

CHARACTERIZATION AND MECHANICAL PROPERTIES ALONG WITH SURFACE MODIFICATION OF NATURAL FIBER COMPOSITE

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering degree in Mechanical engineering.

by

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Accredited with Grade "A" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of GUMMADEVALLI GOPINATH (37150065) and IMMADI MOULI PREMCHAND (37150076) who carried out the project entitled "**CHARACTERIZATION AND MECHANICAL PROPERTIES ALONG WITH SURFACE MODIFICATION OF NATURAL FIBER COMPOSITE**" under my supervision from December 2020 to April 2021.

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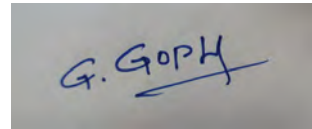
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DECLARATION

I Gummadavalli Gopinath (37150065) hereby declare that the Project Report entitled **“CHARACTERIZATION AND MECHAICAL PROPERTIES ALONG WITH SURFACE MODIFICATION OF NATURAL FIBER COMPOSITE”** done by us under the guidance of **Mr. R. SIVA, M.E., (Ph.D)** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Mechanical engineering

DATE: 01-04-2021

PLACE: Chennai

A rectangular box containing a handwritten signature in blue ink. The signature appears to be 'G. Gopinath' with a stylized underline.

SIGNATURE OF THE CANDIDATE

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ABSTRACT

Now a days the Natural fiber reinforced composites have received much attention because of their advantages like Light weight, Low cost, High porosity, Non-toxic, Non-abrasive, Greater specific stiffness, Specific strength, Better recyclable. Natural fiber has contributed tremendously efficient technology in automobiles and aero industries. Regards to this natural fiber a lot of research has been done all over the world because of its eco-friendly nature and has a unique property compare to synthetic fiber. The aim of this article is to provide appropriate as well as widely used natural fiber reinforced polymer composite and their applications. As further, it represents summary of various surface treatments applied to natural fibers and their effect on properties. This article reports the Extraction process of natural fiber, Characterization of natural fiber and preparation of natural fiber reinforced composite by using two-roll mill and compression molding. In the concentration of 15% fiber and 85% polylactic acid (PLA) for both treated and untreated composite and 100% of Pure PLA composite is are made. Comparing the treated and untreated composite with pure PLA composite through mechanical and morphological analysis and there has been a significant change in each and every composite. The Mechanical Properties are Tensile strength, Impact strength, Flexural strength. In tensile strength treated and untreated samples have shown 15% and 6% higher than composite made of only PLA. In flexural strength treated and untreated samples have shown 6% and 9% higher than composite made of pure PLA. In impact strength treated and pure PLA samples have shown 3% and 12% higher than composite made of untreated sample. There has been a significant change in Nano technology analysis are Scanned Electronic Microscope (SEM), X-Ray Diffraction (XRD), Fourier Transform Infra-Red spectroscopy (FTIR) and Thermo Gravimetric Analysis (TGA). The water absorption capability of the composites and its effect on mechanical properties also reported. It also concludes that chemical treatment of natural fiber will improve adhesion between fiber surface and polymer matrix.

TABLE CONTENTS

CHAPTER No.	TITLE	PAGE No.
	ABSTRACT	i
	LIST OF FIGURES	iv
	LIST OF TABLES	viii
	LIST OF SYMBOLS AND ABBREVIATIONS	ix
1	INTRODUCTION	1
	1.1 Natural Fibers	1
2	LITERATURE SURVEY	5
3	AIM AND SCOPE	10
	3.1 Aim	10
	3.2 Scope of the project	10
4	MATERIALS AND METHODS	11
	4.1 Materials Required	11
	4.2 Methodology	11
	4.2.1 The Production of fiber	11
	4.2.1.1 Untreated fiber	12
	4.2.1.2 Treated fiber	12
	4.2.2 Sample Preparation	14
	4.2.2.1 Blending	14
	4.2.2.2 Compression	16
	4.2.3 Analysis	18
	4.2.3.1 Tensile Strength	18
	4.2.3.2 Flexural Strength	19

	4.2.3.3 Impact Strength	20
	4.2.3.4 SEM Analysis	21
	4.2.3.5 TGA	22
	4.2.3.6 XRD	22
	4.2.3.7 FTIR	23
	4.2.3.8 Water Absorption	24
5	RESULTS AND DISCUSSION	25
	5.1 Tensile Strength	25
	5.2 Flexural Strength	30
	5.3 Impact Strength	36
	5.4 SEM Analysis	39
	5.5 FTIR Analysis	40
	5.6 XRD Analysis	41
	5.7 Water absorption	43
	5.8 Thermo Gravimetric Analysis	45
6	SUMMARY AND CONCLUSION	47
	REFERENCES	49
	APPENDIX	56

LIST OF FIGURES

FIGURE No	TITLE	PAGE No.
1.1	Process cycle of the project	4
4.1	Cissus quadrangularis	11
4.2	Untreated fiber washed with distilled water	12
4.3	NaOH Chemical	13
4.4	Fiber treated with NaOH chemical	13
4.5	Removing the moisture present in the fiber using hot chamber	14
4.6	Preparation of PLA and CQ fiber sheets using two roller machine	15
4.7	Extraction of PLA and CQ fiber into sheet form	15
4.8	Compression moulding	16
4.9	Mould plates with PLA	16
4.10	PLA composite	16
4.11	Untreated CQ fiber + PLA composite	16
4.12	Treated CQ fiber + PLA composite	17
4.13	Tensile, flexural and impact samples of PLA composite	17
4.14	Tensile, flexural and impact samples of treated CQ fiber composite	17
4.15	Tensile, flexural and impact samples of untreated CQ fiber composite	18

FIGURE No	TITLE	PAGE No.
4.16	Tensile strength apparatus	19
4.17	Flexural strength apparatus	20
4.18	Izod impact apparatus	21
4.19	SEM apparatus	22
4.20	Thermogravimetric apparatus	22
4.21	XRD apparatus	23
4.22	FTIR apparatus	24
4.23	Heating of water absorption samples	24
5.1	Tensile samples of pure PLA	25
5.2	Tensile samples of untreated CQ fiber composite	26
5.3	Tensile samples of treated CQ fiber composite	26
5.4	Comparison of tensile strengths of three composites	28
5.5	Average of three composites tensile modulus of elasticity	29
5.6	Average of three composites tensile elongation	30
5.7	Flexural samples of pure PLA composite	31
5.8	Flexural samples of PLA + untreated CQ fiber	31

FIGURE No	TITLE	PAGE No.
5.9	Flexural samples of PLA + treated CQ fiber composite	32
5.10	Comparison graph of flexural strengths of three composites	34
5.11	Flexural modulus of elasticity	34
5.12	Flexural elongation	35
5.13	Impact samples of pure PLA	36
5.14	Impact samples of PLA + untreated CQ fiber composite	36
5.15	Impact samples of PLA + treated CQ fiber composite	37
5.16	Comparison of impact results of three composites	38
5.17	SEM analysis of broken side of high tensile sample	40
5.18	FTIR analysis of treated CQ fiber	41
5.19	FTIR analysis of untreated CQ fiber	41
5.20	XRD spectrum of treated CQ fiber	42
5.21	XRD spectrum of untreated CQ fiber	43
5.22	Water absorption characteristics in distilled, sea and normal water	44

FIGURE No	TITLE	PAGE No.
5.23	TGA with DSC curve of NaOH treated CQ fiber powder	45
5.24	TGA with DSC curve of untreated CQ fiber powder	46

LIST OF TABLES

TABLE No	TITLE	PAGE No.
5.1	Pure PLA composite	
	tensile strength results	27
5.2	PLA + untreated CQ fiber composite	
	tensile strength	27
5.3	PLA + treated CQ fiber composite	
	tensile strength	28
5.4	Pure PLA composite	
	flexural strength	32
5.5	PLA + untreated CQ fiber composite	
	flexural strength	33
5.6	PLA + untreated CQ fiber composite	
	flexural strength	33
5.7	Impact strength of pure PLA samples	37
5.8	Impact strength of PLA + untreated	
	CQ fiber samples	38
5.9	Impact strength of PLA + treated	
	CQ fiber samples	38

LIST OF SYMBOLS AND ABBREVIATIONS

PLA	Polylactic Acid
CQ	Cissus Quadrangularis
CQT	Cissus Quadrangularis Treated
CQUT	Cissus Qaudrangularis Untreated
W_t	Weight of the sample after time t
W_0	Oven dry weight of the sample
MPa	Mega Pascals
I_c	Crystalline index
XRD	X-Ray Diffraction
TGA	Thermo Gravimetry
FTIR	Fourier Transform Infrared Spectrum
SEM	Scanning electron microscope
PLAD	PLA Distilled Water
PLAW	PLA Normal Water
PLAS	PLA Sea Water
CQTD	Treated Distilled Water
CQTW	Treated Normal Water
CQTS	Treated Sea Water
CQUTD	Untreated Distilled Water
CQUTW	Untreated Normal Water
CQUTS	Untreated Sea Water

CHAPTER 1

INTRODUCTION

1.1 Natural fibers

Natural fibers play an essential role in the present generation. These are biodegradable content, which is having less cost and by using fewer human resources. To use instead of synthetic fibers/artificial fibers, we can use natural fibers. In these natural fibers, there are different types of fibers and they have chosen the plant fibers. In-plant fibers, there are five types of fibers. They are

- Wood
- Stem
- Leaf
- Seed
- Grass

In these, we selected the stem fiber. The *Cissus Quadrangularis* have both leaf fiber and stem fiber, but due to the high tensile strength properties, we have chosen the stem fiber as *Cissus Quadrangularis*. Due to it has having wax properties and lignin properties. It has high mechanical properties.

Cissus Quadrangularis reach a height of 1.5 m (4.9 ft.) and has quadrangular-sectioned branches with internodes 8–10 cm (3–4 in) long and 1.2–1.5 cm (0.5–0.6 in) wide. Along each angle is a leathery edge. Toothed triode leaves 2–5 cm (0.8–2.0 in) wide appear at the nodes. Each has a tendril emerging from the opposite side of the node. Racemes of small white, yellowish, or greenish flowers, globular berries are red when ripe. *Cissus Quadrangularis* an evergreen climber growing to 5 m (16 ft) by 5 m (1.6 ft) fast. It is hardy to zone (UK) 10. Suitable for light (sandy), medium (loamy), and heavy (clay) soils, prefers well-drained soil and can grow in nutritionally poor soil. Suitable pH: acid, neutral, and basic (alkaline) soils can grow in very acid and very alkaline soils. It cannot grow in the shade. It prefers dry or moist soil and can tolerate drought.

The *Cissus quadrangularis* is a perennial plant of the grape family. the plant must be aged to get stronger fiber. If we choose the baby plant, it has only a little stronger fiber and fewer mechanical properties. But to the aged one, we have the high mechanical properties fibers. The *Cissus quadrangularis* has a length of 1m to

3m of length and is negatively named Prandial, which is available in the hilly region and Kattur of Kanchipuram district Tamil Nadu state. The CQ composites having high- potential characters of both mechanical and thermal properties. If the CQ had with polymer and formed a polymer composite and the matrix had a more excellent range of properties.

The serviceability of polymer-based composite has expanded day by day. The natural fiber-reinforced composites have various industrial applications such as automobile, construction, and aerospace industries. They are highly appreciated and supported by research on natural fibers because of their advantages like ease fabrication, high strength to weight ratio, complex shape, less weight, low cost, etc.

Fiber is a pollution-free material as they release less level of gases that are harmful to the environment. So far, many natural fibers have been tried for their fitness to be utilized for making solid composite structures and detailed in the literature survey. For investigating the suitability of natural fibers to be used as a better reinforcement medium in making the new natural composite. The fibers are already subjected to several experimental analyses such as mechanical property, chemical composition, physical property, thermal stability, crystalline property and morphological analysis, Strength, reinforcing efficiency. Synthetic fibers are like glass fiber, carbon fiber, ceramic fiber, aramids are costly and rescue to health in exposure condition, and These are opposed to natural fibers.

Natural fibers are biodegradable. They are obtained from nature. The natural fibers are equally suitable for the environment. They are 100% biodegradable and compostable. The natural fibers are used as composite material where the orientation of fibers impacts the properties. Natural fibers are matted into sheets. Most natural fibers are known as an absorber of water and other liquids. These are having advantages like Low density, Low cost, High porosity, Non-toxic, Non-abrasive, Greater specific stiffness, Specific Strength, more resistance to corrosion, Better recyclable, Large fatigue strength, more impact absorption capacity, Lower toxicity, Plentiful availability, recyclability, can overrule the usage of synthetic fiber composite, Human welfare in handling, Lightweight. The current work aims to characterize the natural fibers are collected from the stem of a plant. This fiber is available near our residential area, and our reference from the

paper is seemed to have better Strength and therefore to check suitability of fiber as better is the alternative method has reported the experiments, we have performed on a natural fiber is written in this article. Whatever the studies we have been reported are the Extraction process, Making the fiber into short size by cutting through a length less than 4mm and performing the chemical treatment. We have selected sodium hydroxide (NaOH) and completed the therapy. After that, we have done The Mechanical Properties are Tensile Strength, Impact strength, Flexural Strength.

