

# Influence of Chemical Treatment on Natural Fiber and Fiber Coating on Mechanical Properties of Sisal/Cyperus Pangorei Reinforced Epoxy Composite Material

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**Abstract—** Synthetic fibers pose a significant environmental concern as they contribute to soil pollution and are non-degradable, persisting in the soil even after 15 years of application. The life cycle of synthetic fibers involves resource consumption, greenhouse gas emissions, and the release of pollutants. The production of textiles and ropes generates approximately 200,000 to 500,000 tons of microplastics, which further impact the marine environment. In contrast, natural fibers such as sisal and cyperus pangorei are more durable, provide comparable strength to synthetic fibers, and have a longer lifespan. By washing sisal/cyperus pangorei fibers with NaOH and coating them with epoxidized natural resin (e.g., epoxy resin, epoxidized soya bean oil, epoxidized canola oil), the fibers can be shaped into five different types of specimens. These specimens, including non-chemically treated, chemically treated, single layer coated, double layer coated, and triple layer coated, can be tested using methods such as tensile, fatigue, water absorption, hardness, and impact tests to evaluate their performance as composite materials.

**Keywords—** Chemical treatment, Natural fiber, Sisal, Cyperus pangorei, Reinforced composite material, Mechanical properties, Fiber coating.

## I. INTRODUCTION

Composite materials are created by combining different materials. These discrete materials, also known as component materials, may be divided into two fundamental categories. One is the matrix (binder), while the other is the reinforcement. Each kind must be present in some quantity. The reinforcement is supported by the matrix, which encloses it and maintains its relative placements.

As the reinforcements transmit their extraordinary physical and mechanical qualities, the matrix's characteristics get better. Synergism causes the mechanical characteristics to disappear from the separate constituent materials. The designer of the product or structure is given alternatives to select the best combination from the range of matrix and strengthening materials at the same time. The designed composites must be produced in order to be shaped.

Either the mould cavity or the mould surface receives the reinforcement. The reinforcement might be subjected to the matrix either before or after this. The matrix undergoes a merging event that forces the part's shape. This merging process can occur in a variety of ways depending on the kind of matrix, including chemical polymerization for thermoset polymer matrixes and solidification from a molten state for matrix of thermoplastic polymers composites. Many moulding processes can be used, according to the needs of the final product's design. The kind of the chosen matrix and the reinforcement have the most effects on the strategy. The overall volume of material to be generated is another important factor.

Significant capital investments in efficient and automated manufacturing systems can be supported by large volumes. Small production numbers are aided by cheaper capital expenditures but higher labour and tooling costs that increase more slowly. Many commercially available composites are manufactured using a polymer matrix component called a resin solution. Polymers come in a wide variety of forms accessible depending on the starting basic components. There are a number of major categories, and there are several subclasses within each. The most popular ones are PEEK, polyester, vinyl ester, epoxy, phenol, polyimide, polyamide, and polypropylene.

## II. MATERIALS, MATRIX AND MATERIAL REINFORCEMENT

### A. Introduction

- *Matrix Used:* Epoxy Resin
- *Reinforcement Used:* Sisal Fiber, Cyperus Pangorei (Korai Grass).

### B. Epoxy Resin

The essential components, or dry by-products, of epoxy resins are included in the group of materials known as epoxy. Epoxy resins are a family of substances that include epoxide groups and are sometimes referred to as polyepoxides, reactive prepolymers, and polymers. The word "epoxy" refers to the whole epoxide functional group. Epoxide groups are referred to by the IUPAC as oxiranes.

By catalytic homopolymerization, epoxy resins can interact (or cross-link) with a variety of co-reactants, such as polyfunctional amines, acids (including acid anhydrides), phenols, alcohols, and thiols (sometimes referred to as mercaptans). The cross-linking reaction and the co-reactants are usually referred to as hardeners and curatives. A thermosetting polymer is produced when polyepoxides interact with each other or with multipurpose hardeners. This polymer generally combines great heat and chemical resistance with outstanding mechanical characteristics.

