THE EFFECT OF CHEMICAL TREATMENT ON THE TENSILE PROPERTIES OF SISAL FIBER REINFORCED EPOXY COMPOSITE

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Abstract - *The main objective of this paper is to investigate the effect of chemical treatment on the tensile properties of sisal fiber reinforced epoxy composites. Sisal fiber was extracted from sisal leaves by water retting method. The fiber was treated with 3%, 6% and 9%NaOH solutions. Sisal fiber composites were fabricated by compression molding technique using both the untreated and treated fiber with constant length and volume of fiber. The specimen is prepared according to ASTM standards and the experiment has been carried out by using computerized universal testing machine. The experimental results show that the tensile properties of composites made from alkali treated fibers are better compared to the untreated fiber composite.*

Key Words: **Natural fiber, sisal fiber, chemical treatment, alkali treatment, NaOH treatment, epoxy resin, compression molding, tensile properties.**

1. INTRODUCTION

Composites are combination of two materials in which one of the material is called as the reinforcing phase, is in the form of fibers, sheets, or particles, and is embedded in the other material called the matrix. Matrix surrounds the fibers, acting as load transferring medium and thus protecting those fibers against chemical and environmental attack. Natural fiber composites are more attractive due to their highest specific strength, light weight, low cost, biodegradability, non toxic and good thermal resistivity. The natural fibers such as alfa, aspen, bagasse, bamboo, banana, barley husk, coir, cotton, doum palm, esparto, fique, flax, hemp, isora, jute, kapok, kenaf, kudzu, loofah, madar, maize, malva, milkweed, oat, oil palm, palmyra, pineapple, raffia palm, ramie, rape, rice straw, roselle, rye husk, sabai, sisal, screw pine, sun hemp, turmeric and wheat husk are used for preparing the composites. The natural fibers are having of cellulose, hemicellulose, lignin, pectin, waxes and other materials. The main drawback of using natural fiber is their high level of moisture absorption, insufficient adhesion between untreated fibers and the polymer matrix. The surface of natural fiber are usually not suitable for creating a strong bond with a polymeric matrix. Chemical treatment of the natural fibers can clean the fiber surface, chemically modify the surface, stop the moisture absorption process, increase the surface roughness and improve the adhesion to matrix materials. Chemical treatments include acetyl, acryl, alkali, benzyl, isocyanate, permanganate, peroxide, silane, titanate etc. The most popular treatment are alkali, acetyl and silane. The alkali treatment is the most common method that is used for the treatment of natural fibre because this method is easy, inexpensive (low cost) and effective. The alkali treatment process has some critical parameters like types of alkali used (NaOH & KOH), concentration of the solution, treatment duration and temperature. The types of alkali used, concentration of solution and treatment duration plays major role. There is a positive effect cited when the concentration increases up to certain limit, beyond that the value drops suddenly. The concentration of alkali solution used to treat the fibers is in the range of 0.5% up to 28%, but most of the researchers used below 10% alkali solution. The temperature and soaking time to treat the natural fiber in the solution are in the range of 20-180°C and 15minutes to 48 hours period of time, respectively.

Composite materials can be classified based on the types of matrix used as Metal Matrix Composites, Ceramic Matrix Composites and Polymer Matrix Composites. Polymer Matrix Composites is the most commonly used composites, Due to its many advantages such as light weight, high stiffness, low cost, good corrosion resistance and simple manufacturing principle. Polymer Matrix Composites have two types of polymer that have been used as matrix. These are thermoplastics and thermosetting polymer. Thermoplastic polymer is that polymer which are repeatedly softened and reformed by heating. However, thermosets on the other hand, are materials that undergo a curing process during part fabrication, after which they are rigid and can not be reformed. Important thermosetting resins are epoxy, polyester, polyvinyl ester, phenolic resin, unsaturated polyester, polyurethane resin and urea formaldehyde. Epoxy resin is the most widely used matrix due to its advantages like good adhesion to other materials, high strength, low volatility during cure, low shrink rate, low viscosity etc.