Morphological analysis is SEM, XRD, FTIR, and TGA and water absorption test. There are two types of polymer thermosetting and thermoplastic polymers. In the thermosetting polymer, it has constraints about the harder like epoxy, etc. The thermoplastic polymers like PLA depend upon the fibers' cutting length they would be treated. The thermosetting polymer would be treated for the long length fibers, and with the shorter length the thermoplastic polymer. The *Cissus quadrangularis* has taken due to its high mechanical properties. In the previous natural fiber, the polylactic acid granules (2003D) taken from the nature tech Pvt. Ltd. It is suitable for two roller mill at a temperature of 155°C to 170°C and must be stored at room temperature.

The thermosetting polymer and thermoplastic polymers have very different properties. The primary physical difference is that thermoplastics can be melted back into a liquid, whereas thermoset is always remaining in a permanent solid-state. In general, thermoset products are made through the molding process then the liquid polymers and other agents are injected into a mold cavity. As the material cools and hardens to the configuration of the cavity it goes to the curing process.

Thermoplastics are organic materials that melt when heated they are formed in a viscous phase this generally means they are heated, formed then cooled in their final shape. Thermoplastics are used due to the soften when heated are easy to mould into a variety of shapes and also lend themselves to recycling. common uses for thermoplastics polymers include the fabrications of pipes, ropes, belts, insulators. The melting point of thermoplastic polymers is quite low only 58°C to 60°C so it can be melted in hot water and moulded by hand. It can also be cut or

extruded safe and biodegradable. Most thermoplastics have a high molecular weight.

The polymer chains associate with intermolecular forces which weaken when increasing temperature. They are with fibers are associated with their high cellulose content though tiny portions are being used in the field of feedstock and energy production bio-composites have amplified industrial usage that would release the possibilities to minimize the wastage of renewable materials. It promotes a non-food-based market for the agricultural industry. It is white, smooth, and glossy as silk, medium-length fiber with high tensile Strength. It has a softer surface than other natural fibers and it absorbs and maintains a good colour. Process cycle of project is shown in figure 1.1.

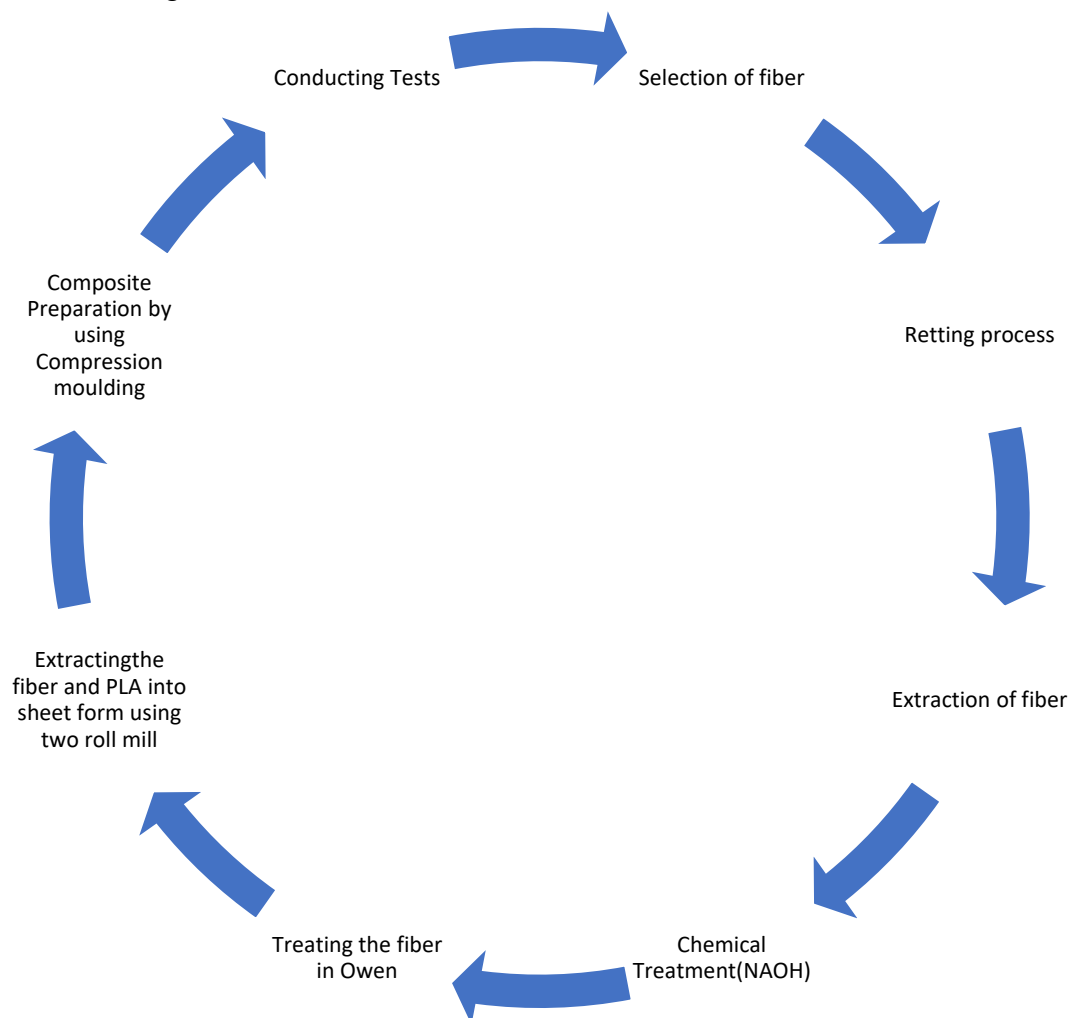


Fig:1.1 : Process cycle of the project

CHAPTER 2

LITERATURE SURVEY

Mayandi et.al., (2015). It declares about how the fiber is extracted from the stem of the *Cissus quadrangularis* plant by retting process at a period of 25 – 30 days, and extracted fiber is dried under sunlight for 48 – 72 hours. After that it tells about the fabrication of a composite through compression moulding by pre-heating the fiber in a hot chamber at a 100°C for 2 – 3 hours. Accordingly, the Morphological analysis of a composite performs a SEM analysis to study the interaction between matrix and fiber because interfacial bonding is a critical factor in deciding the mechanical strength of a composite. Tensile strength not only depends on adhesion, but it also depends on the number of interfacial regions on it.

Indran et.al., (2014). It declares the chemical property of fiber, which contains the cellulose and hemicellulose of the *Cissus quadrangularis* plant's lignin contents determined by using standard procedure. The procedure continued the treating the fiber in a hot chamber at 100°C to remove the moisture content, and also tells about the density of fiber which was determined by a liquid immersion test. The density of fiber is low, around 1.24 g/cm³. It also discussed the TGA of fiber to determine fibers thermal stability in a Powder form to know the nature of fiber after treating on an oven at a temperature of 250°C. After completing the process, declares that fibers nature is cellulose or hemicellulose for both treated fiber and untreated fiber.

Nikunj Patel & Piyush Jain (2020). It declares that the randomly oriented natural fiber is in omnipresent in structural material because this type of fibers is ease to manufacture and good mechanical property. This fiber is short in length and gives very accurate estimation for a mechanical property. And also discussed about different combinations of short fiber with reinforced plastic and their resultant mechanical behaviour in according to the composition of plastic and fiber in a composite preparation, and referred about the mechanical property of an impact strength and tensile strength of a short natural fiber. Where the measurement of force required to break the specimen and when tensile property will react to material

and the load is applied to the tension. Impact strength will increase along with increasing length of the fiber and distribution of impact energy occurs at high speed.

Sanjay et.al., (2019). It declares about comprehensive review of techniques for natural fibers as reinforcement in composites, preparation, processing and characterization. It used as common techniques for natural fibers as composites and explains about the chemical treatments and extraction methods and surface treatment.

Gaurav et.al, (2019). It declares the actual methods in making a composite like polymer matrix, metal matrix and ceramic matrix composite. It has particulate reinforced composite because the particles are non-fibrous and having no long dimensions. These particles are used to enhance properties of matrix materials. It improves the thermal conductivity, wear resistance and abrasion resistance. The polymer composite formed by incorporation fiber into polymer matrix. It provides high strength and stiffness to composite. These are classified as thermosetting and thermoplastic. From this the fiber reinforced composite also prepared by embedded fiber into matrix, here matrix bind with fiber and load transferred to fiber. Matrix protects from environment and damage due to handling it also reaches strength as conventional material.

Baumbach, et.al., (2020). It declares that composite material selection is fabricated from their information jute or flax with epoxy resin. It has the most effective layout of stiffness with regards to section strength. It was noted adding flange edge stiffeners to channel sections significantly increased the maximum stress. The channels were fabricated by hand layup method and machine compressing method. In hand layup method the resin is applied with brush and roller on a fabric laid over a split mandrel and extracting after curing. In machine compressing the composite material is placed on split mandrel and applying load on mandrel at certain temperature and extracting composite after curing.

Arun Kumar et.al., (2020). It declares the basic information about mechanical properties of a fiber and basic procedure of a mechanical properties and discussed about Tensile strength, Flexural strength and Impact strength. The tensile test sample is taken from a fabricated composite as per the American standard for testing and material (ASTM) standard dimension and tensile strength of laminate was measured by ASTM with the help of Universal Testing Machine (UTM) with load capacity of 400KN for load rate of 5mm/min. The flexural test is carried out by three-point bend testing as specified in ASTM using UTM at a room temperature. Study of impact strength is carried out by using Geotech Testing Machine (GTM) and notch is kept at an angle of 90° and tested at an ambient condition according to ASTM and average load is noted and also the strength and resistance is noted.

Sudhir Chakravarthy et.al., (2020). It declares the extraction of fiber, chemical treatment and thermal stability analysis. TGA with differential scanning calorimeter (DSC) curves obtained from analysis are used to determine the thermal stability of various chemical constituents present in the fiber. A dried *Cissus quadrangularis* powder of 10mg was taken in alumina crucible and kept in a thermal analyser. The temperature inside the thermal analyser is increased to 10°C per minute from atmospheric temperature to 600°C.

Siva et.al., (2020). It declares about SEM analysis. It scans the tiny particles can examine the bonding of resin and fiber in the matrix of composite. The highest number of valued tensile samples used for SEM analysis for composite, and they are cut down for small pieces as required for Tensile samples because of its higher breaking stress and bond between them and determine the particle size up to 10nm and magnification from 20x to 100x.

Saravana Kumar et.al., (2019). It declares about the potential value *Cissus quadrangularis* over the synthetic fibers. Because the *Cissus quadrangularis* having a crystalline structure as same the synthetic fibers. *Cissus quadrangularis* is stem fiber (CQSF), have proven thermomechanical properties for polymer composite

reinforcement. Increase in fiber–matrix bonding through chemical treatments such as mercerization and deposition of cotton linters-based microcrystalline cellulose powder on fiber surface are comprehensively investigated. In particular, 5 wt.% cellulose powder-treated polyester composites showed distinguishable enrichment in mechanical and water absorption characteristics.

Jayaprakash et.al., (2019). It declares about the mechanical properties of natural fiber/particulate reinforced epoxy composites, it clearly explained about the fiber Composites and their reaction with epoxy resin. Declares about different type of natural fiber composite with epoxy has their thermo setting polymer and properties of each one has described, mechanical strengths like tensile, impact and flexural test were done on different types of natural fibers with epoxy.

Balaji et.al, (2020). It declares about methodology of making the composite on a compression moulding process. The compression moulding machine need to get a temperature of 200°C and after heating the plates at a 200°C remove the mould plates from the machine and applying a wax removal to get a composite sheet ease removal and placing the fiber in a mould plate and compressing the plates at a range of 40MPa for 20 – 30 min and cool the plates by using water coolant, wait until the temperature reaches to 100°C and after reaching remove the plates and apply load on a plate. After few minutes take composite from out of the mould plates and kept in a room for 24 hours in a normal humidity.

Thomas et.al., (2004). It declares the epoxy resin has excellent properties like adhesion, strength, low shrinkage, corrosion protection, and many other properties. Although it is expensive resin, its mechanical and chemical properties are very good. Natural fibers like jute, flax, sisal, and bamboo fiber with epoxy reinforced have been studied. In case of pineapple nanofiber there is no work done yet. The alkalization process makes the fibers surface rough and improved mechanical hold. A rough surface improves the affinity of epoxy matrix and interfacial adhesion made strong due to deposition of generally green composites also known as biopolymers

reinforced with natural fiber that are more environmentally friendly compared to fiber reinforced plastics. Other than that, green composites are also widely used in application range thus contribute the rapidly growth of composite industry.

Li Zhao et.al., (2020). It declares the morphological analysis of XRD and FTIR. Here XRD mainly used to determine the crystalline structure of a molecules such as average diameter of crystalline (La) average height of crystalline (Lc) and inter – layer spacing (d002). The sample is turned into powder and scanned from 2° to 80° in 2θ range and a broad region between 10° and 35° and a small peak near 40°. The FTIR test scanning range was 4000 cm^{-1} to 400 cm^{-1} , the scanning resolution was 4 cm^{-1} and the number of scans is 32 times. The parameters of peak width, height and areas are obtained.

CHAPTER 3

AIM AND SCOPE OF THE PROJECT

3.1 Aim

This project's main intention is to compare the PLA composite, PLA with untreated natural fibre composite and PLA with treated fibre composite.

