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Influences of Chemical Treatment on Mechanical Properties of Rattan

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Abstract: The current study explores the mechanical properties of untreated and various chemically treated rattan to find its potential as reinforcement in fabrication of advanced composite materials. The rattan will go through various chemical treatments by using alkali and acrylic acid. The most important limitation of rattan is low material durability. The chemical treatment is done to determine whether alkali or acrylic acid has the higher percentages of their initial strength than all fibers after the specified period of exposure in the various mediums. Rattan is an important forest product only second to timber and bamboo and is extensively used as an excellent natural material for furniture, ropes, decorative items, housing, craft products and many more. The mechanical properties of rattan are the most important and most direct performance indicator to determine cane processing and utilization while the most important factors that influence mechanical properties are species, stem position, density and so on. The density will directly affect the strength, hardness, natural durability and many other performances indicators of mechanical properties.

Keywords: Chemical Treatment, Mechanical Properties, Rattan

1. Introduction

In this post developed world, the field of furniture manufacturing has been growing vastly due to the increment of land discoveries and housing developments in many countries including Malaysia, making the consumers for home furniture to increase. In addition, the government has implemented "Skim Perumahan Mampu Milik" throughout the country, which provides low incomers an affordable house. This will provide low budget furniture to compete in the furniture industry and rattan furniture is one of the many options.

Rattan is also known as manila or Malacca named after the ports of shipment Manila and Malacca city[1]. Rattan is a multi-purpose plant resource with long tough slender stems found mostly in the tropical rainforests and has a high economic value and ecological benefits which can be considered as a material with high potential in the construction industry. Rattan is one of the most popular demands in the world of creative hand-woven in Malaysia.

Rattan is an important forest product only second to timber and bamboo and is extensively used as an excellent natural material for furniture, ropes, decorative items, housing, craft products and many

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more. The main problem faced by rattan-made products is the strength, durability and performance. If this matter of problem is going to continue, the opportunity of rattan to be used in making furniture will decrease immensely.

The mechanical properties of rattan are the most important and most direct performance indicator to determine cane processing and utilization while the most important factors that influence mechanical properties are species, stem position, density and so on. The density will directly affect the strength, hardness, natural durability and many other performances indicators of mechanical properties.

Rattans are widely used materials especially in manufacturing of furniture. However, the performance and durability of rattan has been only satisfactory. Since the most important limitation of rattan is low material durability, the chemical treatment is done to determine whether alkali, thermal treatment or acrylic acid has the higher percentages of their initial strength than all fibres after the specified period of exposure in the various mediums. This paper explores the mechanical properties of rattan under the influence of chemical treatment. The current study explores the mechanical properties of untreated and various chemically treated rattan to find its potential as reinforcement in fabrication of advanced composite materials. The rattan will go through various chemical treatments by using alkali, thermal treatment and acrylic acid.

2. Materials and Methods

The materials and methods section, otherwise known as methodology, describes all the necessary information that is required to obtain the results of the study.

2.1 Materials

The material used for Heat Treatment of rattan is the fifty four-years-old Phyllostachys edulis samples without mildew, discoloration and other defects. This rattan sample obtained from Yi Yang, Taojiang region of Hunan. The central part of the third section of the base of the bamboo was randomly selected with dimension of 100(L) x 20(T) x 6(R) mm. the moisture content of the samples was regulated to 15%[2].

The material used for Alkali Treatment is harvested bamboo from a culm that stood 2 meters above ground level and had an initial moisture content of 8–12%. Bamboo was sliced into thin strips (30 mm longitudinally and 92mm in cross section) [3].

The material used for Modification of treatment with Methyl Methacrylate is the rattan species P. kerrana was acquired from native stands In Yingjiang Country, Yunnan Province, China. Seven wild rattan canes with a mean length of 19.6 m and a mean diameter of 31.51 mm have been collected. Each cane was cut from the ground around 30cm, and then labelled at every node. The average node length was 26.80 mm, and all three nodes were sampled[4].

The material used for Dopamine Modification on Bamboo Fiber is the 40-60 mesh size and a length below 380 μm of bamboo fibre (with a water content of 10 percent). was purchased from Sentai Wood Plastic Composites Material Co., Ltd. The grade 4032 D polylactic acid (PLA), used as a polymer matrix, has a melting point of 160 °C with a density of 1.24 g/cm. PLA was supplied by Nature Works (Northford, CT, USA) Ind. Co., Ltd. Dopamine hydrochloride (98.5%) (DA) was purchased from Macklin Biochemical Co., Ltd. (Shanghai, China) and used directly. Other chemicals used in the study including sodium hydroxide and deionized water were purchased from Beijing Chemical Industry Group Co., Ltd. (Beijing, China) [5].