The manufacture of paint brushes, composites, electrical components (like chips on board), LEDs, high-tension electrical insulators, metal coatings, composites, fiber-reinforced plastics, structural adhesives, and other items are only a few of the many applications for epoxy. Epoxy resin chemicals provide health hazards, such as contact dermatitis, allergic responses, and respiratory issues brought on by breathing in vapour and sanding dust, particularly when they are not fully cured.

#### 1. Curing:

An epoxy can be homopolymerized with another epoxy to create a cure, or hardeners or cures can be combined to create a copolymer that have several functions. The characteristics of the material, such as resistance, durability, adaptability, and adherence, are created during the curing process. Theoretically, the epoxy resin's epoxide molecules can react with any molecule that possesses a reactive hydrogen. Amines, acids, acid anhydrides, phenols, alcohols, and thiols are a few prominent forms of hardeners for epoxy resins.

In roughly descending order of relative reactivity (lowest to highest), There are several different types of amines: phenol, anhydride, aromatic, cycloaliphatic, aliphatic, and thiol. Many epoxy resin/hardener mixtures need to be heated to cure at temperatures as high as 150 °C (302 °F) or, in rare circumstances, 200 °C (392 °F). On the other hand, several of these mixtures could cure at room temperature (fig. 1). A network's mechanical, chemical, and thermal resistance will be reduced by inadequate curing heat, which will also result in insufficient polymerization. In order to give the best features, the cure temperature should normally be higher than the glass transition temperature (T<sub>g</sub>) of the completely cured network.

### B. Applications of Epoxy Resin:

Epoxy-based materials have many uses and are regarded as being particularly adaptable. The uses include paints, adhesives, and composite materials like those made with carbon fibre and fibreglass reinforcements (although glass-reinforced plastic may also be made using polyester, vinyl ester, and other thermosetting resins). Cure polymers may be created with a very wide range of characteristics because to the chemistry of epoxies and the variety of commercially accessible variants.

In cementitious and concrete systems, they have been employed often. Along with their acceptable to excellent mechanical, thermal, chemical, and electrical insulating qualities, epoxies are well recognised for their superb adhesion, chemical resistance, and heat resistance. Epoxies have a propensity to be electrically insulating, yet there are silver-filled epoxies with high electrical conductivity available.

Similar to other categories of thermoset polymer compounds, it is usual practise to mix various grades of epoxy resin and add to achieve the necessary processing or final characteristics, or to add fillers, plasticizers, or additives cut costs. Formulating is the term for using mixing, additions, and fillers.

Because the reaction is exothermic, all amounts of the mixture produce their own heat. Large volumes will produce more heat, considerably speed up the process, and shorten working time (pot life). Therefore, mixing smaller quantities that may be consumed quickly is a smart idea to reduce waste and be safer. There are several ways to make them more resilient.

### C. Sisal Fiber

Agave sisalana, a kind of flowering plant, is native to southern Mexico, although it has been widely cultivated and naturalised in many other countries. It creates a stiff fibre that is utilised to create rope and a number of other things. Depending on the context, the word "sisal" may refer to the plant's common name or its fibre. In addition to being used to create paper, textiles, shoes, hats, handbags, carpets, and dartboards, sisal fibre has a number of other applications. Additionally, it serves as a fibre reinforcement for items made of composite fibreglass, rubber, and concrete.

A rosette of sword-shaped leaves on sisal plants ranges in height from 1.5 to 2 m (4 ft 11 in to 6 ft 7 in). When leaves are young, they may contain a few tiny teeth along their borders, but as they become older, they lose them. The sisal plant has a lifetime of 7 to 10 years and normally yields 200 to 250 commercially useful leaves. There are around 1000 fibres in each leaf. Only 4% of the plant's weight is made up of fibres. Due to its preference for temperatures over 25 °C (77 °F) and sunlight throughout production, sisal is regarded as a plant native to the tropics and subtropics.

Both the Mayans and the Aztecs utilised sisal to produce textiles and paper. Sisal farming extended to Florida, the Caribbean islands, Brazil (Paraiba and Bahia), as well as to nations in Africa, particularly Tanzania and Kenya, as well as to countries in Asia in the 19th century.