- To prepare PLA composite, PLA with untreated fibre and PLA with treated fibre using a compression moulding machine.
- To compare the mechanical and physical properties of three composites.
- To determine the tensile strengths, flexural strengths, impact strengths of three composites.
- To study the SEM structure of the composite.
- To analyse the conditions of the composite under XRD, FTIR and TGA.
- To study the water absorption properties.

3.2 Scope of the project

Instead of synthetic and glass fibre, using natural fibre is the best alternative way. Because of the usage of glass and synthetic fiber, environmental pollution will happen. Whereas using natural fibre will be eco-friendly, and the natural fibre cost is less compared to synthetic fibre. Manufacturing the natural fibre composite is also easy. This research will help us to reach the properties of composites.

CHAPTER 4

MATERIALS AND METHODS

4.1 MATERIALS REQUIRED

Cissus quadrangularis fiber, PLA 2003D, NaOH

4.2 METHODOLOGY

The methodology of this project is divided into several stages

- The production of fiber
- Sample preparation
- Analysis

4.2.1 *The production of fiber*

The *Cissus quadrangularis* plant has been collected from the hilly region. Which is located at Kattur, Kanchipuram District, Tamil Nadu state. The plant must be clean, as shown in figure 4.1



Fig:4.1 : *Cissus quadrangularis*

After collecting the plant, all roots of the plant should be removed and by taking a wooden hammer gently force is applied across the *Cissus quadrangularis*. After that these are dipped in the bucket with normal water by retting process for 25 to 30 days.

After that, the biological waste is removed from the top of the bucket by wearing gloves and the wet fiber is extracted from the plant. These wet fibers are cleaned well with clean water. After cleaning this fiber is sun dried for 3 to 4 days, after drying we have to seal the fiber by keeping it in a plastic bag.

For preparation of natural fiber composite the fiber is divided into two types they are treated fiber and untreated fiber.

- Untreated fiber
- Treated fiber

4.2.1.1 Untreated Fiber

For the preparation of untreated *Cissus quadrangularis* fiber, as name itself explains the meaning. The fiber is cleaned well with distilled water and distilled water is rinsed with a cloth. As shown in figure 4.2



Fig:4.2 : Untreated fiber washed with distilled water

After rinsing the distilled water, the fiber is placed in a beaker and heated in the hot chamber for 2 hours at 100°C as shown in the figure 4.5

4.2.1.2 Treated Fiber

For the preparation of treated fiber. *Cissus quadrangularis* fiber is treated with 15% of NaOH chemical in figure 4.3 mixed in the distilled water (fiber to water ratio 1:10). The fiber is kept for an hour in chemical water in figure 4.4, later it was washed well for 2 to 3 times with normal water and once with distilled water. After rinsing water, the fiber is collected in a bowl and then heated in a hot chamber for 2 hours at 100°C as shown in figure 4.5

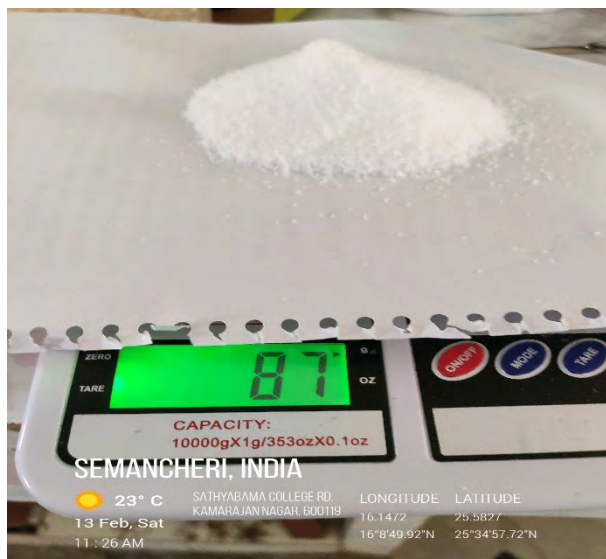


Fig:4.3 : NaOH chemical

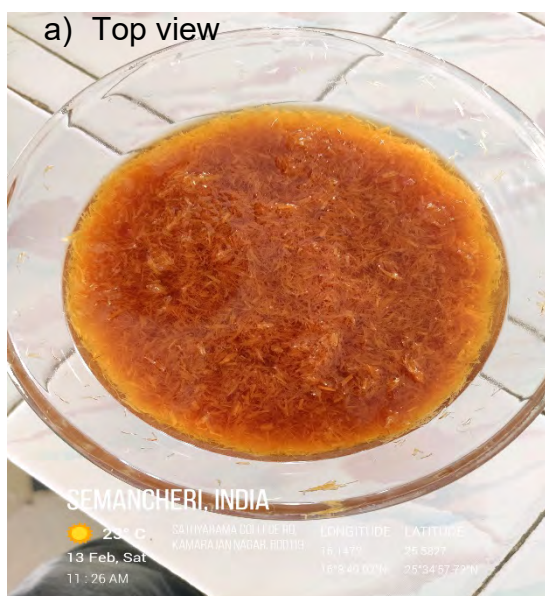


Fig:4.4 : Fiber treated with NaOH chemical

Now both the treated and untreated fibers are kept in a beaker and then heated in a hot chamber at 100°C for 2 hours to remove complete moisture. After heating the fiber it is sealed in the plastic bag without exposing it to air to prevent erosion.



Fig:4.5 : Removing the moisture present in the fiber using hot chamber

4.2.2 Sample Preparation

For the preparation of natural fiber composite, PLA granules (2003D) which are purchased from Naturtec Pvt.ltd, these PLA granules are suitable for compression moulding process at a temperature of 190°C to 200°C this composite preparation process is divided into two stages.

- Blending
- Compression

4.2.2.1 Blending

In this blending process which is held at Kelvn labs, Hyderabad, Telangana. Both polylactic acid granules and fiber are blended into a sheet by using Two roller machine. At a temperature between 150°C to 160°C. Two roller machine is used to prepare polylactic acid and fiber compounds, figure 4.6



Fig:4.6 : Preparation of PLA and CQ fiber sheets using two roller machine

After preparing PLA and CQ fiber sheets, using two roller machine at a temperature 150°C to 160°C it is then removed as shown in figure 4.7.



Fig:4.7 : Extraction of PLA and CQ fiber into sheet form

4.2.2.2 Compression

In this stage of preparation, the blended sheets will be compressed using compression moulding machine figure 4.8. First compression moulding machine turned on and set at a temperature of 200°C , after 5 minutes the moulding plates($150 \times 150 \times 3\text{mm}$) figure 4.9 are inserted into the machine and heated for 10 minutes after heating mould release wax is applied to these plates.



Fig:4.8 : Compression moulding

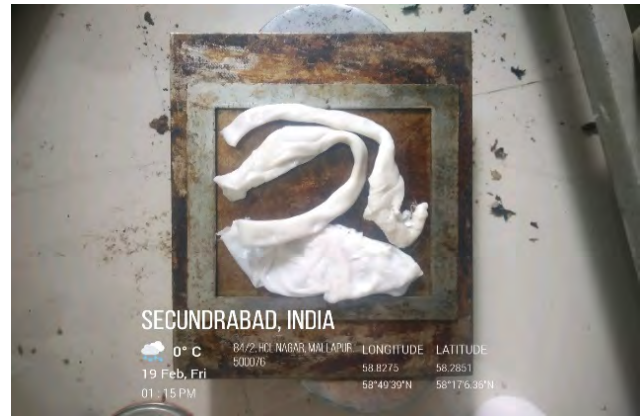


Fig:4.9 : Mould plates with PLA

After compressing it for 30 to 40 minutes temperature is decreased using water colling system after decreasing the temperature from 200°C to below 100°C these compression mould plates are removed and the composite is removed in the same way three composites plates were prepared of dimensions 150×150×3mm.

- Only polylactic acid
- Polylactic acid with untreated CQ fiber
- Polylactic acid with treated CQ fiber

As shown in figure 4.10, 4.11, 4.12.

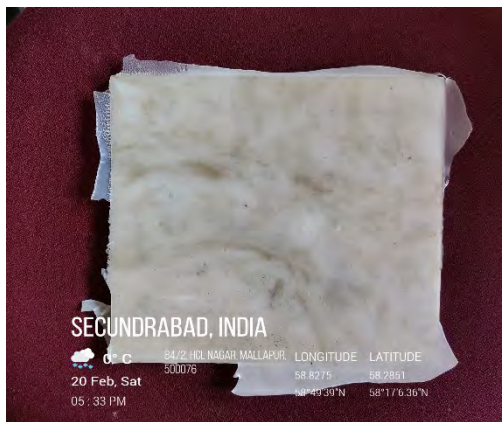


Fig:4.10 : PLA Composite

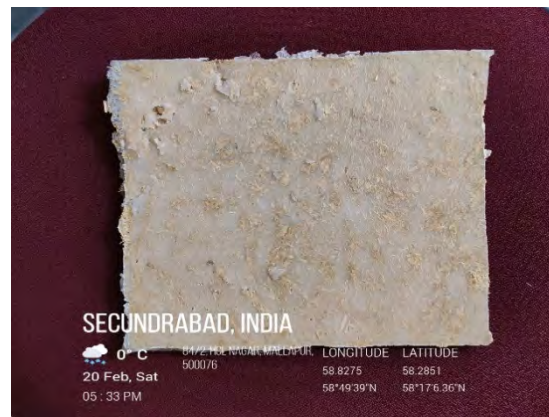


Fig:4.11 : Untreated CQ fiber + PLA composite

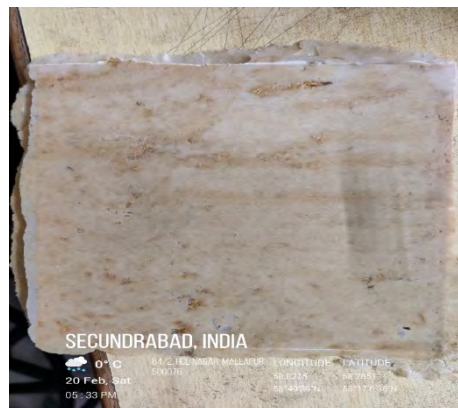


Fig:4.12 : Treated CQ fiber + PLA composite

After preparing the composite plates by using the compression moulding machine. Tensile, flexural and impact samples were made from these composite plates as shown in figure 4.13, 4.14, 4.15.

