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Extraction of Bamboo Fibers by Chemical Techniques

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***Abstract*: Due to growing environmental concerns and rapid depletion of non-renewable resources, researchers are looking to replace older non-renewable materials with sustainable and environmentally friendly materials that can be recycled or biodegraded. Bamboo fiber is a popular alternative to natural plant fibers due to its many advantages such as low cost, low density, environmental friendliness, sustainability and biodegradability. Compared to synthetic fibers, plant fiber extraction was inherently laborious. Due to their similar mechanical properties, bamboo fiber is a strong contender to replace glass, carbon and other synthetic fibers in natural fiber reinforced polymer composites. Extracted fibers should be produced with long fibers, of suitable quality, and with little or no damage during extraction. The properties of bamboo fiber and bamboo fiber reinforced polymer composites are influenced by many factors, including fiber extraction method, moisture content, fiber size, temperature and length. The purpose of this research is to develop mechanical extraction, steam blasting and other bamboo fiber extraction methods for alkali treatment. Mechanical properties (tensile strength, maximum elongation at break, modulus) of bamboo fibers and their microstructure were measured. Researchers are currently working on the mechanism of the fiber separation process that mechanically enhances fiber performance and should still need improvement and modification, albeit morphologically. Although most fiber extraction studies have been published, the process of creating fibers and improving their quality has also introduced deficiencies in their attributes and properties.**

***Keywords*: Bamboo, extraction process, alkali treatment, water retting, chemical extraction, mechanical properties, reinforced composites.**

1. Introduction

Due to growing environmental concerns and rapid depletion of non-renewable resources, researchers are looking to replace older non-renewable materials with sustainable and environmentally friendly materials that can be recycled or biodegraded. Bamboo fiber is a popular alternative to natural plant fibers due to its many advantages such as low cost, low density, environmental friendliness, sustainability and biodegradability. Compared to synthetic fibers, plant fiber extraction was inherently laborious. Due to their similar mechanical properties, bamboo fiber is a strong contender to replace glass, carbon and other synthetic fibers in natural fiber reinforced polymer composites. Extracted fibers should be produced with long fibers, of suitable quality, and with little or no damage during extraction. The properties of bamboo fiber and bamboo fiber reinforced polymer composites are influenced by many factors, including fiber extraction method, moisture content, fiber size, temperature and length. The purpose of this research is to develop mechanical extraction, steam blasting and other bamboo fiber extraction methods for alkali treatment. Mechanical properties (tensile strength, maximum elongation at break, modulus) of bamboo fibers and their microstructure were measured. Researchers are currently working on the mechanism of the fiber separation process that mechanically enhances fiber performance and should still need improvement and modification, albeit morphologically. Although most fiber extraction studies have been published, the process of creating fibers and improving their quality has also introduced deficiencies in their attributes and properties.

2. Bamboo

It is a tall grass that lignifies frequently and grows quickly. That is, plant is an erratic framework made up of 2. Placement of the vegetative axis that is fairly structured: The first is above ground, while the second is below. The Bambusoideae family of grasses includes bamboo. Comprises lignin-matrix-encapsulated cellulose fibers. A sheath Development holds them to the underlying phase and eventually breaks off as the seedling grows. There are five to five varieties of bamboo with a distance between two nodes that exceeds sixty centimeters. In general, the length of a knot moves upward along the culm between the two nodes, moving the bottom toward the center before shrinking because the majority of partial lateral segments of bamboo are made up of filaments, bamboo mechanical properties are changing property is a change in perspective in light of development, climate, and soil moisture level. There are more than a thousand species of bamboo, with 70 of them being the most common abundant in Asia and South America. Most of the time, bamboo is used in development. Consequently, the production of everyday devices with a high weight-to-quality.

3. Production Method of Bamboo Fiber

The investigation reveals that bamboo has an anisotropic

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microstructure, which lowers the energy needed to separate and remove bamboo fibres. The degradation of bamboo fibre and the removal of chemical components like lignin are challenging steps in the manufacturing of bamboo fibre. Chemical, biological, physical, and combined manufacturing methods are currently widely employed. The bamboo fibres can be treated with NaOH. The tensile strength and tensile modulus of bamboo fibres are negatively impacted by increasing the concentration of NaOH; the addition of NaOH converts their brittleness to ductility in the scanning electron micrograph (SEM) of treated bamboo fibre.

