adjust its moisture content and then the filler material was used without any subsequent treatment.

(a) (b) (c)

Figure 1. Three types of bamboo fibers: (a) long fibers, (b) short fibers, and (c) powders.

Table 1. Comparison of observations of material specimens through direct observations and SEM.

	Long Fiber Specimen (A1)	Short Fiber Specimen (A2)	Powder Specimen (A3)
Direct observation			
SEM observation at 200x magnification			

·········· indicates hyphae networks.
– – – indicates bamboo fiber which is covered with hyphae networks (mycelium).

Matrix

Matrix is also known as binder material. It (i) provides shape to the composite material, (ii) makes the composite material generally resistant to adverse environments and (iii) protects reinforcement material from adverse environments. The materials which constitute matrix of composite materials are plastics, metals, ceramics and rubber.

Fibres

The fibres are the load carrying members in the composite material.They are bonded together by using matrix material. Based on formation and the they are classified into two types.

Natural Fibre

Natural fibres are used as conventional reinforcement materials. Natural fibres are low-cost fibres with low density and high specific properties. These are biodegradable and nonabrasive, unlike other reinforcing fibres. Natural fibres include those produced by plants, animals, and geological processes. They are biodegradable over time. The various types of natural fibres are sisal, banana, palm, bamboo etc

Man-Made Fibres

Man-made fibre, fibre whose chemical composition, structure, and properties are significantly modified during the manufacturing process. The chemical compounds from which man-made fibres are produced are known as polymers, a class of compounds characterized by long, chainlike molecules of great size and molecular weight. Some of the inorganic fibres are aramid, boron, carbon, glass, etc

Resin

The resins are used as the bonding material in the composite. The resins are chemical composition, which forms the adhesive bonding. The resin affects the physical properties, fabrication and ultimate properties of composite materials. Variations in the composition, physical state, or morphology of a resin and the presence of impurities or contaminants in a resin may affect handleability and processability, lamina/ laminate properties, and composite material performance and long-term durability. Primary Function is To transfer stress between reinforcing fibres and to protect them from mechanical and environmental damage.

Banana fibre is a natural fibre with high strength, which can be blended easily with cotton fibre or other synthetic fibres to produce blended fabric & textiles.

MATERIAL DETAILS

In the fabrication of the composite material we used two organic fibre and one inorganic fibre. They are,

- Sisal fibre
- Banana fibre
- Bamboo fibres
- Glass fibre
- Epoxy resin

Testing Methods

The main objective is to determine the material properties (Tensile Strength, Flexural Strength, and Impact Strength) of natural fibre reinforced composite material by conducting the following respective tests.

- Tensile Test
- Flexural Test
- Impact Test

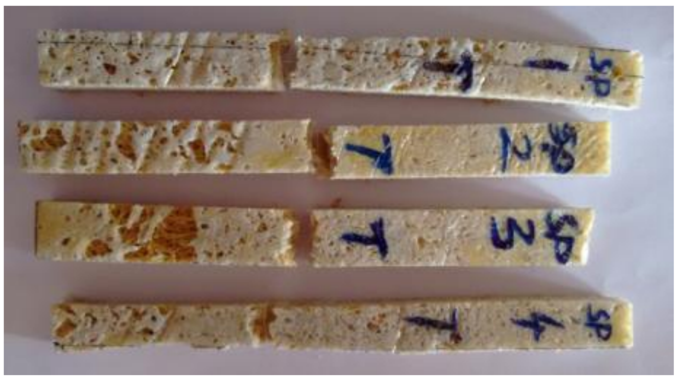
Summary Report

Sample Specimen	CS Area [mm^2]	Peak Load [N]	Flexural Strength [MPa]	Flexural Strength [GPa]
Min	144.0	221.108	12.092	4.947
Max	144.0	306.023	16.736	223.069
Avg	144.0	262.513	14.356	74.738
Std Dev.	0.000	35.602	1.947	100.859
Variance	0.000	1267.467	3.791	10172.567
Median	144.00	261.461	14.299	35.468

Table 5.1 Flexural test values on UTM machine

The composite samples are tested in the universal

Testing machine (UTM) and the stress-strain curve is plotted. The typical graph generated directly from the machine for tensile test for composite specimen samples is presented in Graph 1 .The composite sample specimen tensile strength to withstand maximum load and its load.



Tensile Strength comparison of different composite Specimens

Tensile Test and Flexural Test Results

Tensile strength, Tensile modulus, Flexural strength and Flexural modulus of untreated and alkali treated fiber reinforced composites are represented.

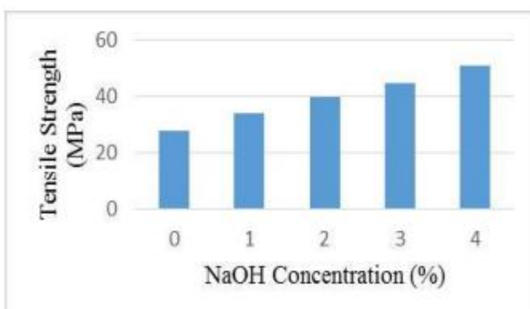


Figure 2. Tensile strength of untreated and alkali treated Bamboo fiber reinforced epoxy composites.

Bamboo as stems have been widely manufactured for composite. However, fiber as the smallest constituent component of bamboo stems supporting the strength and flexibility of the plant has not been widely employed as raw material. These strong and flexible properties, coupled with easy planting treatment and fast harvesting, apparently make bamboo highly potential developed as sustainable raw material for composite. Unfortunately, the current manufacturing process of bamboo for composite by using chemical substances would have ended bamboo up as no longer environmentally friendly. By utilizing lignocellulose content within its fiber, this research studied fabrication of a novel composite boards from bamboo fibers through biologically binding mechanism by using fungal mycelium. Gigantochloa apus bamboo stems are extracted into three types: long fibers, short fibers, and powder.

CONCLUSION

The sisal and banana with glass fibre hybrid composite specimens are prepared and subjected to tensile, flexural loading and impact strength. From the experiment, the following conclusions are derived.

- The sisal and banana with glass fibre composite samples possess good tensile strength and can withstand the strength up to 65.5 MPa.
- The composite specimen is withstanding the maximum flexural strength of 14.356 Mpa
- The composite specimen is withstanding the maximum impact strength of 1.1 J.
- From the results, it can be concluded that sisal and banana with glass fibre composites performing better for tensile loading.

The sustainable composite board of bamboo fiber through biologically binding mechanism with fungal mycelium is a novel biocomposite. The three variations of composite boards are highly potential to be developed for building non-structural function. Of three variations, the boards made of bamboo powder are assessed very well from the aspect of density, internal bonding, and swelling thickness. In architecture, this novel biocomposite board is expected to replace the need of non-structural composite boards which are not environmentally friendly and have been widely used in buildings. The function of this material as the insulation board is expected to be used for interior space purposes, including as thermal insulation boards, acoustic boards, space partitions, ceiling boards, and decorative boards in low-rise buildings such as residential houses to high-rise buildings with high demand of insulation components. To achieve better performance of this board, further research to determine acoustic and thermal performance needs to be done.

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