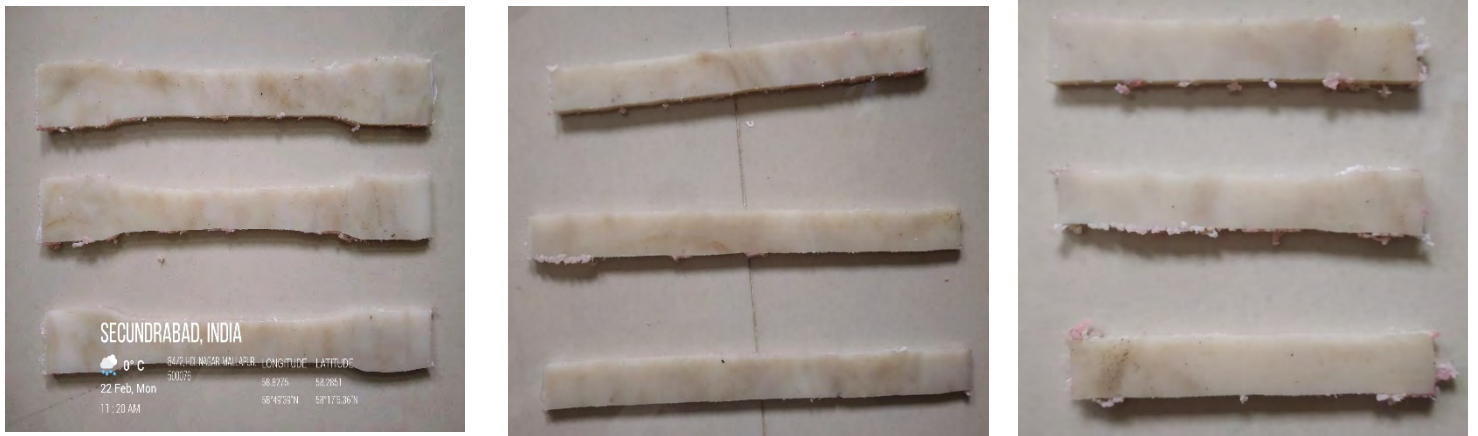


Fig:4.13 : Tensile, flexural and impact samples of PLA composite

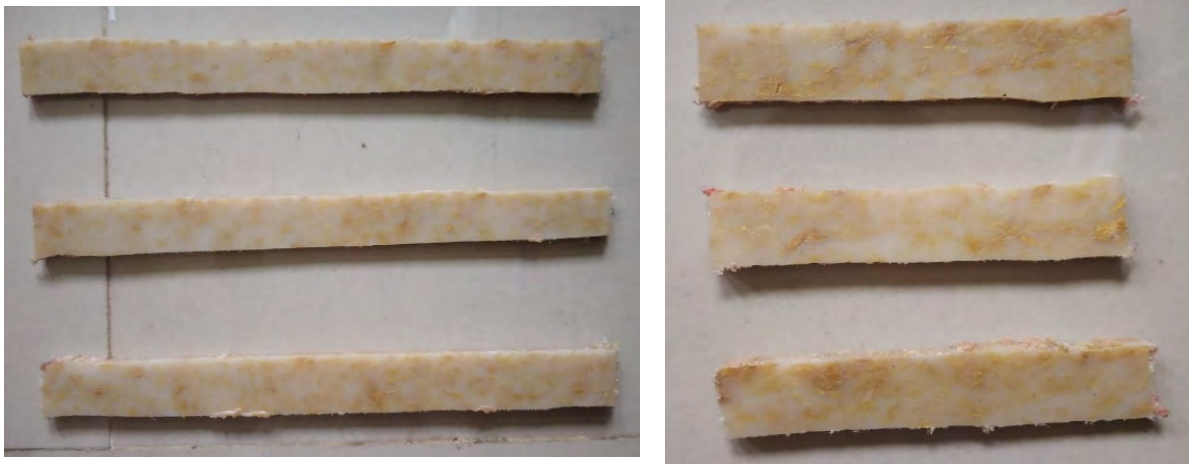
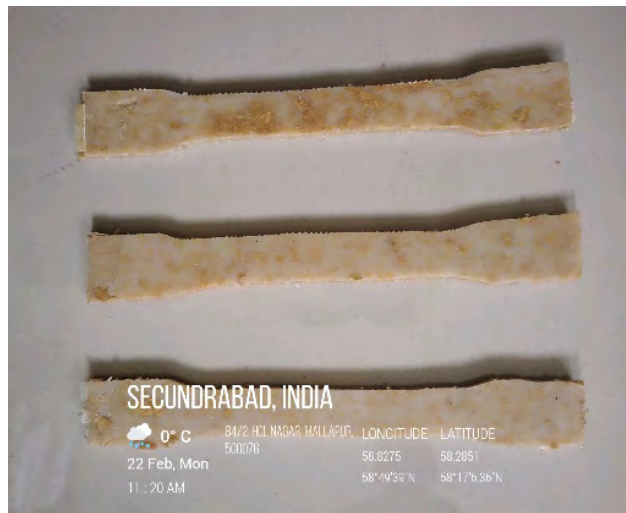


Fig:4.14 : Tensile, flexural and impact samples of treated CQ fiber composite



Fig:4.15 : Tensile, flexural and impact samples of untreated CQ fiber composite

4.2.3 Analysis

In this project Mechanical properties, physical properties along with morphological analysis are done. Mechanical properties like Tensile, Flexural and Impact. Physical properties like SEM, morphological analysis like XRD, TGA, FTIR and also Water absorption is done.

4.2.3.1 Tensile Strength

The maximum load a material can bear without breakage when being stretched, divided by the original cross-sectional area of the material. It has dimensions of force per unit area. When the stresses are less than tensile strength is removed and the material reaches to its original shape and size either completely or partially. If stress reaches the value of tensile strength, however if the material is ductile than it has already begun to flow rapidly forms a constricted region called neck, where it fractures. The test is carried out as per the ASTM D3039 the testing process includes the mounting in a machine and exposing to pressure in testing machine and afterwards applying strain to it until it breaks. The ductile power is recorded as element of expansion in check length during utilization of strain and

prolongation of measured area is recorded in versus to applied power. The test is performed on Universal testing Machine with load capacity of 400KN for the load rate of 5mm/min.



Fig:4.16 : Tensile strength apparatus

4.2.3.2 Flexural Strength

It informs about the resistance of a material against deformation. It indicates how much force is required to break a test sample of a defined diameter. The higher the value the more impacting forces the material is able to withstand. The purpose of flexural test is to measure the strength and modulus of a flexural sample, the flexural strength is defined as maximum stress at outermost fiber on either compression or tension side of specimen. The flexural strength is calculated from below equation

$$\sigma_f = 3pl/2bd^2 \text{ ----- (1)}$$

Flexural modulus is calculated from slope of the stress vs strain in deflection curve. the equation is

$$E_f = L^3m/4bd^3 \text{ ----- (2)}$$

The flexural strength is carried out at a room temperature through three-point bend testing as specified in ASTM D-790, using instron model 5582 in Universal Testing Machine. The speed of the cross head is 2mm/min



Fig:4.17 : Flexural strength apparatus

4.2.3.3 Impact Strength

Impact strength is the capability of a material to resist an instantly applied load and its expressed in terms of energy. It also measured in Izod impact strength and Charpy impact strength. It determines the amount of energy was absorbed by a material during fracture. The absorbed energy is a measure of materials toughness and brittleness and ductile transition. The temperature is lowered over a series of tests to indicate the brittle temperature of a material. Before starting the Izod impact test the sample is notched at a GTM Model-7045 MD after making a notch at an angle of 90 degrees and carried out the test on Izod impact tester. The impact strength is calculated from Impact strength and impact resistance of a sample



Fig:4.18 : Izod impact apparatus

In physical properties we had done scanning electron microscope analysis to study about the bonding between the fiber and polylactic acid at the broken part of the composite material. It is done by using scanning electron microscope. And also using this analysis we can also study how the fiber is mixed with the polylactic acid

4.2.3.4 SEM Analysis

It scans the tiny particles can examine the bonding of resin and fiber in the matrix of composite. The highest number of tensile valued samples are used for SEM analysis for composite and they are cut down for small pieces as required for Tensile samples because of its higher breaking stress and bond between them and also determine the particle size up to 10nm and magnification from 20x to 100x. It scans the sample with an electron beam to produce a magnified image for analysis after we get a visual analysis of surface contributes to identification of contaminants or unknown particles, the cause of failure and interaction between materials and also used to obtain information about surface topography and composition.

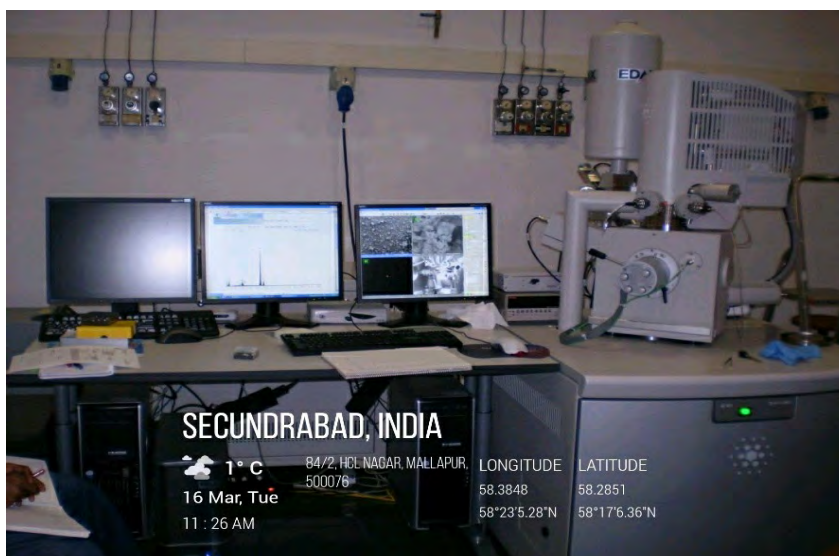


Figure:4.19 : SEM apparatus

4.2.3.5 TGA

TGA and DSC curves obtained from analysis we used to determine the thermal stability of various chemical constituents present in the fiber. A dried *Cissus quadrangularis* powder of 10mg was taken in alumina crucible and kept in a thermal analyser. The temperature inside the thermal analyser is increased to 10°C per minute from atmospheric temperature to 600°C with these conditions observe the change that occurs in sample in furnace and weight is measured on analytical balance that remains outside of the furnace.



Fig:4.20 : Thermogravimetric apparatus

4.2.3.6 XRD

XRD mainly used to determine the crystalline structure of a molecules such as average diameter of crystalline (L_a), average height of crystalline (L_c) and inter – layer spacing (d_{002}). The sample is turned into powder and scanned from 2 to 80

degrees in 2θ range and a broad region between 10 and 35 degrees and a small peak near 40 degree. Three fitting peaks can be obtained, which are γ peak fitted near 20° , (002) peak fitted near 26° and (100) peaks fitted around 40° . The peak positions, intensities, full width half maximums (FWHM), areas were determined.



Fig:4.21 : XRD apparatus

4.2.3.7 FTIR

FTIR is used to identify compounds such as compounded plastics, fillers, rubbers and resins. It identifies the chemical bonds in a molecule producing an infrared absorption in spectrum. It is rapid and non-destructive method that can detect range of functional groups and is sensitive to change molecular structure. It provides information on basis of chemical composition and physical state of whole sample. The FTIR test scanning range was 4000 cm^{-1} to 400 cm^{-1} , the scanning resolution was 4 cm^{-1} and the number of scans were 32 times. The parameters of peak width, height and areas are obtained.



Fig:4.22 : FTIR apparatus

4.2.3.8 Water Absorption

In this water absorption test composite plates are cut into small pieces of dimensions 20×20mm and these composites are heated in oven at 100°C for 5 minutes so that the moisture present on the top of the sample will evaporate. After heating weight of the samples is noted and dipped in three different water like normal water, sea water and distilled water. These composite plates are observed in water for 120 hours and weight gain is calculated by using the below equation

$$W (\%) = ((w_t - w_0) / w_0) \times 100\% \text{ ----- (3)}$$



Fig:4.23 : Heating of water absorption samples

CHAPTER 5

RESULTS AND DISCUSSION

In these results are discussed of the tests we have done on the composite materials like Tensile, Flexural, Impact, SEM, XRD, FTIR, TGA, and Water absorption test these are represented either by using bar graphs, pie charts or pictorial representation.

5.1 Tensile Strength

This tensile strength test is performed at KELVN Labs, Hyderabad, Telangana. By using universal testing machine. The dimensions of the samples are 125×14×3mm as shown in the figure 5.1



Fig:5.1 : Tensile samples of pure PLA

These are the tensile samples after testing the tensile strength. The composition of this composite is 100% PLA 0% Fiber with dimensions of 125×14×3mm are shown in this picture.



Fig:5.2 : Tensile samples of untreated CQ fiber composite

In this figure 5.2 the tensile samples of untreated CQ fiber composite are shown, the dimensions of these samples are 125×14×3mm the composition of these samples are 85% PLA and 15% of fiber.



Fig:5.3 : Tensile samples of treated CQ fiber composite

In this figure 5.3 the tensile samples of treated CQ fiber composite are shown, the dimensions of these samples are 125×14×3mm the composition of these samples are 85% PLA and 15% of fiber.

Table 5.1 : Pure PLA composite tensile strength results

Sample No	Tensile Strength (N/mm ²)	Modulus of elasticity (N/mm ²)	Elongation (%)
Sample 1	49.15	169.44	3.15
Sample 2	45.58	481.94	2.73
Sample 3	61.16	960.11	3.16

Table 5.1 gives us the tensile strength results of the pure PLA along with modulus of elasticity and elongation. Average value of pure PLA tensile strength is 51.96 ± 8.16 N/mm², average of modulus of elasticity is 531.16 ± 398.21 N/mm² and average of elongation is $3.01 \pm 0.24\%$

Table 5.2 : PLA + untreated CQ fiber composite tensile strength

Sample No	Tensile Strength (N/mm ²)	Modulus of elasticity (N/mm ²)	Elongation (%)
Sample 1	51.75	842.49	3.12
Sample 2	55.89	937.52	3.90
Sample 3	59.94	1012.6	3.52

Table 5.2 gives us the tensile strength results of the PLA + untreated CQ fiber along with modulus of elasticity and elongation. Average value of tensile strength is 55.86 ± 4.09 N/mm², average of modulus of elasticity is 763.71 ± 85.24 N/mm² and average of elongation is $3.51 \pm 0.39\%$

Table 5.3 : PLA + treated CQ fiber composite tensile strength

Sample No	Tensile Strength (N/mm ²)	Modulus of elasticity (N/mm ²)	Elongation (%)
Sample 1	62.61	70.93	5.02
Sample 2	59.64	1151.64	3.10
Sample 3	57.06	1068.57	3.13

Table 5.3 gives us the tensile strength results of the PLA + treated CQ fiber along with modulus of elasticity and elongation. Average value of tensile strength is 59.77 ± 2.77 N/mm², average of modulus of elasticity is 924.87 ± 601.40 N/mm² and average of elongation is $3.75 \pm 1.09\%$

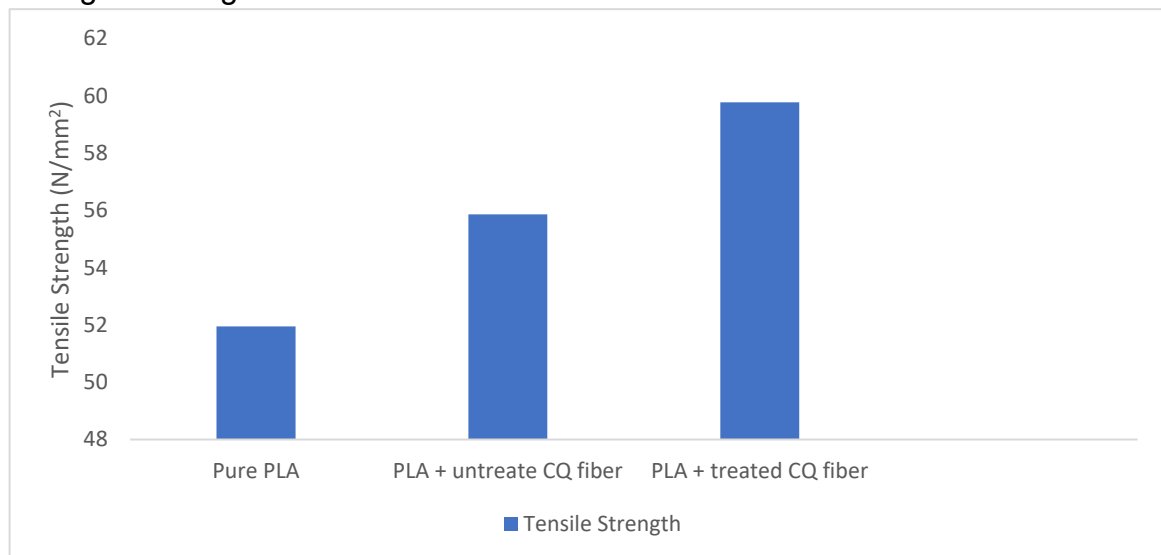


Fig:5.4 : Comparison of tensile strengths of three composites

figure 5.4 shows the comparison of tensile strengths of three composites in which PLA + treated CQ fiber is having maximum tensile strength of 59.77 N/mm².