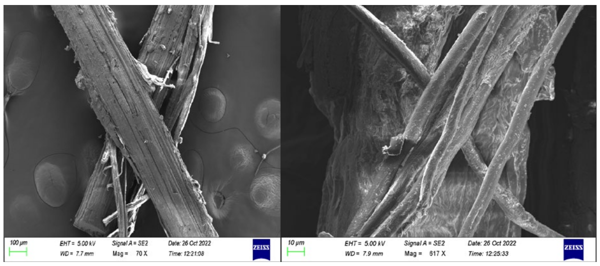

Fig. 1. SEM images of bamboo fiber: Longitudinal section of bamboo fiber and cross-section of bamboo fiber

4. Classification of Bamboo Fiber

Bamboo fiber can be divided into the natural bamboo fiber, bamboo pulp fiber, and bamboo charcoal fiber. Natural bamboo fiber is a fiber directly extracted from bamboo using physical or microbial degumming. The crystalline structure properties of the original bamboo fiber do not change during the extraction process, which makes the fiber natural. Bamboo pulp fiber is made from bamboo.

Fig. 2. Macroscopic of Bamboo Fiber

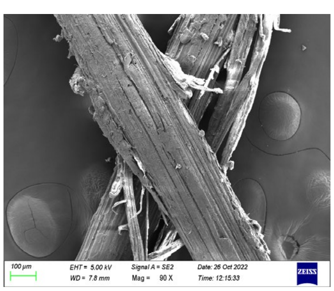

Fig. 3. Scanning Electron Microscopic Image

Pulp, suitable for the production of fiber, from which the fiber is then obtained. Bamboo charcoal fiber is made by surface treatment of Nano-level bamboo charcoal powder, then slurry is added to the viscose and drawn into a wire shape; this method is mostly adopted in the textile industry. In China, bamboo fiber is mainly divided into the aforementioned three categories. Natural bamboo fiber retains the characteristics of the original bamboo but this requires more raw materials making the manufacturing process of natural fibers technically inefficient. At present, bamboo fiber products on the market are mainly made of bamboo pulp fiber and bamboo charcoal fiber.

5. Chemical Composition of Bamboo Fiber

Bamboo fiber is a natural bio-composite and the main chemical constituents of bamboo fiber are cellulose, hemicellulose, and lignin.

A. Cellulose

The material that makes up the cell wall of bamboo fibre, cellulose, is primarily made up of three elements: carbon, hydrogen, and oxygen. Analyzing the chemical makeup of bamboo fibre used for textiles after separation revealed that its cellulose content reached 73.83%. Cellulose often persists in the form of microfibrils within the cell wall of plants. The principal component impacting the tensile strength of bamboo fibre along the grain is cellulose, and the cellulose content is directly correlated with bamboo age. It is important to note that as bamboo ages, the cellulose content of the same bamboo material reduces.

B. Hemicellulose

Between fibres, hemicellulose is an amorphous material with a low degree of polymerization. Hemicellulose is a complex polysaccharide containing 4-O-methyl-D-glucuronic acid, L-arabinose, and D-xylose as its primary branches and xylan as its main chain. The bamboo polysaccharide components were extracted using two different methods, and it was reported that the majority of the polysaccharide components after extraction with distilled water were glucose while the content of xylose was higher after extraction with alkaline. Researchers studied the polysaccharide fraction of Phyllostachys makinoi extracted with 5% and 17.5% NaOH and observed that its main component was arabinoxylan.

C. Lignin

Lignin is a variety of polymer with intricate structures. Guaiacyl, syringyl, and p-hydroxyphenyl monomers are the primary components of lignin. Ether bonds and carbon-carbon single bonds are the primary means by which the structural components of lignin are joined. The secondary wall of the bamboo fibre is not equally dispersed with lignin. Lignin is often found in lower concentrations in the broad layer and higher concentrations in the narrow layer. Lignin also lends a certain degree of stability to bamboo materials. The age of the bamboo also affects the lignin content.

6. Basic Structure of the Bamboo Fiber

Fiber cells, parenchyma cells, ducts, epidermal cells, sieve tubes, companion cells, and a few more types of cells make up the majority of bamboo cells. Previous research has found that bamboo fibre cells lack an inner wall but do contain a multilayered secondary wall in the middle of the cell. Distinct layers of the bamboo fibre cell wall and various bamboo species have different microfiber orientations. While microfibers in the large layer are arranged in a nearly axial spiral pattern, those in the narrow layer are arranged in a nearly horizontal spiral pattern. Bamboo is anisotropic as a result of the diverse fibre orientations of the narrow layer and the wide layer. Variable longitudinal permeability of bamboo is caused by different vascular bundle distribution.