According to legend, sisal "came to Africa from Florida, through the mechanism of a remarkable German botanist, by the name of Hindorf." Its production was first practised in Cuba in 1880 in Matanzas by Fernando Heydrich.

After starting its first commercial sisal plantings Brazil initially marketed sisal fibre in 1948, around the late 1930s. Even though construction on the beginning of many spinning mills in Brazil's history began in the 1960s, it wasn't until then that actual production began. Currently, Brazil is the world's leading sisal producer. Growing sisal has an influence on the environment, both good and bad.

### 1. Propagation:

In addition to bulbils, which are created from buds in the flower stalk, sisal is commonly multiplied by suckers, which form around the plant's base and are nurtured in nursery fields until they are big enough to be moved to their ultimate locations. Genetic advancement is quite unlikely with these techniques. A specific genetic material may be replicated in vitro via meristematic tissue culture, which has great potential for the development of improved genetic material.

### 2. Fibre Extraction:

During a procedure called decortication, only the fibres are left after the crushed leaf material, battered, and swept away by a revolving wheel equipped with blunt blades. As an alternative, To a central decortication, the leaves are delivered factory in East Africa, where manufacturing normally takes place on big estates, in which the waste parts of the leaves are removed with water.

Following drying and brushing, the fibre is then baled for shipment. As the moisture content has a significant impact on fibre quality, proper drying is crucial. Sisal is produced in less developed nations, where artificial drying is not always possible but has been proven to yield typically higher grades of fibre than sun drying. Sisal is mostly farmed by smallholders in the arid north-east of Brazil, and teams utilising portable, waterless raspadors are used to remove the fibre. Brushing is then used to clean the fibre. Dry fibres are mechanically combed and graded, often using the previous in-field grading of leaves.

### 3. Environmental Impacts:

Despite the fact that sisal growing is currently viewed as less damaging than other agricultural practises, it did originally cause environmental deterioration since sisal plantations replaced native forests. While occasionally using herbicides, there are no chemical fertilisers used in the production of sisal, and as most weeding is done by hand, even this impact may be reduced.

When the effluent from the decortication process is allowed to run into watercourses, it seriously pollutes the environment. In Florida and Hawaii, sisal is viewed as an invasive species.

### D. *Cyperus Pangorei* (Korai Grass)

To make the composite materials, CPF was employed. a *Cyperus pangorei*, a tropical plant grows along river margins and can reach lengths of 50–90 cm. Although it may also be found in Southeast Asia and Africa, its native land is presumably India or Sri Lanka. India makes a lot of mats from the plant. In southern India, it is particularly well known for producing 'Pathamadai' mats. In the Tamil dialect, they are frequently referred to as Korai. This plant thrives in rivers' banks and interiors as well as irrigation canals. South Tamil Nadu, India's Tamil Nadu region is where this plant was found at Pappankulam and Pathamadai.

Bundles of stalks are submerged in water during the most popular retting technique, known as water retting. Water seeps into the middle of the stalk, swells the interior cells, and bursts the outer layer, increasing the absorption of moisture and germs that cause deterioration. It's important to carefully assess the retting duration since both under- and over-retting weaken the fibre and make separation more challenging. In twofold retting, a delicate procedure that yields great fibre, the stalks are taken out of the water before retting is finished, allowed to dry for several months, and then retted. Natural water retting uses still or slowly moving water from ponds, bogs, slow-moving streams, and rivers. Depending on the water's temperature and mineral content, the stalk bundles are weighted down for around 8 to 14 days, often with stones or wood.