The obtained tensile strength values of NaOH treated with 15% fiber volume composites are 6% and 15% higher when compared with untreated 15% of fiber volume and virgin PLA. From the tensile results addition of 15 wt.% of NaOH increases the tensile strength of the fiber, this may be due to structural and chemical modifications on the fiber surface these surface modifications influence the interfacial bonding between fiber and matrix. It increases the roughness on the

surface of the fiber resulting in best mechanical interlocking between fiber and matrix [41]. This attributes a good stress transfer from matrix to fibers and the consecutive reinforced fibers thereby minimizes the stress concentration in the matrix [51]. High tensile strength may occur due to the concentration of less hemicellulose and lignin present in the fibers [49]. Hemicellulose and lignin were removed during alkali treatment. The interfibrillar region is less dense and less rigid, making the fibrils rearrange themselves along the tensile loading direction. When fibers were stretched, such arrangements among the fibrils resulted in better load sharing and hence higher stress development in the fiber [16].

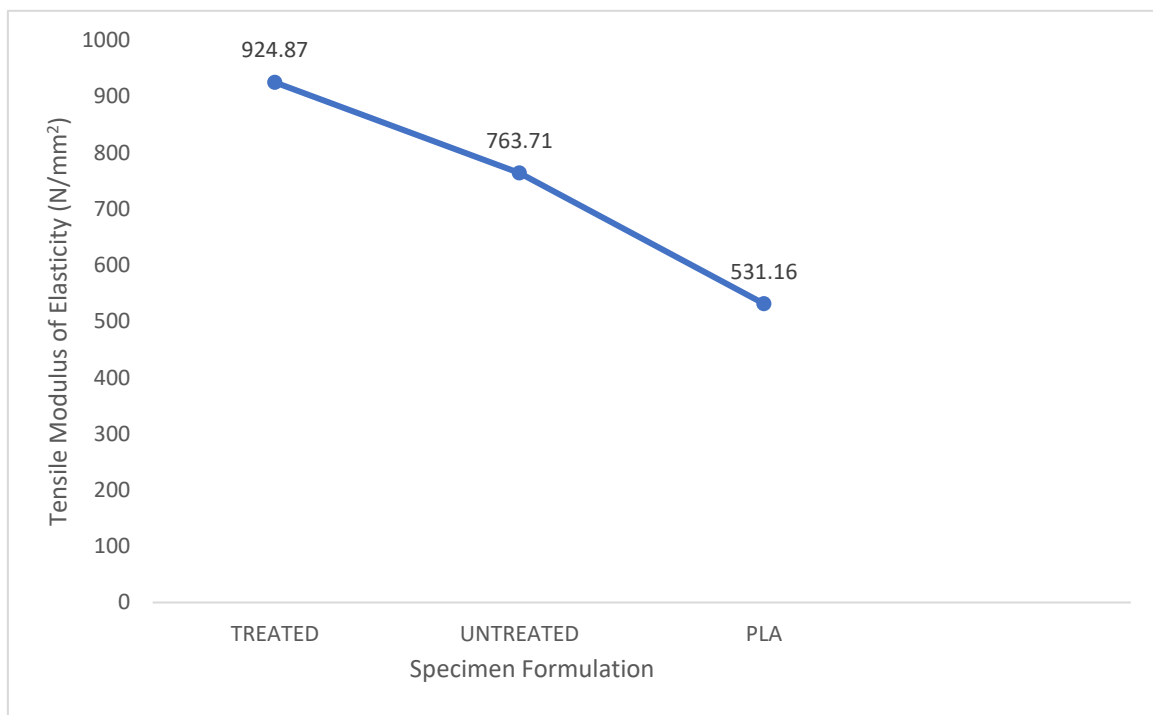


Fig:5.5 : Average of three composites tensile modulus of elasticity

The modulus of elasticity is a function of the stress to strain ratio of hardened elastic stage. In identical composites, the higher the modulus of elasticity of the material, the greater the rigidity.

figure 5.5 displays the tensile modulus of elasticity for three composites in which treated fiber composite shows high tensile modulus of elasticity of 924.87 N/mm² which is 17% higher than the untreated fiber composite. At this point deformation of specimen took place. Besides, the maximum modulus of elasticity observed for the treated fiber specimen, understandably the interfacial bonding

between the fiber and PLA through alkaline treatment is the ultimate reason for the higher tensile and modulus of elasticity [51].

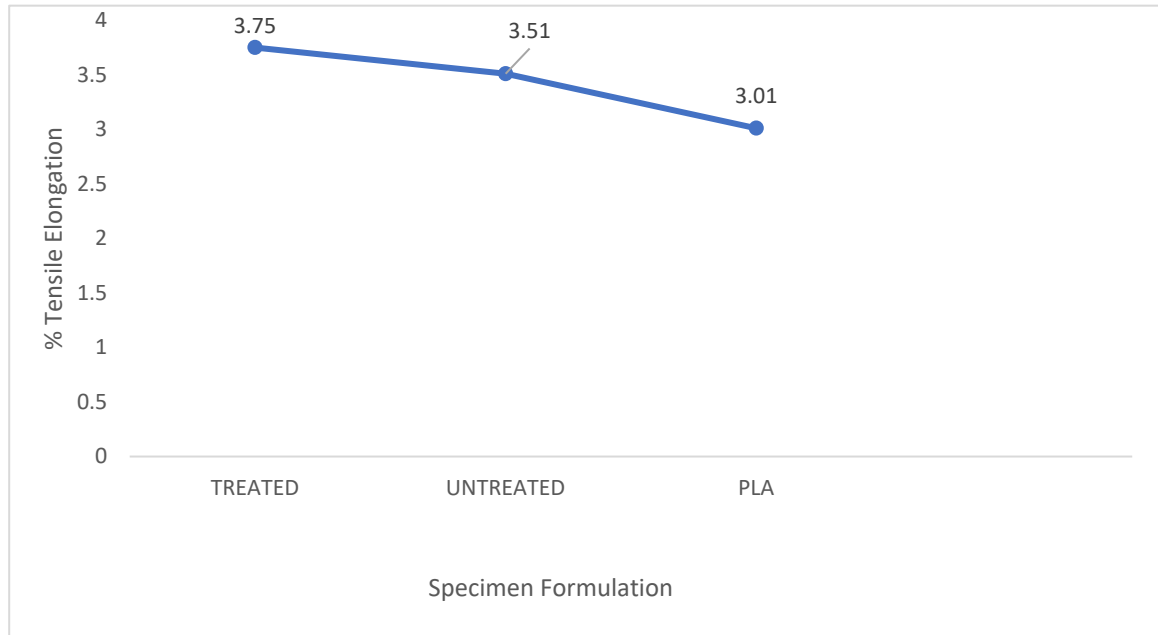


Fig:5.6 : Average of three composites tensile elongation

Elongation is stretching a material undergoes as it is pulled in tension. Tensile elongation is a measure of both elastic deformation and plastic deformation which shows in percentage, it is used in stress and strain values to determine the mechanical properties of a material when performing the tensile strength.

Elongation is used to establish what the mechanical properties of a material are, a high tensile elongation is indicative of a soft, ductile material. If tensile elongation is nearly zero then the material is most likely hard and extremely brittle. A high-tension force velocity could skew the tensile elongation results.

5.2 Flexural Strength

This flexural strength test is performed at KELVN Labs, Hyderabad, Telangana. By using universal testing machine. The dimensions of the samples are 150×135×3mm



Fig:5.7 : Flexural samples of pure PLA composite

In this figure 5.7 these are the flexural strength samples of pure PLA and the composition is 100% PLA 0% fiber with dimensions 150×135×3mm



Fig:5.8 : Flexural samples of PLA + untreated CQ fiber composite

In this figure 5.8 these are the flexural strength samples of PLA + untreated CQ fiber composite and the composition is 85% PLA 15% fiber with dimensions 150×135×3mm.



Fig:5.9 : Flexural samples of PLA + treated CQ fiber composite

In this figure 5.9 these are the flexural strength samples of PLA + treated CQ fiber composite and the composition is 85% PLA 15% fiber with dimensions 150×135×3mm.

Table 5.4 : Pure PLA composite flexural strength

Sample No	Flexural Strength (MPa)	Modulus of elasticity (MPa)	Elongation (%)
Sample 1	72.19	586.95	3.60
Sample 2	70.00	2972.94	3.60
Sample 3	69.97	1864.04	3.49

Table 5.4 gives us the flexural strength results of the Pure PLA along with modulus of elasticity and elongation. Average value of flexural strength is

70.72±1.27 MPa, average of modulus of elasticity is 1.8±1.19 GPa and average of elongation is 3.56±0.06%

Table 5.5 : PLA + treated CQ fiber composite flexural strength

Sample No	Flexural Strength (MPa)	Modulus of elasticity (MPa)	Elongation (%)
Sample 1	84.01	2764.20	6.70
Sample 2	79.97	3510.45	6.56
Sample 3	68.46	8404.55	5.87

Table 5.5 gives us the flexural strength results of the PLA + treated CQ fiber along with modulus of elasticity and elongation. Average value of flexural strength is 77.48±8.06 MPa, average of modulus of elasticity is 4.8±3.06 GPa and average of elongation is 6.37±0.44%

Table 5.6 : PLA + untreated CQ fiber composite flexural strength

Sample No	Flexural Strength (MPa)	Modulus of elasticity (MPa)	Elongation (%)
Sample 1	70.50	2102.01	4.86
Sample 2	71.90	2022.95	4.86
Sample 3	76.80	3564.82	4.97

Table 5.6 gives us the flexural strength results of the PLA + untreated CQ fiber along with modulus of elasticity and elongation. Average value of flexural strength is 73.06±3.30 MPa, average of modulus of elasticity is 2.5±0.86 GPa and average of elongation is 4.89±%

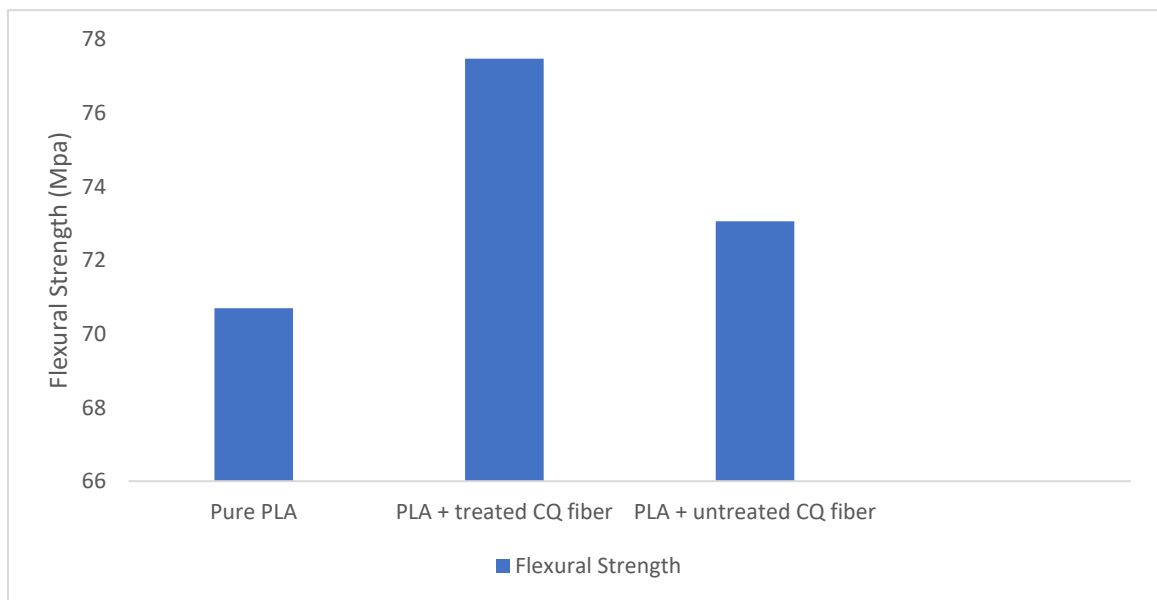


Fig:5.10 : Comparison graph of flexural strengths of three composites

figure 5.10 it explains the comparison of flexural strength of three composites of Pure PLA, PLA + untreated CQ fiber and PLA + treated CQ fiber composites in which PLA + treated CQ fiber composite is having maximum flexural strength of 77.48 MPa. Which is 6% and 9% higher than untreated CQ fiber and Pure PLA composite. This may due to alkali treatment, the composites load transfer efficiency is improved significantly [3]. Compared to PLA + treated CQ fiber, PLA + untreated CQ fiber is having less flexural strength. This may be occurred due to the PLA resin was not able to enter the fibers which lead to two phenomena's as the high porosity of the composite and less interaction of the core of the fiber with the surrounding matrix [53].