The polymer composite have been fabricated by various method. They are compression molding, hand lay-up process, injection molding, resin transfer molding, spray lay-up process etc. Compression molding is widely used to manufacture natural fibre composites because of its good surface finish, high rate of production, little waste, lower tooling cost than injection molding, less damage to fiber, low residual stress, good dimensional accuracy, good flexibility in part design and short cycle time. In compression molding, base plate is stationary while upper plate is movable. Matrix and reinforcement are placed in the steel mold and the whole assembly is kept in between the compression molder. Pressure and heat is applied as per the requirement of composite for a definite period of time, followed by cooling. Curing of the composite may carried out either at room temperature or at some elevated temperature. After curing (solidified), mold is opened and composite product is removed. Good quality composites can be produced by controlling pressure, curing time, temperature taking account of matrix and type of fibre. If applied pressure is not sufficient, it will lead to poor interfacial adhesion of fiber and matrix. If pressure is too high, it may cause fiber breakage, expulsion of enough resin from the composite system. If temperature is lower than desired, fibers may not get properly wetted due to high viscosity of polymers. If temperature is too high, properties of fibers and matrix may get changed.

The natural fiber composites are used in various applications such as aerospace, automobiles (e.g. door panels, instrument panels, seat shells etc), railway coaches, military applications, sports, building and construction area (e.g. walls, ceiling, partition, window and doorframes etc), packaging, storage devices(e.g. bio-gas container, postboxes etc.), furniture(e.g. chair, table, shower, bath units etc.), electronic devices, toys, consumer products etc.

In this study, sisal fiber was selected and treated with different concentration of alkali solutions (0%, 3%, 6% & 9%NaOH solution). In this work prepare a polymer matrix composite using untreated and treated sisal fiber as a reinforcement and epoxy as matrix material, to investigate the effect of chemical treatment on the tensile properties(tensile strength, young's modulus and % of elongation) of sisal fiber reinforced epoxy composites. The tensile properties of a natural fiber reinforced composite are determined depending on many parameters, such as fiber strength, volume fraction of the fibers, fiber length, fiber-matrix adhesion, types of polymer, processing methods etc.

1.1 Objectives

The objectives of the project are outlined below.

- To extract the sisal fiber from the leaves of sisal plants.
- To treat the raw sisal fiber by using NaOH solutions.
- To prepare the sisal fiber reinforced epoxy composites.
- To prepare test specimen according to the ASTM standards.
- To investigate the tensile strength, young's modulus and % of elongation of composites.

2. METHODOLOGY

2.1 Matrix and Hardener

The epoxy resin is selected as the matrix. Epoxy is a thermosetting polymer that cures when mixed with a hardener(HY-951). Epoxy resin of the grade LY-556 with a density of 1.1–1.5 g/cm^3 was used. The Epoxy resin and the hardener were mixed in ratio of 10:1 by weight. The epoxy resin and hardener was purchased from Covai Seenu & Co, Coimbatore, Tamilnadu, India.

2.2 Extraction of Sisal Fiber

Sisal fibers are extracted by the following methods.

(1) Retting process.

(2) Chemical extraction.

(3) Mechanical extraction.

2.2.1 Retting Process:

The sisal leafs are cut from sisal plants (figure-1). These leafs are tied in to bundles and it was immersed in water (river, pond or tank) for 2 weeks until it become decay. The retted leafs were washed in running water and then sisal fiber was cleaned. Then fiber was dried under sunlight for one day. This process takes more time but it is economical.

Figure-1: Sisal leaf cut from sisal plant

2.3 Alkali Treatment of Sisal Fiber

The chemical treatments are used to increase the mechanical properties of natural fibers. The natural fibers were subjected to a alkali treatment to remove natural waxes and other unwanted particles. Three aqueous solutions of NaOH with different concentrations (3%, 6% and 9% by weight) were prepared by dissolving sodium hydroxide pellets in distilled water. This treatment was made in some steps. First, the sisal fiber were immersed in a bath of sodium hydroxide (NaOH) solution for 75 minutes at room temperature. The fibre to solution weight ratio was maintained at 1 : 20. During this process the bath was stirred continuously using a mechanical agitator. Finished the immersion stage the solution presented a yellow colour, because of the substances removed from the fibers. Next, the fibre was washed thoroughly in distilled water to remove excess of NaOH. The washed fibers were dried at sun light for 7 hours. Finally, sisal fibre were cut in the length of 150 mm.