## III. FABRICATION OF HYBRID NATURAL COMPOSITES

### A. Manufacturing

Open moulding and closed moulding are the two main categories of composites production methods. The gel coat and laminate are exposed to the environment throughout the fabrication process using open moulding. In closed moulding, the composite is treated either in a vacuum bag or a two-sided mould set. Within the categories of open and closed moulding, there are several processing techniques:

#### 1. Open Molding:

- Hand Lay-Up
- Spray-up
- Filament Winding

#### 2. Closed Molding:

- Compression molding
- Pultrusion
- Reinforced Reaction Injection Molding (RRIM)
- Resin Transfer Molding (RTM)
- Vacuum Bag Molding
- Vacuum Infusion Processing
- Centrifugal Casting
- Continuous Lamination



## B. Hand Lay-Up

The easiest and most traditional open moulding technique for composites is hand lay-up. It is a labor-intensive, limited volume process that works well for big components like boat hulls. Resin is then physically poured, brushed, or sprayed over the glass plies and into the open mould after being manually filled with glass or another type of reinforcing mat, woven cloth, or roving.

The manufacture of the laminates is finished by manually releasing any trapped air using squeegees or rollers. Epoxies and polyesters, the two most widely used kinds of matrix resins, both cure at room temperature. Without the use of external heat, the fiber-reinforced resin composite begins to solidify as a result of a catalyst in the resin system.

An initial layer of coloured gel coat is applied to the mold's surface to create a component surface of the highest calibre. The open moulding method known as "hand lay-up" may be used to make a broad range of composite items, ranging in size from extremely small to very big, including boats, tanks, bathware, housings, RV/truck/auto components, and many other things. Despite the modest production volume per mould, several moulds can be used to achieve significant manufacturing numbers.

### 1. Process Description:

Using a spray gun, gel coat is applied to the mould to provide a better surface. When the gel coat has thoroughly cured, the roll stock fibreglass reinforcement is manually placed on the mould. Laminating resin can be applied by pouring, brushing, spraying, or rolling with a paint roller. Use squeegees, paint rollers, or FRP rollers to adequately wet the reinforcement, consolidate the laminate, and remove trapped air. Fibreglass reinforcement is layered on top of the laminate to thicken it. In order to create sandwich structures, low density core materials like end-grain balsa, foam, and honeycomb are often used to reinforce the lamination.

### 2. Molds:

The most common moulds used are single-cavity, simple fibreglass composite moulds. Moulds can be very little or very massive in the variety of composites moulds, and they are also reasonably priced.

### 3. Major Advantage:

The simplest approach, giving inexpensive equipment, straightforward processing, and a variety of component sizes. Design adjustments are simple to make. There is a little equipment investment. Good production rates and reliable quality are possible with experienced workers. utilised extensively for many years. Teaching simple ideas. If polymers that cure at room temperature are utilised, tooling costs are low. many sources and material kinds to choose from. greater fibre content and lengthening of fibres compared to spray lay-up.

### 4. Main Disadvantage:

Laminators' talents have a big impact on resin mixing, laminate resin content, and laminate quality. Laminates with little resin content are typically impossible to produce without adding a lot of voids. Resins and health and safety issues.

Hand lay-up resins often have smaller molecular weights than higher ones, which means they have a larger potential for injury. The sample materials are made of alkali-treated and untreated fibre composites with varying weights of fibre (0, 10, 20, 30, and 40%). mixing of hardener with epoxy resin

Epoxy resin and hardener were first combined at a 10:1 ratio. 2ml of accelerators are carefully applied drop by cautious drop for every 100g of resin. Local suppliers were used to obtain the resin.

## C. Mould Preparation

A mallex sheet of 50 by 50 cm was used to create the mould, and a rubber block piece with dimensions of 300 by 300 mm was attached on each of its four corners. The manufacturing process included the hand lay-up method. To ensure that the artwork won't stick to the mould, a releasing agent had been sprayed to the mould before to the lay-up procedure. To prevent debris from entering composite components during curing, the top and bottom plates were covered with mallex sheet, and the fibres were crushed with epoxy glue.

### 1. Fabrication of Composites:

Sisal and Cyperus pangorei fibre mats are used as reinforcing materials and epoxy resin serves as the matrix material to create hybrid natural composites. Chellam Resin (P) Ltd., in Puducherry, provides the hardener and epoxy resin. For the initial phase of composite production, 50 x 50 cm-sized moulds were constructed. Different compositions with changing fibre content, such as 10%, 20%, 30%, and 40%, are used to create the composite samples. Epoxy resin and hardener were first combined at a 10:1 ratio. 2ml of accelerators are added to 100g of the resin mixture before being applied to the mould.