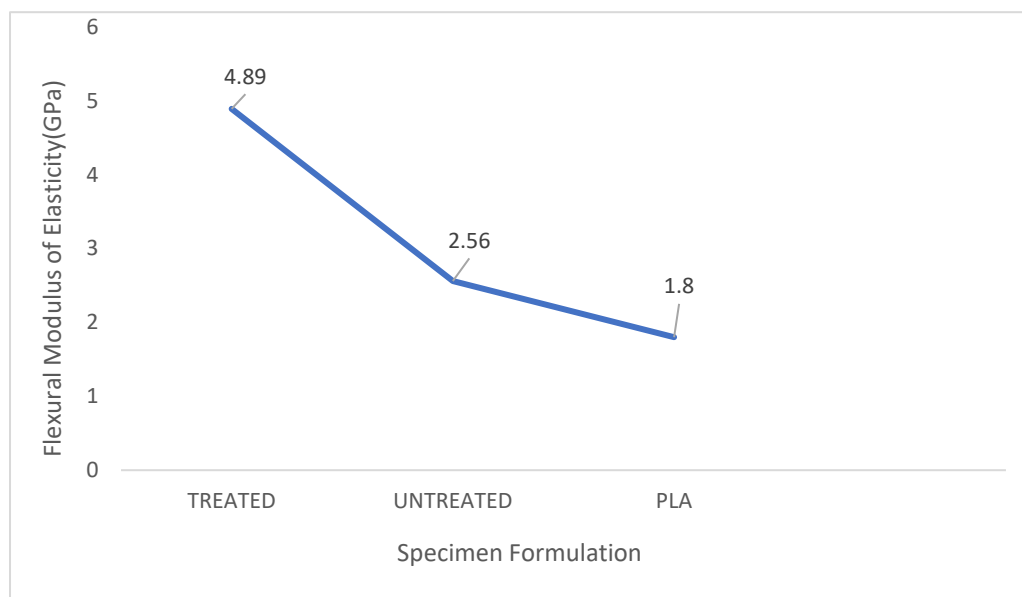


Fig:5.11 : Flexural modulus of elasticity

Flexural modulus of elasticity denotes the ability of material to bend, a measure of a materials resistance to bend when a force is applied perpendicular to the long edge of a sample is known as three-point bend test. Ratio of stress to strain is used to measure the flexural modulus

The higher the flexural modulus the stiffer the material the lower the flexural modulus material is more flexible; it helps to improve design quality for load bearing applications. In figure 5.11 flexural modulus of elasticity is shown for three composites in which treated fiber composite is having high flexural elasticity of 8.4 GPa. Flexural modulus of treated fiber shown 15% higher than the flexural modulus of untreated fiber. This may be due to interfacial bonding between fiber and the PLA after alkali treatment [51].

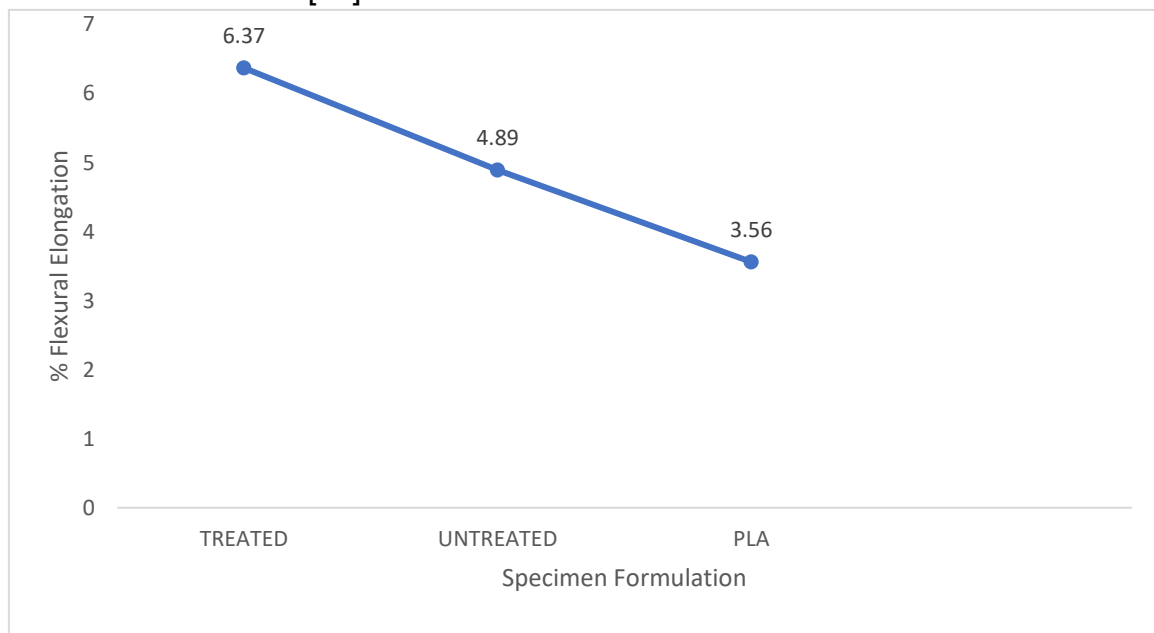


Fig:5.12 : Flexural elongation

It is measure of the ductility of a material as determined by a tension test, higher elongation equals to higher ductility. Elongation is important in manufacturing as it measures how much bending and shaping a material can withstand without breaking. Elongation is inversely proportional to tensile strength and modulus. The greater materials tensile strength and modulus the less it will elongate under stress

Elongation is equal to the failure strain, it has no units but is often given in percentage strain, usually strength refers to the ability of a structure to resist loads without failure. Failure may occur by rupture because of excessive stress, analysis of force elongation or stress-strain curve can convey much about the material being

tested and it can help in predicting its behaviour. Flexural elongation is high for treated fiber compare to untreated fiber and PLA, Because of Tensile strength increasing modulus of elongation also increase.[24]

5.3 Impact Strength

This impact strength test is performed at KELVN Labs, Hyderabad, Telangana. By using Izod impact machine. The dimensions of the samples are 65×13×3mm as shown in the figure 5.13



Fig:5.13 : Impact samples of pure PLA

In this the samples of impact strength of Pure PLA are shown. Which are having the composition of 100% PLA and 0% fiber.



Fig:5.14 : Impact samples of PLA + untreated CQ fiber composite

figure 5.14 the samples of impact strength of PLA + untreated CQ fiber are shown. Which are having the composition of 85% PLA and 15% fiber.



Fig:5.15 : Impact samples of PLA + treated CQ fiber composite

Figure 5.15 the samples of impact strength of PLA + treated CQ fiber are shown. Which are having the composition of 85% PLA and 15% fiber.

Table 5.7 : Impact strength of pure PLA samples

Samples	WIDTH (mm)	THICKNESS (mm)	W/d×1000 (J/m)	IMPACT STRENGTH (KJ/mm ²)
Sample 1	12.34	3.67	0.876	24.25
Sample 2	11.30	4.12	0.934	25.76
Sample 3	11.92	3.90	0.760	20.68

Table 5.7 the impact results of Pure PLA samples are discussed and sample 2 is having the high impact strength of 25.76 ± 2.6 KJ/mm². All dimensions are in mm

Formula to calculate impact strength is

$$\text{Impact strength} = \text{work done} / (\text{thickness} \times \text{width}) \times 1000 \text{ kJ/mm}^2.$$

Table 5.8 : Impact strength of PLA + untreated CQ fiber samples

Samples	WIDTH (mm)	THICKNESS (mm)	W/d×1000 (J/m)	IMPACT STRENGTH (KJ/mm ²)
Sample 1	11.16	3.46	0.760	25.36
Sample 2	12.25	3.30	0.760	23.62
Sample 3	12.11	3.31	0.760	23.89

Table 5.8 the impact results of PLA + untreated CQ fiber samples are discussed and sample 1 is having the high impact strength of 25.36 ± 0.93 KJ/mm².

Table 5.9 : Impact strength of PLA + treated CQ fiber samples

Samples	WIDTH (mm)	THICKNESS (mm)	W/d×1000 (J/m)	IMPACT STRENGTH (KJ/mm ²)
Sample 1	12.65	3.94	0.818	20.25
Sample 2	13.12	3.74	0.760	19.13
Sample 3	13.17	3.91	0.818	19.60

Table 5.9 the impact results of PLA + treated CQ fiber samples are discussed and sample 1 is having the high impact strength of 20.25 ± 0.56 KJ/mm².

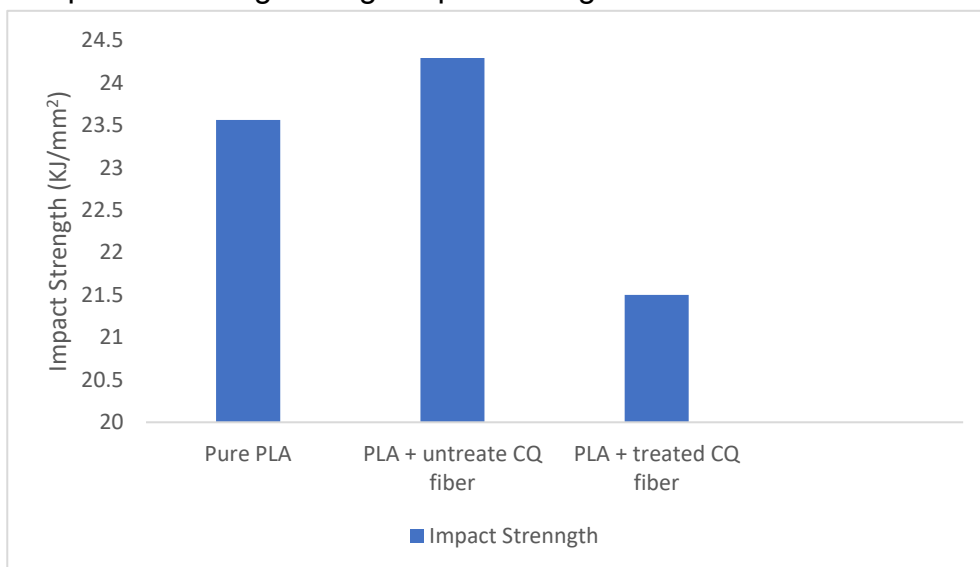


Fig:5.16 : Comparison of impact results of three composites

figure 5.16 it shows the comparison between all three composites about impact test results. In which PLA + untreated CQ fiber composite is having high impact strength of 24.29 KJ/mm². Impact test conducted for treated, untreated fiber and PLA composites in which untreated fiber shows high impact strength of 24.29 KJ/mm² which is 3% higher than PLA composite and 12% higher than treated fiber composite, it is mainly occurs due to the high bonding between matrix and fiber [24].

Unlike to tensile and flexural properties, Izod impact strength of treated composites was lower than the untreated composite. Similar trend was reported by Aziz and Ansell [15]. Debonding, pull out and fiber fractures are the mechanisms of energy absorption during impact. Among these, fiber pull out requires higher energy than that of the fracture of fibers and debonding. High impact strength of untreated composites may be attributed to more fiber pull outs due to weak interface between the fiber and the matrix. In the case of treated composites, fiber fracture occurs instead of pull outs. Fiber fracture requires less energy compared to the energy required for pull outs. This may be the reason for lower impact strength of treated composites compared to untreated composites [7].

5.4 SEM Analysis

This SEM test has been done in KELVN Labs, Hyderabad, Telangana. It is a physical property test it is the scanning electron microscope which produces images of samples by scanning the surface with a focused beam of electrons on it. These electrons will interact with several atoms on the surface and produce signals which contains the information about the surface and composition.

figure 5.17 SEM analysis is taken at the broken side of high tensile sample and we can see the boning between the fiber and composite also the fiber position and there is also some porous hole on the composite and some weak bonding between fiber and polylactic acid composite. There are some void gaps because of improper composite mixing.

