RESEARCH ARTICLE

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Effect of Chemical Treatment on Physical and Mechanical properties of Coconut Fibre

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Abstract

Natural fibre has potential candidate of new eco friendly, sustainable recourses to reduce dependency on conventional synthetic material. Over the past few years among the different kinds of vegetable fibres, coconut fibre has seen limited utilization. The current study improves our understanding of how chemical treatment could optimize natural fibres for innovative uses or advanced application especially in the creation of sustainable materials. The impact of chemical treatments on the physical and mechanical properties of coconut fibres is investigated in this study. The study can be divided into three phases, preparation of materials, treatment and testing of coconut fibre. For the first pre-trial fibre is treated with different chemicals like 10% to 15% concentration of NaOH and NaOCL solutions for 3 hours. After being immersed in NaOH solutions and treated with NaOCL solutions, the fibres were dried. The second treatment is coconut fibre soaked in Hydrogen peroxide (H_2O_2) solution with a concentration of 18% for temp of 90° c time of 1 hour. After the treatment the fibre is dried in atmosphere for 24 hours. Raw coconut fibre and the second chemically treated fibres were tested and evaluated for different physical and mechanical properties. The fibre surface morphology was examined using microscopic method. The result shows that mechanical strength of fibre increase slightly after the second treatment however the fibre surface becomes rough and porous.

Keywords: Natural fibre, Coconut fibre, chemical treatment, hydrogen peroxide, microscopic method, Physical and Mechanical properties.

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Introduction

Natural fibres, such as coconut fibre (coir), offer a sustainable, renewable, and inexpensive alternative to synthetic materials, with the added benefits of high specific strength, stiffness, and fewer health risks. In comparison to synthetic fibres like glass and carbon, natural fibres are more eco-friendly and readily available, making them highly attractive for various engineering applications, particularly in civil engineering and composite materials.[1]

Coconut fibre, or coir, is a naturally occurring cellulosic fibre extracted from the husk of the coconut. The husk is the layer between the outer shell and the inner coconut. Coir fibres are classified into two main types based on the maturity of the coconut: brown fibre (from mature coconuts) and white fibre (from immature coconuts).[2] Brown fibres are thick, durable, and resistant to abrasion, making them suitable for applications requiring toughness, while white fibres, which are finer and smoother, are generally weaker. Three commercial categories of coconut fibre exist: decorticated fibres (mixed fibres), mattress fibres (very short fibres), and bristle fibres (long fibres). Each type serves distinct purposes depending on its specific characteristics, with brown fibres being predominantly used in engineering applications due to their greater strength.[3]

In addition to its strength, coconut fibre offers several advantages such as high water absorption, resistance to UV degradation, and biodegradability after a period of 4–10 years. These properties make coconut fibre an excellent choice for applications exposed to harsh environmental

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conditions. Furthermore, coir is flexible, resilient, flame-retardant, and resistant to moths, fungi, and rot. It has been shown that the addition of coconut fibre to concrete and mortar can improve their brittleness, ductility, and toughness, making it a valuable additive for enhancing the properties of construction materials.[2,4]

Recent research has focused on enhancing the bonding of coconut fibre to the matrix by employing various chemical treatments, including alkaline treatments with sodium hydroxide (NaOH) and hydrogen peroxide (H_2O_2). These treatments remove impurities such as waxes and oils, roughening the fibre surface and improving its adhesion to the composite material, thereby increasing the strength and stability of the resulting material.[5,6] The modifications to the fibre structure induced by chemical treatments also improve the fibre's thermal stability, making it suitable for high-performance applications in construction.[1]