### 2. Material used in Fabrication:



Fig.1. Mould with Resin



Fig.2. First Layer of Sisal Fiber



Fig.3. Second layer of Cyperus Pangorei



Fig.4. Hybrid composite material

#### IV. PROCESSING AND TREATMENT OF FIBER

##### A. Fiber Preparation

Retting and decorticating were used to remove natural fibres like sisal and Cyperus Pangorei Fibre (CPF). To completely liberate the flesh, the cured fibres were then cleaned, combed, and dried. By slamming the dried fibres, the undesired short and broken fibres were removed.

##### B. Surface Treatment

The fact that cellulose and lignin's hydroxyl groups are present in natural fibres means that they may be altered. The cellulose molecules' hydroxyl groups may participate in hydrogen bonding, which lowers the activity towards the matrix. These groups could be made active chemically, or new molecules could be added that could successfully interlock with the matrix. The fibre surface can be cleaned, chemically altered, the process of absorbing moisture ceased, and the roughness of the surface increased by pretreatments. Before being submerged in a 10% sodium hydroxide solution for 24 hours to remove the remaining alkali, all of the fibres were first rinsed five times with water, dried at room temperature for 48 hours, and then washed with very weak hydrochloric acid (HCl). The fibres were after that cleaned twice or three times with distilled water. It took 23 days to dry the washed fibres at room temperature.

##### C. Chemical Treatment on Interfacial Adhesion

###### 1. Alkali Treatment:

The typical process for creating high-quality fibres is an alkali treatment of cellulosic fibres, commonly known as mercerization.

Due to the elimination of both natural and manufactured contaminants, alkali treatment enhances the fiber-matrix adhesion. Additionally, alkali treatment promotes fibrillation, which causes the composite fibre bundle to disintegrate into individual fibres. In other words, Treatment with an alkali lowers the diameter of the fibre, increasing the aspect ratio. Therefore, raising the aspect ratio and creating a rough surface topography improve mechanical characteristics and the fiber's capacity for sticking matrix interface. Increased surface roughness after alkali treatment increasing the quantity of cellulose exposed on the fibre surface and improving mechanical interlocking. This expands the potential response sites and enables greater fibre wetting. Below is a probable outcome of the fibre and NaOH interaction.



Natural fibres that had been alkali-treated favoured the reinforcement in the thermoplastic matrix in the composite by displaying an ideal chemical connection and higher interface adhesion, increasing the hybrid composite's tensile strength samples. Natural fibre thermoplastic hybrid samples failed with lengthy tails after the main damage and were brittle in nature. It is therefore predicted that an interfacial contact in the current composite will cause a larger elongation to break owing to alkali treatment. The treated fiber's fibre wetness is readily discernible, and there is also strong fibre matrix interaction.

###### 2. Hydrogen Peroxide Treatment:

As coupling agents, hydrogen peroxide is utilised to change the surface of the fibre. While being treated with the fibre, it goes through numerous the processes of bond formation, hydrolysis, and condensation. The cellulose hydroxyl group in the fibre interacts with it, improving the fibre matrix adherence, which stabilises the characteristics of the composite. The chemical makeup of hydrogen peroxide enables the cellulose fiber's surface to create a chemical bond. Additionally, it offers the hydrocarbon chains needed to prevent fibre swelling in the matrix.



Fig.5. Specimen Made



Fig.6. Specimen Made

#### IV. RESULT AND DISCUSSION

##### A. Mechanical Test

The mechanical behaviour of composite materials is significantly influenced by the bonding at the fiber-matrix contact. The distribution of applied stress among the fibres is the matrix's primary role in polymer matrix composites. The interfacial bond strength is substantially responsible for the transverse and longitudinal shear strengths of a polymer matrix composite. The applied stress must be passed through the fiber/matrix contact. In order to realise the maximum strength of the reinforcing fibre, bonding must be maximised, necessitating proper interfacial bonding characterisation in composite materials. About 70% of current sales of advanced composites are used in aerospace applications. Sports equipment like tennis racquets and golf clubs has increased by another 27%.