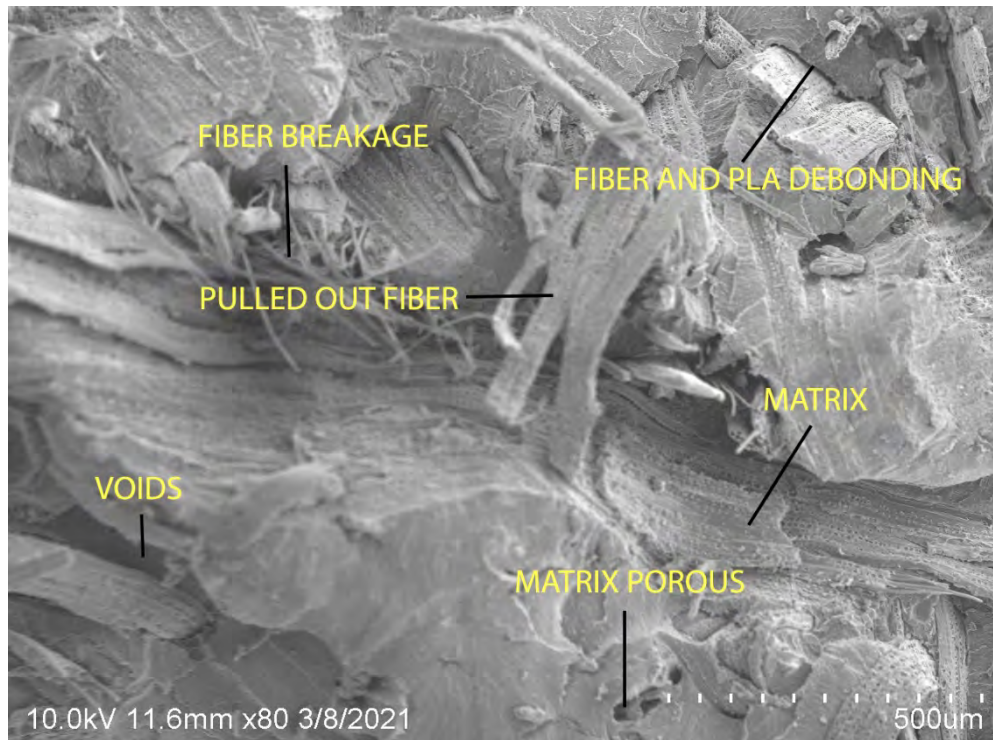


Fig:5.17 : SEM analysis of broken side of high tensile strength sample

Higher tensile strength observed on treated fiber sample thus the composite made of 15% Fiber and 85% PLA was taken for microstructural analysis performed on tensile sample figure 5.17 shows the SEM image of sample, the presence of voids and broken fiber was observed in treated fiber composite.

In chemical treatment fiber, a limited number of voids and broken fibers were observed. Further, the penetration of resin increases the strength between matrix and fiber. In treated fiber, the surfaces are porous, which denotes better bonding. The interfacial bond between the fiber and matrix stronger and better in chemical-treated fiber. Fiber pulled out, which is the main reason for voids present in the composite, occurs due to improper and low bonding between fiber and matrix [17].

5.5 FTIR Analysis

This test FTIR is done at SRM University, Chennai, Tamil Nadu. This FTIR test is used to identify the functional groups present in the samples the FTIR analysis was performed and the graph is shown below

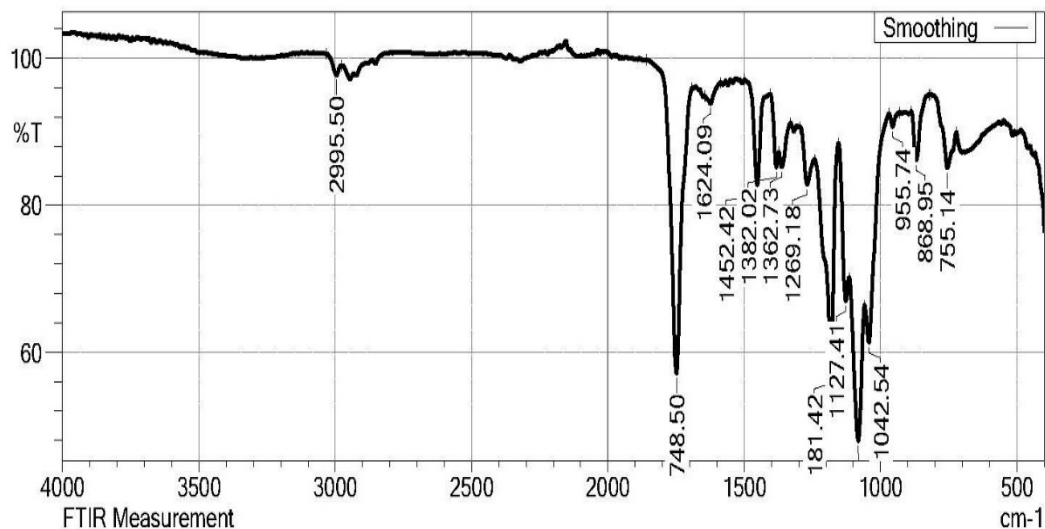


Fig:5.18 : FTIR analysis of treated CQ fiber

The peaks observed in the FTIR spectrum are responsible for treated and untreated fiber particles. The band at 2995.50cm^{-1} & 2996.47cm^{-1} are responsible for the acidic O-H stretching [19] and the bond at 1624.09, 1452.42, 1382.02 and 1268.22 were to the C=O and C-O stretching [28]. the peak at 1042.54, 1127.41 and 956.71 are the region of deformation vibration of outside the group [47]. The remaining peaks at 1382.02, 1269.18, 955.74, 755.14, 1452.42, 1318.37, 868.95, 666.42 these were formed due to secondary metabolites [19]. The untreated peak indicates the elongation of the O-H bond in cellulose [47].

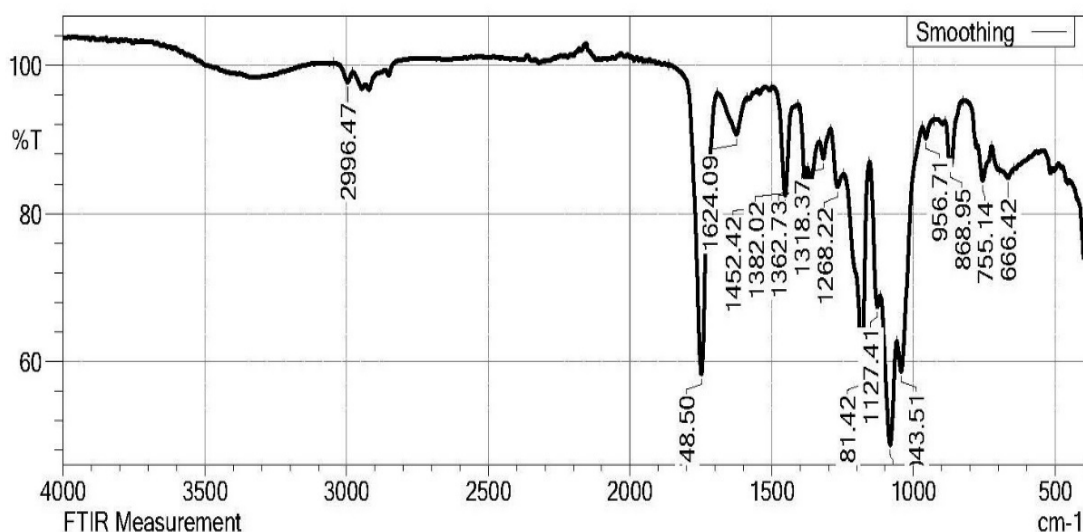


Fig:5.19 : FTIR analysis of untreated CQ fiber

5.6 XRD Analysis

The crystalline nature of *Cissus quadrangularis* has been determined using XRD analysis. It is illustrated in below graph 5.20 the effect of the chemical treatment on the fiber cellulose crystallinity was determined using the X-Ray diffractometer are presented the CQ'S determination is crucial to observe the

change in the amorphous content in the fiber after chemical treatment. A higher crystallinity index emphasizes the effectiveness of chemical treatment.

There are three major peaks found in treated, where $2\theta = 14.70^\circ$, and 16.15° . It represents the presence of amorphous content and alpha-cellulose [32]. The untreated fiber shows two major peaks at $2\theta = 16.15^\circ$ and 13.98° . The crystalline index CI for treated and untreated fiber is 10.8% and 24.9%, The crystalline index of untreated fiber is more, compared to treated fiber. This may be due to increase amorphous constituents in treated fiber after chemical treatment [51] Crystalline index CI is calculated by using below equation.

$$CI = \frac{\text{Highest Peak} - \text{Lowest Peak}}{\text{Highest Peak}}$$

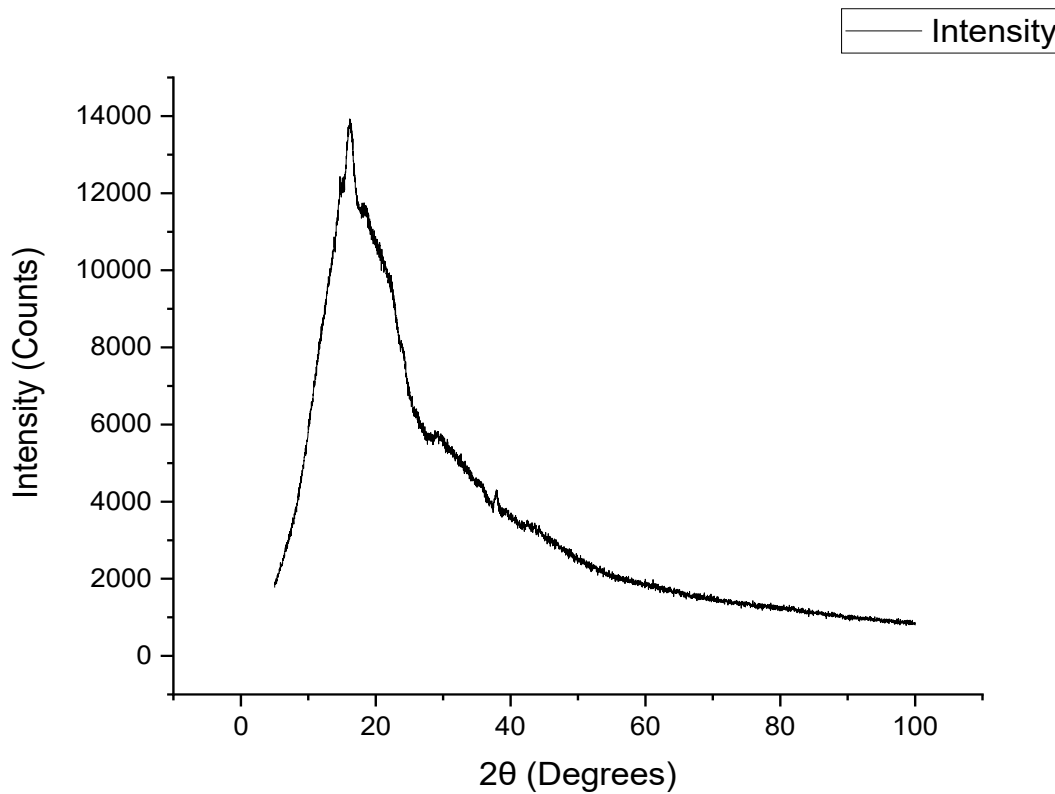


Fig:5.20 : XRD spectrum of treated CQ fiber

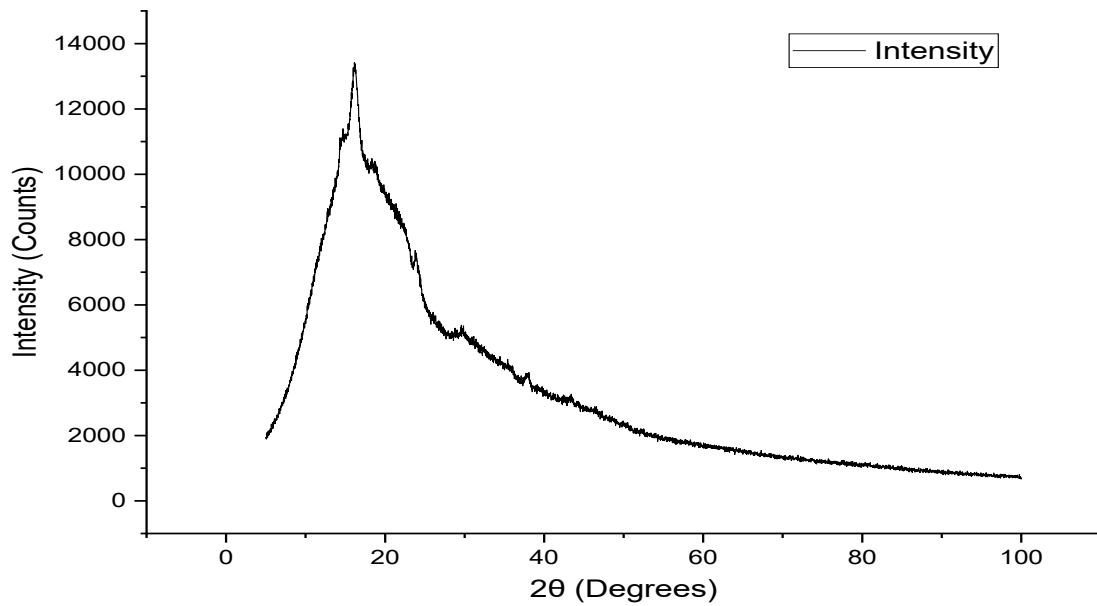


Fig:5.21 : XRD spectrum of untreated CQ fiber

5.7 Water absorption

Water absorption test is carried out with three different types water, sea water, distilled water and normal water. These specimens are immersed in the water at room temperature.

This test was conducted to find out the amount of water absorbed on the workpiece in every 24 hours for 5 days of immersion. It depends on the matrix fiber content, environmental conditions and method of fabrication. For all the samples the process of water absorption is at the beginning linear type. After extending immersion time the samples approach to the saturation point.