The lignin content in coconut fibres is very high.[2,3,7] Cellulose and hemi-cellulose is a polysaccharide compound while lignin is a macro molecules polyphenolic compound.[2] In general, treated natural fibres used as a composite reinforce treatment give tensile strength and modulus of elasticity greater than the untreated natural fibre composites. Therefore, modification of the fibre surface treatment is considered to increase the strength of natural fibre composite.[8,9] Various treatments have been explored to enhance the properties of coconut fibre for use in composites. One of the most common treatments is alkali treatment, which removes unwanted substances like lignin and waxes from the fibre surface, improving its adhesion to the matrix in composite materials. Other chemical treatments, such as hydrogen peroxide (H_2O_2) and sodium sulphide, have been used to accelerate the retting process, making the fibres softer and more suitable for use in composites.[10,11] These treatments not only enhance the fibre's mechanical properties but also increase its surface roughness and surface energy, improving its interaction with other materials in composite formulations. Furthermore, the combination of different fibres, such as coconut and sisal, has been proposed to create composites with improved mechanical properties and thermal resistance.[12] Bleaching enhanced the alkaline treatment's effects by removing residual lignin and raising the surface fibre energy and crystallinity index.[13]

Natural fibres from coconut and banana plants were examined using a textural and chemical method. Numerous findings were observed, including the following: (1) the location of the fibres within the tree and the type of tree they originate from (green wood or not); (2) the preferred and quick breakdown of banana fibres with rising pyrolysis temperatures. The samples were rough and made up of hollow fibres with cellulose microfibrils forming their walls. These investigations will enable us to forecast the behaviours of developed composites (insulating or not) with substantial porosity in particles and to choose the temperature at which fibres will pyrolyze before being incorporated into the cement matrix.[14]

Coir board has developed permeable textiles called coir geo textiles, or Coir Bhoovastra, can reduce soil erosion. It preserves valuable top soil while fostering plants and safeguarding the planet. It comes in both woven and non-woven varieties. The 100% organic and renewable natural fibre used to make Coir Bhoovastra has high tensile strength and modulus, is biodegradable, naturally resistant to rot, mold, and moisture, has good dimensional stability, and is non-slip. It is inexpensive, readily available in India, biodegradable and environmentally. It is used in road construction for drainage, filtration, reinforcement and separation. It is also stiff and has limited extensibility[15].

Chemical properties of coir fibre

The primary chemical components of coconut fibres include cellulose, hemicellulose, and lignin. These components significantly influence the fibre's mechanical properties. Cellulose and hemicellulose are polysaccharide compounds, while lignin, a phenolic compound, contributes to the fibre's rigidity and resistance to environmental degradation. Fibres undergo various pre-treatment processes, which alter their composition and consequently, their properties, either enhancing or sometimes diminishing their performance. The pre-treatment of fibres alters their composition and characteristics of composites [3]. The chemical composition of coconut fibres is presented in Table 1 [11].

Material And Methods

Materials

The fibres used in the present study were obtained from mature coconut husk extraction. This study is mainly focus on utilization of coir for technical purpose for that fibres blended with other natural fibre. Coir fibres are hard natural fibre so they required cleaning of impurities, bleaching and softening treatment, washing for the carded web production. Fibres are manually cleaned then bleaching and softening was done.Without any treatment, these fibres are considered as raw or natural fibres.

Table 1: Chemical composition of coir fibre.[11]

S. No.	*Properties*	*% mass on dry basis*
1	Cellulose	43.44%
2	Hemi cellulose	0.25%
3	Liginin	45.84%
4	Pectin substance	3.00%
5	Water soluble	5.25%
6	Ash content	2.06%

Coir fibre collection

Coir fibre is extracted from the outer husk of the coconut. Coir, Cocosnucifera, and Arecaceae (Palm) are the colloquial, scientific and plant names for coconut fibre, respectively. The coir fibres were sourced from mature coconuts mostly harvested in the coastal regions of India, during the dry season (October to December) to ensure optimal fibre quality. The outer husks of the coconuts were removed manually using machetes or mechanically using specialized machine in Gujarat coir industries, vaisnodevi circle khoraj, Ahmedabad of Gujarat from India. In Manual dehusking: After being harvested, the coconuts are manually dehusked in order to separate the fibre husk from the hard outer shell .This is carried out either manually or mechanically using specialized machines. In manual methods, workers use large knives or machetes to carefully remove the outer shell, revealing the fibrous brown husk inside. Mechanical dehusking: For larger-scale operations, mechanical dehusking machines are used to remove the coconut husk. These machines employ with rotating drums or blades that strip away the outer shell.