7. Extraction Method of Bamboo Fiber

Automobile, textile, and construction industries all use bamboo fibres in various applications. However, the process of separating the bamboo fibres from the bamboo culm involves complicated actions. The quality and yield of bamboo fibres were decided by the different extraction techniques, and they were also chosen based on the various application fields. The three main categories of bamboo fibre extraction techniques are mechanical, chemical, and chemical and other extraction methods.

A. Water Retting

For three days, bamboo strips were rinsed in a bowl of water. These moist strips were then flattened, baked to dry, and combed to produce long fibres. The disadvantage of this extraction technique was the damage and negative influence on quality caused by scraping lengthy strands.

B. Chemical Extraction

Utilizing 15 g/L of Na_2CO_3, chemicals that are NaOH+Acetic acid were then used to clean. Method A: For 1 hour, fibres were submerged in 5% NaOH and 2.5% Acetic acid solutions at a wet temperature. Method B involves soaking fibres in 0.1 N NaOH for 72 hours at 35°C. Method C: 0.7% NaOH solution was applied to the fibres for 1 hour at 90°C and pH-4, followed by 2% NaOH at room temperature for 15 minutes. Method D involved boiling the fibres for two hours in 20 g/L of NaOH and 5 g/L of acetic acid to cure them. Method E involved curing fibres for 45 minutes at 80°C in a 150 g/L NaOH solution. Materials to liquor 1:40 for all alkali treatments, followed by cleaning at 40°C for 15 minutes.

C. Alkali Extraction

Alkali solutions of 0% and 10%wt were applied to bamboo strips that were about 15 cm long. A decrease in extractives, hemicelluloses, and gums was predicted by FTIR analysis. Furthermore, no brand-new functional group was seen. In addition, compared to untreated fibre, alkali treated fibre displayed improved thermal characteristics and a smooth surface. After being cured for 24 hours with 10% NaOH, the performance of the fibres was greatly improved. After alkaline curing, tensile and modulus were optimised. Bamboo strips were treated with solutions containing 0, 1, 3, and 5 weight percent NaOH, then rinsed in water and allowed to air dry for 24 hours. Greater bonded length, a short contact angle, and a higher NaOH % all improved interfacial shear stress fibre with polyester. Increased alkali content increased mechanical strength while decreasing density and strain at break.

Untreated fibres included a parenchyma and other contaminants that were linked to the extraction process. Furthermore, the fibres; stickiness and roughness were both reduced. Hot water pretreatment of fibres caused numerous cell breaks, which strengthened the connection between the fibres and matrix. While fibres are prepared with water and then treated with sodium hydroxide, which totally dissolves starch. When the lignin and hemicellulose concentrations are decreased as a result of treating the fibres with hot H_2O and NaOH, the interferential bonding of fibre to matrix improves.

8. Application of Bamboo Fiber

Various forms of bamboo fibre are being employed in the textile, papermaking, and building sectors. Researchers studying composite materials have recently become interested in bamboo fibre, which has been progressively entering the composite material market.

A. Textile Industry

Bamboo fibre, which can be used to make garments, has superior hygroscopicity compared to other fibres, may reflect light and limit the absorption of heat radiation. In addition, bamboo fibre has a potent antibacterial action and can be utilised to make medical supplies like masks and gauze. Bamboo fibre can be used alone or in conjunction with other materials like silk and cotton fibres in the textile industry. Although bamboo fibre has a lot of promise and is used widely in the textile industry, several of its drawbacks, such as the short length of a single bamboo fibre and the ease with which bamboo fibre garments absorb water, should be addressed through fundamental study.

B. Papermaking Industry

Bamboo fibre can be utilised in the production of paper because it has an antibacterial effect and has alength that is comparable to coniferous trees. Bamboo has been used to make paper in China for a very long time. As early as 1700 years ago, bamboo was used to make paper. Additionally, China started using bamboo for the manufacture of machine-made paper in the 1940s. Due to the scarcity of wood fibre in recent years, bamboo fibre has taken the place of essential raw materials for papermaking. Although bamboo fibre is a good alternative to wood for creating paper, planting, storing, and transporting bamboo are more expensive, and the price of bamboo fibre is easily influenced by the market.