Water absorption performance is identified with the dimensional stability of the composites. The dimensions of the sample used for water absorption test are 20 × 20mm in three different mediums of water. PLA, CQT and CQUT samples are used for absorption test. There has been significant increase in the amount of water absorption along with time, after 24hours the percentage of water intake of PLA distilled water(PLAD) is 0.2%, Treated distilled water(CQTD) is 1%, and Untreated distilled water(CQUTD) is 0.6% respectively percentage of water intake of PLA normal water(PLAW) is 0.3%, Treated normal water(CQTW) is 1.3%, and Untreated

normal water(CQUTW) is 0.8% similarly percentage of water intake of PLA Sea water(PLAS) is 0%, Treated Sea water(CQTS) is 0.8%, and Untreated Sea water(CQUTS) is 0.4%.

After 72hours the percentage of distilled water intake of PLAD is 0.9%, CQTD is 1.5%, and CQUTD is 1.2% respectively percentage of normal water intake of PLAW is 1.2%, CQTW is 2%, and CQUTW is 1.6% similarly percentage of sea water intake of PLAS is 0.8%, CQTS is 1.4%, and CQUTS is 1%. After 120hours percentage of distilled water intake of PLAD is 1%, CQTD is 1.5%, and CQUTD is 1.12% respectively percentage of normal water intake of PLAW is 1.24%, CQTW is 1.94%, and CQUTW is 1.6% similarly percentage of sea water intake of PLAS is 1.2%, CQTS is 1.4%, and CQUTS is 1.16%.

After 120hours CQT samples absorbed more amount of water compared PLA and CQUT samples. This may be due to the hydroxyl group and other groups present in the treated fiber absorbed water through hydrogen bonding. Porous holes in the composite also influence the absorption capacity. The porosity has resulted during composite fabrication [25].

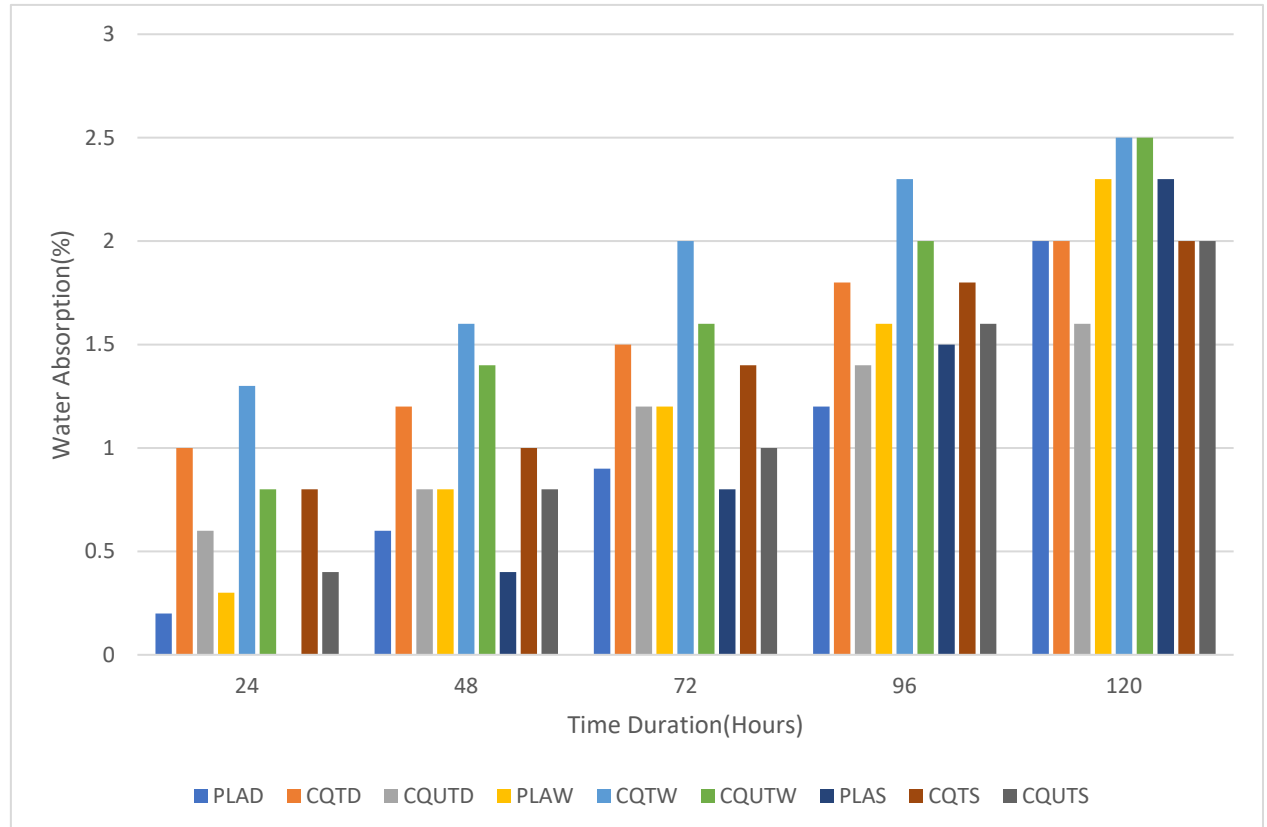


Fig:5.22 : Water absorption characteristics in distilled, sea and normal water

5.8 THERMOGRAVIMETRIC ANALYSIS

Thermogravimetric analysis (TGA) is done at VELS University, Chrompet, Chennai. This test is taken at the temperature range of 0°C to 1000°C, and atmosphere N₂ and using crucible Al₂O₃. Heating rate is 10°C

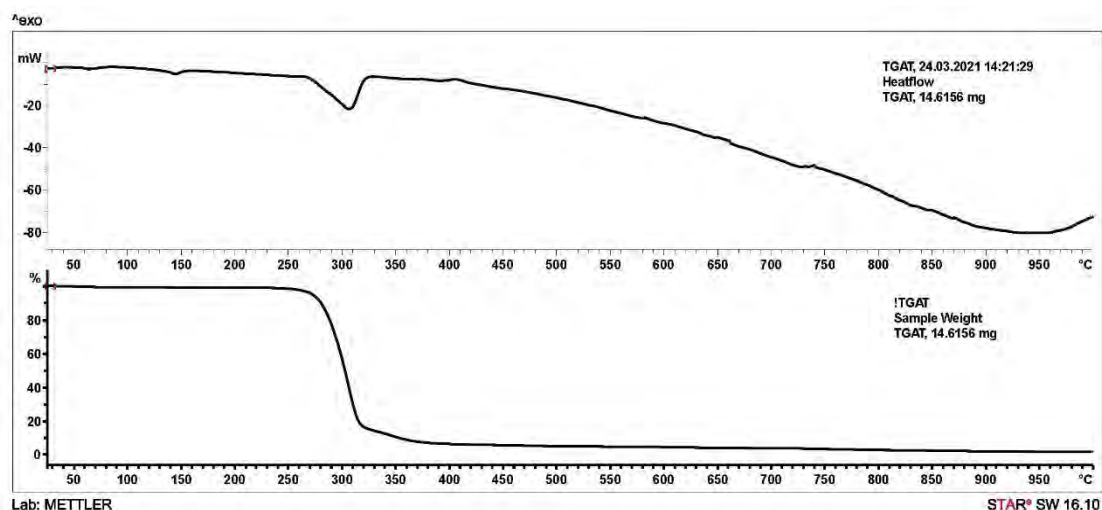


Fig:5.23 : TGA with DSC curve of NaOH treated fiber powder

The thermal stability of the CQT and CQUT, the composite powder investigated by TGA with DSC the resulting TGA with DSC curve of treated and untreated fiber are shown in figure 5.23 and figure 5.24. The onset temperature (T_o) of the TGA curve is around 180°C, the temperature at which 8% weight loss is reported, this weight loss is mainly due to moisture caused by structurally bonded water molecules [51]. As the temperature raises the thermal stability gradually decreases and thermal decomposition finally takes place in three stages. First stage of disintegration occurs in the range of 180-330°C for the treated fiber and untreated fiber composite powder. This indicates the loss of hemicellulose and lignin content present in the fiber. The weight loss in this temperature range was about 15%.

The second stage of disintegration occurs in the range of 330-600°C for treated fiber and untreated fiber composite powder. Cellulose and lignin contents may decompose at this range of temperature. Weight loss in the temperature is about 60% the results revealed that the disintegration temperature of the composite powder changed to greater temperature showing the higher thermal stability of treated composite powder up to 20%. An inorganic material present in the untreated composite generally enhances the thermal stability of the treated composite [25].

The final stage of degradation takes place due to decomposition of α -cellulose at range of 600°C - 940°C and 600°C - 930°C with a weight loss of 40% and 55% of treated and untreated fiber. According to DSC curve degradation temperature range increases in the case of untreated fiber. This may be due to presence of amorphous constituents in the treated fiber [25].

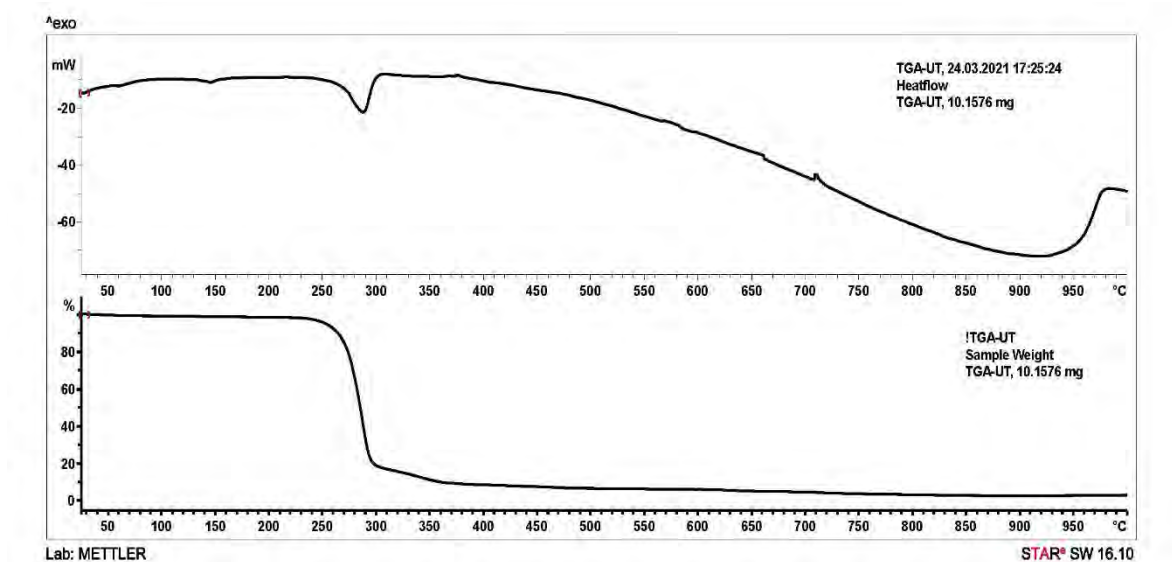


Fig:5.24 : TGA with DSC curve of untreated CQ fiber powder

CHAPTER 6

SUMMARY AND CONCLUSION

Based on the study conducted on the three composite specimens of Pure PLA, Untreated natural fibre composite and Treated natural fibre composite of mechanical and morphological analysis were done

- Tensile strength of treated and untreated natural fibres is 15% and 7% (59.77N/mm^2 and 55.86N/mm^2) higher than the Pure PLA composite.
- Tensile strength the ASTM D 3039 shown the treated fibre composite has higher value 62.61N/mm^2 .
- Tensile modulus of elasticity is higher in treated composite compared to untreated composite and PLA composite with the value of 924.87N/mm^2 .
- Tensile elongation is higher in treated composite 13.75%.
- Flexural strength of untreated and treated natural fibres are stronger than the Pure PLA composite. 73.06 MPa and 77.48 MPa.
- Flexural modulus of elasticity is higher in treated composite compared to untreated composite and PLA composite with the value of 8.4GPa.
- Flexural elongation is higher in treated composite 11134.8%.
- The flexural strength in ASTM D 790 shown the treated fibre composite has higher value. 77.48MPa.
- Impact strength of untreated fiber composite is higher than the treated fiber composite and PLA composite 24.29KJ/mm^2 .
- Presence of voids and broken fiber was observed in SEM analysis.
- In FTIR Analysis, the untreated sample peak given elongation higher in O-H bond in cellulose.
- In XRD analysis crystalline index of untreated fiber (24.9%) is higher than treated fiber composite (10.8%).
- Higher crystalline index emphasizes the effectiveness of chemical treatment.
- Higher percentage of water absorption is took place in distilled water and low percentage of water absorption took place in sea water.
- First stage of disintegration occurs in the range of 180-330°C, second stage of disintegration occurs in the range of 330-600°C.

- In first stage of disintegration 8% of weight loss in observed for both treated and untreated fiber.
- In second stage of disintegration 20% of weight loss in observed for both treated and untreated fiber.
- 15%TQF/PLA composite samples absorbed more amount of water compared to PLA and 15%UCQF/PLA composite samples.

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APPENDIX

CQFC CISSUS QUADRANGULARIS FIBER COMPOSITE