2.2 Methods

For Heat Treatment according to [2] is the bamboo samples were dried in the drying chamber to a humidity content of 6% and then heat treated in the usual pressurised superheated steam kiln heat treatment unit (capacity: 30 m3, maximum temperature: 220°C) at 4 temperature levels: 120, 140, 160 and 180°C for 2 hours. At the end of the soaking cycle, the heater was switched off, but before the dry-bulb temperature fell below 110°C, the fan and the humidifier remained on. The oven was subsequently sealed and cooled to room temperature. Samples and control specimens were crushed to 80 meshes independently, then dried at 1003°C in a drying oven. Using an XRD-6000 diffractometer, the dried materials were squeezed into thin slices to assess their X-ray diffraction characteristics[6].

Alkali Treatment use individual bamboo fibers were separated from tiny bamboo strips by soaking them in a chemical solution. (one part 30% hydrogen peroxide and one part glacial acetic acid) at 65°C for 18.5 hour. Individual bamboo fibers were neutralized with deionized water, then dipped in 6, 8, 10, 15, and 25% NaOH solutions for 2 hours at room temperature (23 2 C), maintaining a fiber weight to alkali volume ratio of 1:100. Individual bamboo fibers were carefully rinsed with deionized water after the treatment to remove NaOH and bring the pH back to 7. The fiber suspensions were frozen in liquid nitrogen and then dried in a freeze dryer for 24 hours[3].

Modification with Methyl Methacrylate use rattan canes have been cut into bending and compressive specimens from internodes. For the compression test, the specimen diameter was 30.25 ± 2.84 mm and the height-todiameter ratio was held at 2 for successful experimentation. The surfaces of both ends were parallel and vertical to the specimen's centerline. The bending specimens were 29.71± 2.42 mm in diameter. Before and after the MMA resin treatment, the weights of all oven-dried specimens were determined using a balance with a precision of ±0.001 g. In a vacuum stainless cylinder, the rattan specimens were placed and a relative vacuum of 0.1 MPa was applied for 1h to extract air from the rattan voids. A monomeric solution consisting of 0.5% AIBN radical was added into 100% MMA by weight. The rattan specimen The excess resin was cleaned off the surface with a paper towel after impregnation. This were immersed into the monomer solution at atmospheric for 4 hour for impregnation. The specimens were then wrapped in aluminium foil and heated to begin the thermally-induced polymerization process for 8 h at 60°C[7].

The preparation of the composites for Dopamine Modification of Bamboo Fiber, the proportion of bamboo fiber was 40 wt%. The compounding of PLA with untreated and DA-modified BFs, with and without alkali-pre-treatment, was accomplished using a co-rotating twin-screw extruder (KESUN KS20, Kunshan, China). The twin screw rotation speed was maintained at 100 rpm, and the temperature from the inlet to the head were set as follows: 165, 170, 175, 175, 165, and 160 °C. The mixtures were chopped until the diameter of the particles was 4 mm, and the particles were then hot-compression-molded (HAPCO, BY 602 × 2/2 150 T Testing Press, Suzhou, China) for 6 min at 170°C and a pressure of 4 MPa. Before full-press, the sample was pre-heated for 3 min at 170 °C. Finally, the sample was cold-pressed for 10 min at 4 MPa and at room temperature via cold compression (CANGAO, CGYJ-100, Shijiazhuang, China)[5].

For Alkali Treatment, previous work was used to calculate relative crystallinity. Equation Eq. 1 below was used to compute relative crystallinity.

$$C_r I = \frac{I_{002} - I_{am}}{I_{002}} \text{ x } 100\% \quad \text{(Eq. 1)}$$

Where: $C_r I$ - the relative crystallinity (%)

I_{002} - the maximum intensity of the (002) lattice diffraction angle (arbitrary units)

I_{am} - the scattering intensity of the non-crystalline background diffraction. When the 20 angle is close to 18°, I_{002}, I_{am} have the same units.

For Dopamine Modification of Bamboo Fiber, Samples were analyzed by a D8 Advanced X-ray diffractometer (BRUKER, AXS, Germany) using radiation (λ = 0.154060 nm), a radiation tube voltage of 40 and a current of 40 , and the scanning range performed is 2θ = 5°–40° in the steps of . Cellulose crystallinity index (I) was calculated by the following equation Eq. 2..

$$I_{XRD}(\%) = \frac{I_{002}-I_{101}}{I_{002}} \text{ X } 100 \text{ (Eq. 2)}$$

Where: I - the maximum intensity of the 002 lattice diffraction plane at an angle of between 22° and 23°, and I is the intensity diffraction at an angle close to 17° representing amorphous areas in the cellulosic fiber

3. Results and Discussion

All of the result was obtained from previous journals and articles. The data analysis has been carried out through the comparison of the mechanical properties of rattan before and after the treatment. The sample consists of different mechanical properties of rattan and the rattan are being tested by using impact load, tensile load and others. Therefore, by undergoing the test, the data has been collected and tabulated in the table.