Methods

Chemical treatment of coconut fibre

Due to the presence of high quantity of lignin, coir fibre is very hard. A "softening treatment" is required to enhance the smoothness and pliability of the coir natural fibre that is taken from the coconut husk. Because of their initial stiffness, coarseness, and brittleness, coir fibres are not easy to process. A softening treatment increases the fibres pliability, facilitates processing, and expands their range of applications. For the preparation of fibres coir fibres are first manually cleaned to remove any dirt or other impurities. Chemical treatment of coir fibre is done using hydrogen peroxide treatment to increase whiteness of the fibre, which can be advantageous for aesthetic purposes or to improve flexibility especially when the fibre is to be blended with other fibre. After treatment the fibres are wash to remove any residual hydrogen peroxide and by products. The treated fibres are dried.

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Table 2: Sampling Data

S. No.	*Code*	*Fibre sample*
1	A1	Raw coir fibre
2	A2	Chemically treated fibre

For the pre-trial first coir fibre is treated with different chemical like strong alkaline sodium hydroxide (NaOH) is mostly used to clean impurities such as natural oils, waxes, pectin, and dirt from the scouring process of natural fibres (like cotton, wool, and linen) and other chemical used is sodium hypochlorite (NaOCL) is a powerful oxidizing agent and commonly used in the bleaching of cotton and cellulose base fibres as shown in Figure 1.

The chemical treatment for coir fibre using hydrogen peroxide involves several key steps:

For the preparation of coir fibers are first manually open and cleaned to remove any dirt or other impurities.

⇩

For the hot process material to liquor ratio is taken 1:20 according to that for e.g. sample of fiber if we take 50 gm then prepare 1000 ml of water with addition of 80 ml of H2O2 solution and 50 gm sodium silicate .

⇩

After that cleaned fibres are then soaked in a solution of hydrogen peroxide (usually at concentrations ranging from 10 to 18%) mixed with water and sodium silicate for hot process with boiling temp (90°c) for time of 1hour. Sodium silicate may used to enhance the effectiveness of the fiber properties.

⇩

After treatment fibres are thoroughly rinsed with water to remove any residual hydrogen peroxide and by-products. The treated fibers are then dried in atmosphere for 24 hours.

The above flow chart shows the process steps of chemical treatment of coir fibre. As per hot process the all extracted coir fibre sample immersed in solution of 18% H_2O_2 (hydrogen peroxide) with sodium silicate stabilizer for time of 1hour and temp of 90°c. The fibre to liquor ratio was maintained at 1:20. First the basic sample testing was done for raw and chemical treated fibre for evaluating the effect of chemical treatment on the morphology of coconut fibre. For this study coir fibre preparation softening treatment was done to make coir fibre whiter by treating it with hydrogen peroxide. As shown in Figure 2 raw coir fibre and Figure 3 chemically treated coir fibre. This can be done for aesthetic reasons or to make the fibre more flexible, especially when it is going to be blended with other fibres.

Testing of fibre

Prior to conducting the evaluations, pre-testing conditioning period within standard atmospheric conditions, characterized

Figure 1: Coir fibre treatment with different chemical

Figure 2: Raw coir fibre

Figure 3: Chemically treated coir fibre

by a temperature of 27 ± 2°C and a relative humidity of 65 ± 2%, spanning a duration of 24 hours. The extracted fibres are analysed for the physical properties such as length (ASTM D 5103-12), % hollowness of fibre (Microscopic method) The coconut fibre's microstructure was examined using the digital microscope. This device combines observation of captured images and measurement functions while providing a screen interface that makes visualization easier, mechanical properties such as breaking strength fibre strength and % elongation (ISO 5079) by standard test methods and obtained results are depicted in Table 3.

Results And Discussion

The first pre-trial of coir fibre is treated with different chemical like strong alkaline sodium hydroxide (NaOH) and sodium hypochlorite (NaOCL) for the bleaching of coir fibres is not successful due to whiteness of the coir is not achieved as shown in Figure 1.

Hence, the second treated with Hydrogen peroxide (H2O2) coir fibre is analysed using microscope and it is possible to observe cross-section and external surface of coconut fibres. The surface and cross-section of coconut fibres tested using the microscopic method. Microscope images of surface and cross-section of fibre: (a) raw fibre (RF); (b) Chemically-treated fibre (CTF) as shown in Figure 4 & 5.