2.4 Fabrication of Composites

A steel mould with size dimension 300mm×300mm×3mm was used to prepare the composites. The mould was cleaned to remove the dust particles and a thin layer of wax was applied by using a brush. This layer prevents the sticking of the composite to the mould during curing; hence the composite can be removed easily from the mould. The epoxy resin and hardener were mixed together in ratio of 10:1 by weight and then it was stirred for 5 minutes. The composite specimens for both untreated and treated fibers were made by compression molding technique using 20wt% of sisal fibers. Initial layer of the mould was filled with epoxy resin mixture and then sisal fiber was spread over epoxy resin mixture. Again, epoxy resin mixture was poured on the fibre. Thus, the starting and ending of the layers were of epoxy resin. After completing curing process composites were cut as per ASTM standard.

2.5 Tensile Test

The tensile test specimens were prepared according to ASTM D3039; the most common specimen for ASTM D3039 has a constant rectangular cross section. The specimen size is 250mm x 25mm x 3mm. Tensile test specimens are shown in figure-2. Tensile tests were conducted using computerized universal testing machine with a cross head speed of 2mm/min. Tests were carried out at room temperature and each test was performed until tensile failure occurred. In each case, three samples were tested and average value was tabulated. Tensile test is the most common mechanical test for determining the tensile properties of natural fibers such as tensile strength, elastic modulus, strain etc.

Figure-2: Tensile Test Specimens.

3. RESULTS AND DISCUSSION

The main objective is to determine three important tensile properties of composite by conducting the tensile test. Test results is given below.

Table-1: Tensile Test Results

S.No	NaOH Concentration (%)	Tensile strength (MPa)	Young's modulus (MPa)	% of Elongation
1	0	49.12	3290.99	1.493
2	3	55.02	3681.39	1.495
3	6	41.06	3710.24	1.107
4	9	34.04	3078.39	1.106

3.1. Tensile Strength

Table-1 and chart-1 shows the tensile strength with different NaOH concentrations. The composites with 3%NaOH treated fibre achieved the highest tensile strength of 55.02MPa, which is 12% higher than the untreated fiber composites. This can be understood that the removal of the hemicellulose and a part of the lignin by NaOH treatment can increase the interfacial adhesion between the matrix and treated fibre. However, the tensile strength of fibre is reduced at higher concentration of NaOH. Similar results were found by A. Khalina *et al.,*[1] whose work was on The Effect of Alkaline Treatment on Tensile Strength and Morphological Properties of Kenaf Fibres for Yarn Production. The Juteko kenaf fibers were treated with different concentrations of NaOH solutions (0%, 3%, 6% , 9% and 12%). Maximum tensile strength was obtained from 3%NaOH treated fiber composite compared to other four types of Juteko kenaf fiber composites. In another research done by F.A.Fauzi *et al.*,[6] The Investigation of Mechanical Properties on Natural Fiber Composites for Recurve Bow

Material Selection were studied. 3% NaOH treated mengkuang fiber composite have highest tensile strength then untreated fiber composite as well as 1% and 5% NaOH treated mengkuang fibre composites.