3.1.1 Heat Treatment

Table below shows the length-width ratio of untreated bamboo fibers was 129.25, but it increased significantly after heat treatment, with length-width ratios of 30.9, 35.5, 35.3 and 36.9%, respectively by [2]. The length-width ratio of fibers was clearly affected by temperature, as seen in the table 1. During the heat treatment, the wood fibers shrank due to the reduced cavity material and water. The arrangement of the micro fibrils in treated bamboo was more ordered than in untreated bamboo.

Table 1 Fiber characteristic of heat-treated bamboo[8]

Temperature (°C)	Length of fibers (μm)	Width of fibers (μm)	Length-width ratio fibers (%)	Replicates	STDEV
120	2187.277	15.698	169.19	50	31.7
140	2043.378	12.150	175.16	50	21.9
160	2256.235	12.906	174.82	50	36.8
160	22321.377	17.028	176.89	50	25.3
Untreated bamboo	1683.744	14.544	129.25	50	35.5

According to [2] research article, the micro fibrils in the secondary cell wall were placed in axial and transverse alternating directions in the structure of the bamboo fiber multilayer structure model. Meanwhile, in the multilayer structure of bamboo micro fibrils, axial micro fibrils accounted for a bigger share, thus the rearrangement process causes the axial size of fibers to grow. The relativity between crystallinity and fiber diameters of heat-treated bamboo will be explored in detail in additional research[9].

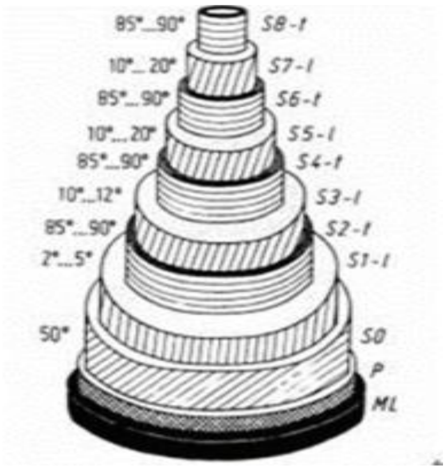

Figure 1: Bamboo fiber multilayer structure model[2]

3.1.2 Alkali Treatment

According to [3], the effect of alkali concentration on the microstructure and mechanical properties of individual bamboo fibers was shown to have a considerable impact on mechanical properties due to changes in fiber structure. Figure below shows the usual stress–strain curves of untreated individual bamboo fibers and fibers treated with NaOH at various doses. The surface appearance and microfibril aggregates in the cell wall were altered by alkali treatment. When compared to untreated bamboo fibers, the alkali treatment resulted in greater wrinkles on the surface. The microfibril aggregates changed from a randomly interwoven structure to a granular structure after being treated with 15 and 25 percent NaOH[10].

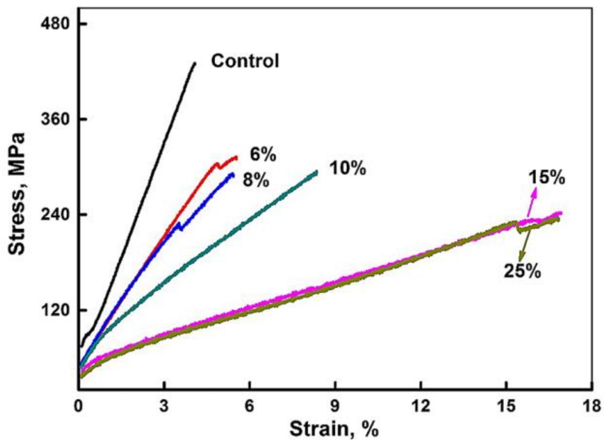

Figure 2: Typical tensile stress–strain curves on individual bamboo fibers treated with varied concentrations of NaOH solutions[8]

3.1.3 Modification with Methyl Methacrylate

According to [3], the treated and untreated specimens' typical load-displacement curves in bending and compression are shown in Figure below. The treated rattan composite had a larger ultimate bending load than the untreated rattan, as shown in Figure 2A, indicating the efficiency of the mechanical boost given by the MMA rattan composite. Because of the nature of the resin, the load-displacement curve of treated rattan was more brittle than that of untreated rattan. Figure 2B shows that the compressive load-displacement curves of treated and untreated specimens were identical.

