FEASIBILITY STUDY OF CHEMICAL TREATMENT OF BAGASSE FOR BAGASSE/EPOXY COMPOSITE APPLICATIONS

A major project report submitted in the partial fulfillment of the requirement for the award

of the Degree of
Master of Technology

In
Polymer Technology

Submitted By

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DECLARATION

I hereby declare that the work presented in this minor project report entitled **"Feasibility Study of Chemical Treatment of Bagasse for Bagasse/Epoxy Composite Applications "** is original and has been carried out by me in the partial fulfillment of the requirement for the award of the Master of Technology in Polymer Technology in the Department of Applied Chemistry, Delhi Technological University, Delhi – 110042, under the supervision of **Dr. Manish Jain**, Assistant Professor, Faculty of Polymer Science and Chemical Technology, Department of Applied Chemistry. This report is contribution of my original research work. Wherever research contributions of others are involved, effort has been made to cite that in text. To the best of my knowledge, this research work has not been submitted in part or full for the award of any degree or diploma of Delhi Technological University or any other University/Institution.

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CERTIFICATE

This is to certify that the work presented in this minor project report entitled **"FEASIBILITY STUDY OF CHEMICAL TREATMENT OF BAGASSE FOR BAGASSE/EPOXY COMPOSITE APPLICATIONS** " has been submitted to the Delhi Technological University, Delhi-110042, in fulfilment for the requirement for the award of the degree of **M.Tech. in Polymer Technology** by the candidate **Mr. Vikas Maurya (2K17/PTE/09)** under the supervision of **Dr.Manish Jain,** Assistant Professor, Faculty of Polymer Science and Chemical Technology, Department of Applied Chemistry. It is further certified that the work embodied in this report has neither partially nor fully submitted to any other university or institution for the award of any degree or diploma.

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ABSTRACT

Now a days, natural fiber based composite material are getting popularity for different applications. These materials are considered environment friendly as they are made of biodegradable natural fibers which are often the agricultural waste or byproduct. However, the chemical treatment processes applied to improve the mechanical strength and adhesion properties of fibers may produce a lot of waste water with very high BOD and COD. Thus, the natural fiber based composite industry may harm environment more than the traditional composite industry if this waste water will discharge untreated. On the other hand, treatment of such polluted water may increase the operating cost of the composite production and effect the economy of the industry.

In this study, the waste water produced during chemical treatment of natural fibers are examined for the amount of BOD and COD present in it. This indicates the expenditure required on the waste treatment plant. Results showed that waste water has BOD value 1200 ml/L and COD value 5800 ml/L, which are very high. COD values is five times higher than BOD value. Thus, biological treatment may not decompose all impurities present in the waste and more expensive advance treatment may require before discharging the waste.

Mechanical properties of treated and untreated bagasse fiber/epoxy composites are also analyzed to investigate the requirement of the treatment. Result showed significant enhancement in mechanical properties of both treated and untreated fiber based composites in comparison to pure epoxy sample. However, mechanical properties of treated fiber based composites are found higher than the untreated fiber based composites. This study suggests that if composite material is used in any commodity application or where any specific mechanical properties are not required, the pretreatment of natural fiber is totally unnecessary.

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1. INTRODUCTION

In recent years, the natural fibers have involved considerable importance as potential structural material. The striking point of natural fiber is its use in industrial application which made its availability added demanding. Low cost, light weights, high specific modulus, renew ability and biodegradability are some of most important properties which make natural fibers very attractive. The world focused their consideration on natural composites reinforced with Bagasse, Jute, Sisal, Coir, Pineapple etc, the main reason is to decrease the cost of raw materials.

Keeping this in mind this work has to develop a polymer matrix composite with polymer matrix (epoxy resin) and natural fiber (bagasse fiber as reinforcement) to study its mechanical properties and performance. The composites will prepare at different weight fraction of bagasse fiber.

Natural fibers are found lingo-cellulosic in nature. These composites find good importance due to its bio-degradable and non-carcinogenic properties. The natural fiber composites are used specially in building and construction industry due their low cost and availability.

Bagasse made of about 40% cellulose, 30% hemi-cellulose, and 25%-28% lignin and rest inorganic minerals. Sugar cane mill are use bagasse as fuel in furnaces. The calorific vale of bagasse is low so it is a wastage of natural resources, if we can utilize bagasse in industrial purpose to produce composites suitable for building materials.

Keeping this in view my present work is to develop a polymer matrix composite (epoxy resin) using bagasse fiber as reinforcement with volume fractions 5, 7.5 and 10 to study its mechanical properties. In this project the main prominence is laid on the experimental work at the mechanical behavior of composite.

Natural fiber made composites give light-weight; high strength-to-weight ratio and stiffness properties to the products, which made them in replacing of conventional materials (metals, wood etc) products.