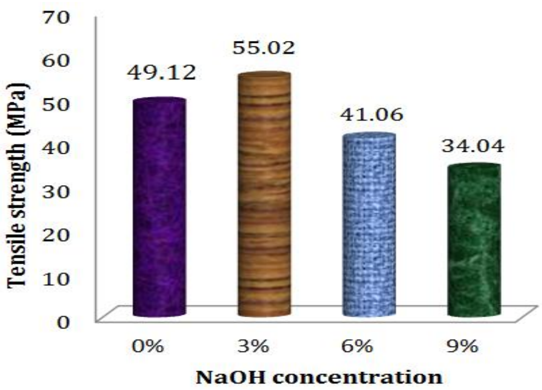

Chart-1: Tensile strength

3.2 Young's Modulus

From chart-2 and table-1, it is clear that NaOH treatment improves the young's modulus of the sisal fiber epoxy composites. The 6% NaOH treated fiber composite exhibited the highest modulus of elasticity of 3710.24MPa. This suggests that the 6%NaOH treated fiber composite exhibit highest degree of stiffness compared to the other composites. This is similar to the findings of Allan C. Manalo *et al.*,[2] that have conducted a study on Effects of alkali treatment and elevated temperature on the mechanical properties of bamboo fibre-polyester composites. Bamboo fibers were treated with sodium hydroxide in the concentration of 0%, 2%, 4%, 6%, and 8%. It was found that the maximum young's modulus was obtained for the treated fibers that have been treated with 6% NaOH. Similarly, A. Khalina et al.,[1] reported that 6%NaOH treated Juteko Kenaf fiber composite has a higher young's modulus value compared to 0%, 3%, 9%, and 12% NaOH treated samples.

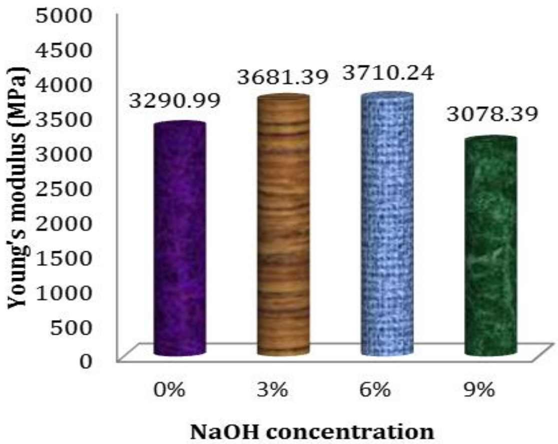

Chart-2: Young's modulus

3.3 Percentage of Elongation

Chart-3 and table-1 shows the % of elongation with different sodium hydroxide concentrations. The sisal fibre composite gave the optimum % of elongation with a value of 1.495 corresponding to the 3% NaOH treated fibre composite. The percentage of elongation at break values depends on the fibre-matrix interaction. This indicated that higher elongation of fibers indicated higher ductility and lower elongation indicates lower ductility of materials. Chandra Mohan H.K *et al.*,[4] whose work was on Mechanical Properties of Untreated and Alkali Treated Sida Acuta Stem Fibre reported similar behaviour. The alkali treatment of sida acuta fibre were carried out at different concentration of NaOH solution (0%, 1%, 3% and 5%) for 20hours. The composite produced from fiber modified with 3 wt% concentration of NaOH solution exhibited the highest percentage elongation at break. Moreover, C. Romã et al.,[3] reported that 4% NaOH treated sisal fibre composite exhibited the highest percentage of elongation than 0% and 8% NaOH treated composites.

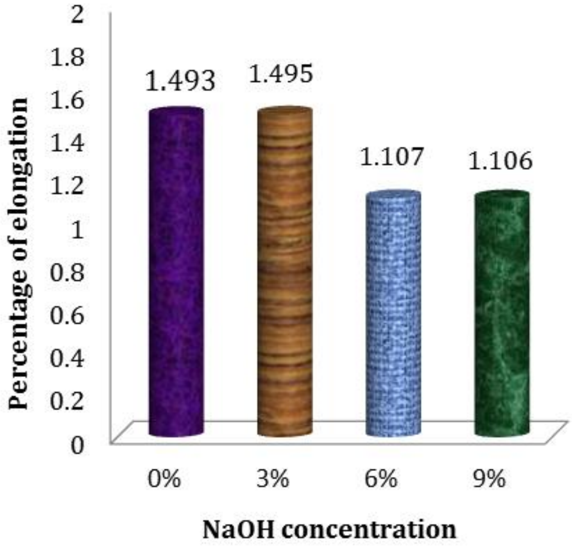

Chart-3: Percentage of elongation

4. CONCLUSIONS

In this research, the effect of chemical treatment on the tensile properties of sisal fiber reinforced epoxy composites were investigated on the basis of the experimental evidence. The following conclusions are made from the results and discussions.

- It is clearly observed that the alkali (NaOH) treatment improves the tensile properties.
- The 3% NaOH treated sisal fiber composite has optimum tensile strength.

- The 6% NaOH treated fiber possess highest young's modulus.

- The maximum percentage of elongation is obtained from 3%NaOH treated fiber composite.

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