Polymer matrix composites are used in the production of industrial and automotive equipment. Large military and commercial transport aircraft represent the next significant challenge for polymer matrix composites. In order to lighten the weight of commercial aeroplanes, polymer matrix composites are employed. In the manufacture of the car's body panels, drive shafts, and leaf springs are polymer matrix composites. They could also be appealing for maritime buildings because of their resistance to corrosion. Polymer matrix composites are being explored for the tubular structure of the NASA space station, and a variety of composite materials might be utilised in the planned aerospace plane for use in space. Research and Development Priorities In contrast to the majority of structural ceramics, polymer matrix composites have a stellar track record of service, notably in military aircraft.

##### B. Tensile Test

The Universal Tensile Testing Machine was used to examine the mechanical behaviour of the composites created from the manufactured samples. The testing load range was 5 Tonnes, and the gear rotation speed was 1.25, 1.5, and 2.5 mm/min. At typical room temperature, the trials were carried out. Using cutting machining, the test specimens were cut in accordance with ASTM requirements. a cross head seed speed of 1.25 mm/min and a typical gauge length of 50 mm were used to assess tensile strength in line with ASTM D638.

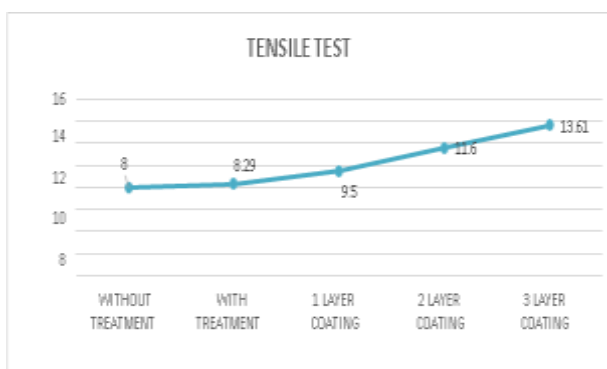


Fig.7. Comparison of tensile test of samples

##### C. Impact Test

According to ASTM D256 standard, using impact testing equipment from Izod, the composite specimens' resistance to impacts was evaluated. The specimen measured 67.5\*12.7\*3 mm with a 2.5 mm depth under the notch. The amount of energy a material can withstand before breaking is determined using the izod impact test, a high strain rate test that is standardised. This absorbed energy serves as a gauge for the toughness of a material and a tool for investigating temperature-sensitive ductile-brittle transition.

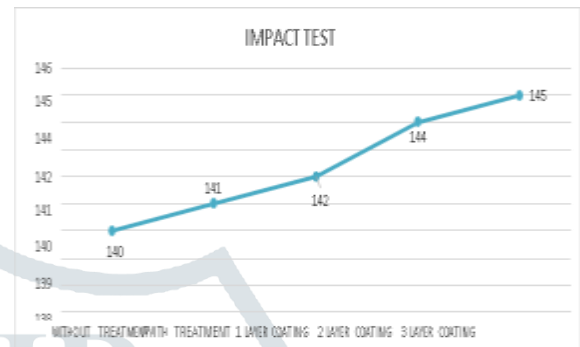


Fig.8. Comparison of impact test of samples

##### D. Flexural Test

With the use of three distinct loading scenarios, a beam's ability to bend is measured by the flexural test. The three point bending test was conducted according the requirements of ASTM D 790. The samples were divided into 50.8\*12.5\*3 mm pieces. Choosing components for portions that will support loads without inflection frequently makes use of the data. Flexural modulus is used to quantify a material's stiffness during bending. Testing materials at temperatures that resemble the environment they will be used in is acceptable since the physical properties of various components can change based on the ambient temperature.