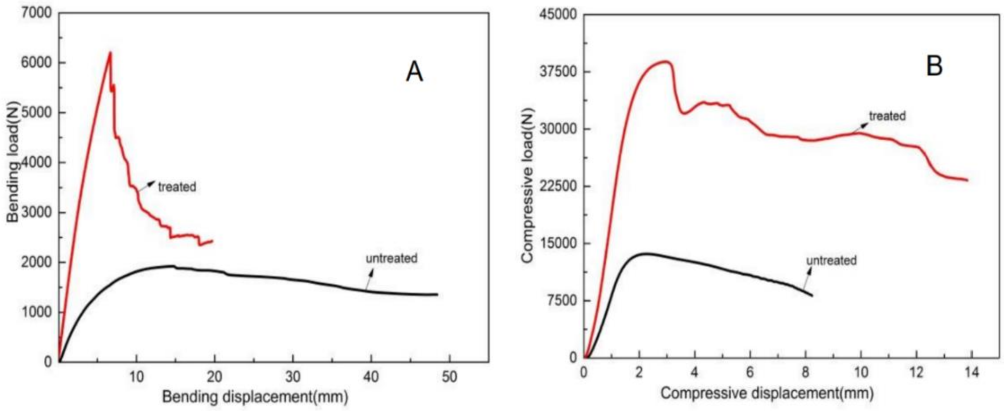

Figure 3: Untreated and treated rattan mechanical load displacement: Bending load displacement (A) and compression load displacement (B)[11]

Table 2 below summarizes the bending and compressive parameters of untreated and treated rattan. These increases were higher than prior research findings, which were 206 percent and 109 percent, respectively. The bending modulus of PF-impregnated C. manna increased by 11 to 15%. Calamus simplicifolius and Daemonorops margaritae had 36 percent and 75 percent increases in bending modulus, respectively, after being impregnated with MMA. PMMA chain molecules intercalated both voids structure and surface in the rattan, which could have been more efficient in improving the mechanical properties of the composites than wood particles impregnation[4].

Table 2 Mechanical Properties of Untreated and Treated P. kerrana Rattan[12]

Mechanical properties	Treated rattan	Untreated rattan	Increase (%)
Bending modulus (MPa)	2593.8	846.8	206
Bending strength (MPa)	97.9	31.1	215
Compressive modulus (MPa)	1735.4	831.6	109
Compressive strength (MPa)	37.0	17.9	107

3.1.4 Dopamine Modification on Bamboo Fiber

Energy propagation in fiber-reinforced composites would be hampered by improved interface strength, resulting in localized stress in the composites. When crack propagation through the interface was hampered, overall energy absorption for composites reduced, resulting in a brittle fracture mode when the composites were loaded. he flexural and tensile strengths of the ADB4/PLA composites were enhanced by 16.1% and 34.4 percent, respectively, after the synergistic treatment compared to the UB/PLA composites[13].

The aforesaid results are due to the removal of some hemicellulose and pectin in the bamboo fiber by alkali treatment, which increases the specific surface area of the bamboo fiber and hydroxy groups, resulting in an increase in the physical bonding area between the matrix and reinforcing materials. Furthermore, the PLA melt quickly penetrated the bamboo fiber's deep layer, forming rubber nails under pressure, further enhancing the physical combination of PLA and bamboo fiber. When the alkali concentration reached 8wt percent during the synergistic treatment, the flexural and tensile strength fell to 56.75 and 32.86 MPa, respectively[5].

The treatment of the bamboo fibres with sodium hydroxide improved the mechanical properties of the composites. The improved adhesion between the bamboo fibres and the polyester resin is responsible for this improvement. The optimum alkali content for bamboo composites was found to be 6%, which resulted in the best mechanical characteristics. The bending, tensile, and compressive strength and stiffness of bamboo composites treated with this alkali concentration are 7, 10, 81, and 25% higher, respectively, than untreated composites[14].

The mechanical characteristics of composites made with bamboo fibres treated with 8% NaOH were found to be reduced. This was attributed to significant delignification and deterioration, which resulted in a damaged fibre, reducing load transfer and matrix bonding. However, since this polyester resin influences these mechanical properties, the compressive strength and stiffness are 12 and 4% higher than the untreated composites[15].

4. Conclusion

The most suitable chemical treatment that has been selected is by using Alkali Treatment. According to the previous researchers, this alkali treatment is the best way to improve the mechanical properties of rattan. This has been proved in the results of this study. But in some situation, the alkali treatment also has their deficiency as stated in results and discussion section of this study. Findings on the result of this study shows that various mechanical testing that has been carried out to find the mechanical properties of rattan after treatment. All of the results has been stated in.

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