Table 3: Fibre properties

S. No.	*Fibre properties*	*CODE A1*	*CODE A2*
		Raw Coir fibre	*Chemically treated Coir Fibre*
1	Fibre Length (mm)	95-148 mm	95-148 mm
2	Fibre hollowness (%) (microscopic method)	4.0 %	4.2%
3	Breaking strength (gf)	896 gf	953 gf
4	Fibre Strength (gpd)	12.0 gpd	12.7 gpd
5	Fibre elongation (% elongation at break)	18.1%	28.4%
6	Longitudinal View	Rod like structure with striations	Rod like structure with striations
7	Cross sectional view	Round & Oval shape	Round & Oval shape

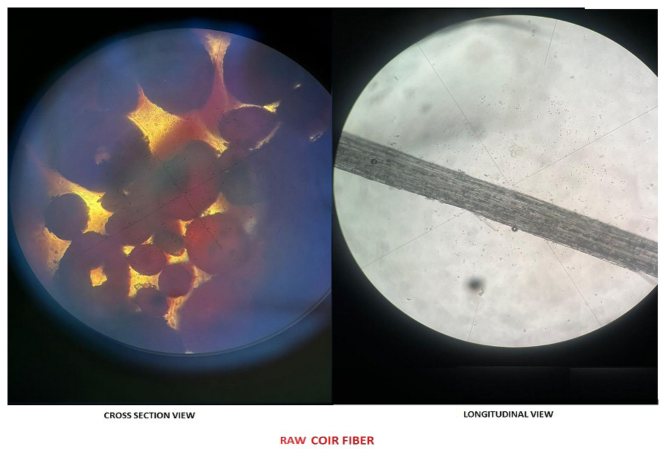

Figure 4: Cross section and longitudinal view of raw coir fibre

Figure 5: Cross section and longitudinal view of chemically treated coir fibre

According to the results cross sectional shape of the coir fibre is round and oval, longitudinal view shows rod like structure with striations. As illustrated, In addition, the images shows that the process of treatment of fibres causes morphological changes with an increase in voids and a rougher surface because of the removal of most of the pectin, ash and other impurities.

Mechanical Properties

The complex molecular structure called lignin that hold the cellulose fibre together could be broken down by hydrogen peroxide an effective oxidizing agent causing change in coir fiber. One of the primary reasons for coir fibre stiffness is lignin. The second treated H_2O_2 improving the fiber's mechanical properties and enhancing its ability to absorb dyes and helps to remove or partially degrade this lignin. The oxidative treatment decreases the lignin content in the fiber, making the fibers more pliable and increases their flexibility. Also H_2O_2 is bleaching agent improves the whiteness of the coir fiber which can be advantages for aesthetic purpose or blended with other fibers. The fibers tensile strength and elongation characteristics can increase based on the concentration and duration of H_2O_2 exposure; however overtreatment (i.e. prolonged exposure or high concentration of H_2O_2) may cause the fibre degradation or reduction in tensile strength.

For the second treated coir fibre with hot process also include stabilizer sodium silicate to improve its physical and chemical properties for better use in industrial applications. Use of stabilizers must be added to the solution to control the decomposition of hydrogen peroxide. Stabilizers function by providing buffering action to control the pH at the optimum level and to complex with trace metals which catalyze the degradation of the fibres. Sodium silicate increases the tensile strength of fibre, which increase their durability and is particularly helpful for strong and long lasting fibre. Also the treatment with sodium silicate increase the fibre resistance to external elements such as moisture, UV rays extremely high and low temperature. Sodium silicate treatment is less costly and more environment friendly .It is used to change the fibre surface and improve its thermal characteristics.

Conclusion

The result shows that in general the mechanical strength of the fibre, breaking strength and elongation increase. However, the fibre surface morphology becomes rough and having voids which is helpful to get better thermal insulating material. Test results clearly show that chemical treatment with use of sodium silicate increases the tensile strength of fibre. The chemical treatment is also beneficial for enhancing the aesthetic appearance of the fibre and increasing its flexibility, particularly when it is blended with other fibres.

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