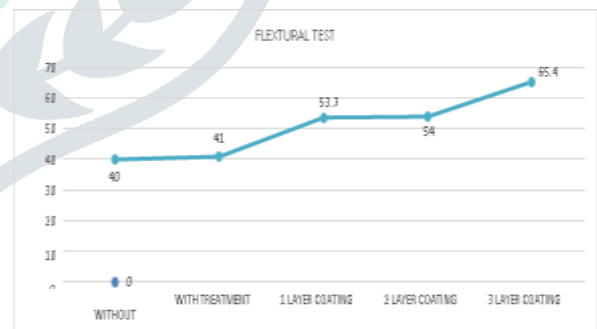


Fig.9. Comparison of flexural test of samples

##### E. Water Absorption Test

To estimate how much water will be absorbed in a specific circumstance, water absorption can be employed. Pre-dried samples (25\*25\*3 mm) were submerged in plain water, distilled water, and sea water independently at room temperature to measure the composites' water absorption. Accordingly, the impact of water absorption on composites reinforced with banana and sisal fibres was examined. The samples were dried for 24 hours at normal room temperature. The samples were weighed with a 0.001 precision.



The composite specimens were subjected to water absorption tests by being submerged in tap water and sea water in a plastic tub at room temperature during intervals of 14 days. After an interval of 14 days, the samples were carefully taken out of the water, blotted to remove any excess water on the surface, and then wiped with a dry, clean towel. The specimens were then weighed right away at 0.001g. By using the weight differential, the moisture absorption was estimated. For the same 14-day intervals, the % weight increase of the samples in both freshwater and seawater was assessed. By using the weight differential, the moisture absorption was estimated.

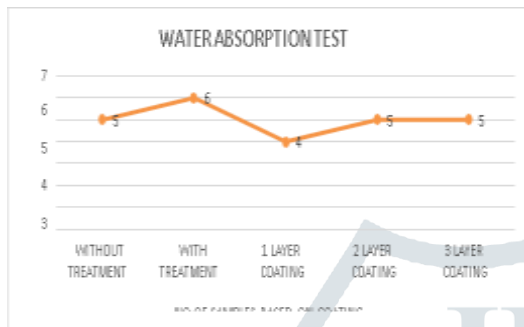


Fig.10. Comparison of water absorption test of samples

#### F. Hardness Test

The primary goal of the hardness test is to assess a material's fitness for a certain treatment. Always consider the type of indenter and its shape when evaluating the quantitative value of hardness. The ability to resist permanent deformation, piercing, indenting, and scraping depends on a material's hardness. Because it typically enhances resistance to wear from friction or erosion from moisture, fuel, and liquid, hardness is significant from an engineering perspective. The rock well hardness test is primarily a crucial test for harness testing in industry. Hardness testing is a great technique to find out if the component can handle the application's demands, which frequently need the material to survive excessive pressure or temperature. Testing for hardness is essential for quality control because of this.

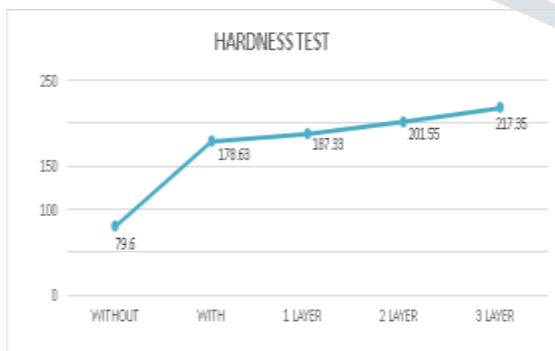


Fig.11. Comparison of hardness test of samples

## IV. CONCLUSION

Sisal fiber/*Cyperus pangorei* reinforced thermoplastic composites have had the effects of different factors including alkali treatment and fibre loading examined. The natural fibres, including sisal fibre (SF), have proven to be quite compatible with the matrix. The alkali-treated composite has a somewhat greater tensile strength than the untreated composite. The fiber/matrix interaction of natural fibres was enhanced by hydrogen peroxide treatment.

The bonding and mechanical strength of composite material are enhanced by the application of zinc phosphate coating. Natural fibre reinforced composites' mechanical properties were significantly impacted by the NaOH treatment, according to the findings of a tensile test. The examined composites' maximum tensile strength was attained with a fibre loading (weight fraction) of 25–30%.

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