C. Construction Industry

Studies have demonstrated that natural fibres can substitute standard steel and synthetic fibres in the construction of several building materials, improving their mechanical qualities. Better physical and mechanical properties result from adding bamboo fibre to concrete, a natural fibre with high mechanical properties. When the mechanical properties of concrete were studied with bamboo fibre added at 0%, 1%, and 2% (by volume), it was discovered that the bamboo fibre content increased the flexural strength, tensile strength, and compressive strength of the reinforced concrete. In order to assess the splitting tensile strength of concrete at ages 28 and 90 days, Wahyuni et al. added 0.50% bamboo fibre based on the weight of cement. Test findings revealed that the new type of concrete mix mechanical properties were comparable to those of regular concrete. The deformation characteristics of bamboo fibre concrete were investigated, and it was discovered that the addition of bamboo fibre might lessen the coagulation; shrinkage deformation. It was discovered through experiments that bamboo fibre composite plate (BFCP) reinforced concrete beams had a 10-12% higher structural bearing capacity than unreinforced beams. To create bamboo fibre reinforced cement, bamboo fibre can also be added to the cement mixture. According to studies, adding bamboo fibre in the right proportion can increase cement toughness; however, adding too much bamboo fibre can lead to fibre aggregation, which prevents it from increasing the composites' maximum flexural strength and impact resistance. The impacts of several pre-treatment techniques on bamboo fibre cement composite materials were studied, and it was shown that alkali treatment with microwave assistance improved mechanical qualities. reported that the applied alkali treatment provided increased flexural strength when they compared the performance of bamboo fibre reinforced cement constructed from treated and untreated bamboo fibres. They also noticed that the contaminants on the bamboo fiber surface were significantly decreased after alkali treatment, making it cleaner. tested the hygrothermal properties of bamboo fibre and bamboo charcoal, as well as simulating the building component and the enclosed area, to determine their suitability as fillers for buildings in tropical and subtropical climates.

D. Composite Material Industries

Bamboo fibre composite materials have the potential to be employed in a variety of industries, including aerospace, maritime engineering, advanced rail transit, power equipment, and vehicle manufacture. These benefits include low density, light weight, and good extensibility. Bamboo fibre composite materials can be used to create furniture, flooring, and sporting goods like decks in daily life, just like wood. Although the manufacturing method of such composites would require a lot more research, test results on bamboo fibre reinforced composites are highly encouraging. We were inspired by the transition zone in the secondary bamboo fibre wall, which consists of alternating broad and thin layers with a clear transition zone between the layers, and we designed a comparable zone in the glass fiber/epoxy and glass fiber/polyester composites. The test findings revealed that, for the composites under consideration, the interlaminar shear strengths of the glass fiber/epoxy and glass fiber/polyester composites with transition zones were, respectively, 15.8% and 13.3% greater than those without transition zones. studied the characteristics of hybrid composites created by substituting 25%, 50%, and 75% (by weight) of glass fibres with bamboo fibres and reinforced with unsaturated polyester resin. The findings of the tests revealed that while adding 25% bamboo fibre did not result in fibre aggregation and had no impact on the performance of composites, adding too much bamboo fibre induced fiber/matrix segregation, which resulted in subpar performance. examined how the amount of maleic anhydride-grafted polypropylene (MAPP) affected the mechanical characteristics of reports, MAPP boosted the mechanical properties of the composite, including the tensile strength, flexural strength, flexural modulus, and impact strength, as well as the interface contact between the fibre and matrix. The bending and compression characteristics of hybrid composites made of bamboo and glass fibre. The test findings revealed that the performance of composites derived from bamboo fibre treated with alkali was superior and that the bending and compression capabilities of composite materials increased with an increase in glass fibre content.

9. Conclusion

In particular, in densely populated areas of the world where bamboo is readily available, bamboo could provide good sustainable solutions to reducing the carbon footprint of the construction sector. Although round bamboo has been used for building for many years, current improvements in manufacturing techniques have led to innovation in constructed bamboo products as well as the use of bamboo fibre in a variety of applications. Several methods can be used to directly harvest bamboo fibres from natural bamboo, albeit the current production methods for doing so are rather complex. Bamboo fibres are often produced in a number of processes to provide outstanding mechanical characteristics. The manner of treatment is also important for maintaining the fibers beneficial mechanical properties; alkali treatment has been shown to be more effective than other approaches. Nanoindentation and single fibre tensile testing are two typical techniques used to assess the mechanical characteristics of bamboo fibre. According to reports, a variety of elements, including bamboo fibre structure, moisture level, and chemical makeup, might influence the mechanical capabilities of bamboo fibres. According to test results, bamboo fibre has exceptional mechanical qualities; its tensile properties are both far better than those of wood fibres and some artificial fibres used to make composite materials. The overall performance of composite materials has been investigated using bamboo fibres in a variety of composites, and the reported results are highly encouraging. However, more methodical and thorough research would be needed to create commercial-level business cases for the manufacture of composite materials based on bamboo fibre.

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