Fiber reinforcement is done to gain high strength and modulus. So is essential need for the fibers to have higher modulus than the matrix material so that load could be sustained by fiber, transferred from the matrix more effectively. Fiber reinforced composites are mainly used in industrial applications because of their high specific strength and stiffness. Their excellent structural performance made them useful for tri-biological applications.

The physical properties of natural fibers are mainly depending on their physical and chemical configuration, such as fiber structure, percentage of cellulose content, angle of fibrils, cross section and on the degree of polymerization. An important property to use natural fiber in reinforcement is their obtainability in large quantities. For several technical applications, the fibers are specially prepared or modified accordingly, degree of polymerization and crystallization, adhesion among matrix and fiber, moisture resistance and flame-retardant properties.

Nowadays natural fibers are replacing the traditional synthetic plant fibers are renewable and their availability as near unlimited, when composite come at the end of their life cycle, such as combustion or landfill the CO2 released from the fibers is neutral. The abrasive properties of fiber is lower which tends to advantages in material recycling, when fiber in biodegradable polymers matrix that composite will be the most environment friendly material.

2. LITERATURE SURVEY

Since last decade, material scientists are giving a lot of attention on natural fiber reinforced composites due to their several benefits such as low density, cost, lower footprint on environment etc. Natural fibers are emerged as a viable replacement of glass fibers and other inorganic reinforce materials. Moreover, in most of the cases, these natural fibers are the byproduct of agriculture industry such as bagasse or rise straws. Thus, the application of these materials in composite manufacturing will solve the solid waste management problem of agriculture industry, and may provide an alternative source of income for farmers. It also considered to reduce the adverse effect of composite industry on the environment, as we are replacing the inorganic materials to biological products. This study is focused on the Bagasse based composites. Bagasse is the solid waste product of sugar industry. Bagasse does not have any significant application, thus, it is generally burn in the boilers as a low density fuel, which creates huge air pollution problem. Bagasse may be more efficiently use as composite reinforcement as more valuable and environment friendly application. Several researchers have studied different aspects of bagasse based composites. Some are summarized in table below

Publication Detail	Work Done	Major Finding
A .Mohd Mustafa Al Bakri et al.	Prepare Polystyrene/bagasse based composite at different concentration and major the water absorption properties of the composite.	Composite absorbs more water with increasing bagasse composition in it.
P. C. Gope et al.	Examine mechanical properties of bagasse/glass fiber/epoxy composites	Presence of bagasse in composite material significantly increases its mechanical strength
Isaak Oluwole Oladele	Optimize the bagasse composition in polyester composite by comparing tensile strength	10% fiber content gives maximum tensile strength.
J. O. Agunsoye et al.	Investigate mechanical properties of recycled polyethylene/bagasse composite materials	Bagasse reinforcement significantly improves the mechanical properties of the thermoplastic. 30%

		(wt.%/wt.%) bagasse composition is found optimum.
Vazquez A. et al.	Prepare the chemically treated bagasse/polypropylene composites	Chemical treatment improves the polymer fiber adhesion and thus improves the mechanical properties.
Sherif Mehanny et al	Prepared starch/chemically treated bagasse composites.	Composite shows good mechanical properties, thus, suitable for several application. 60% of fiber content are found optimum based on mechanical properties.
Cao Y., Shibata S. et al.	Compare polyester composite with treated/untreated bagasse fiber reinforcement for mechanical properties	Chemical treatment (Alkali) of fiber improves (5 to 30%) mechanical properties of the composite.
Zheng Yu-Tao et al.	Prepare polyvinyle choride/ bagasse composites. Compare the mechanical properties of composite with surface modified bagasse fiber (by benzoic acid) to the composite with untreated bagasse.	Chemical treatment improve the mechanical properties up to 10%
Samir Kumar Acharya et al	Prepare the alkali treated bagasse/epoxy composite with variations in chemical treatment operating parameters (Alkali concentration, temperature and duration of treatment.	Only flexural properties showed the significant variations with varying treatment procedure.
Bilba K. et al	Prepare chemically treated bagasse fiber/cement composites and compare the properties with	Both types of composites showed similar properties.

	heat treated bagasse/cement composites	

Gape in Literature

Literature survey showed that most of the study in this field is focused on the chemically treat the bagasse to remove the amorphous lignins and hemicellulose from it so that reinforcement fibers only contain crystalline cellulose material, which has higher mechanical properties in comparison to lignin and hemicellulose containing material. Removal of lignin and hemicellulose are improving the adhesion properties of fiber with matrix and hence further improves the mechanical properties.

However, as discussed before, lignin and hemicellulose make up to 60% of plant mass and only 40% is cellulose. Thus, if hemicellulose and lignin are removed from the reinforce material, a large part of the biomass will remain unused. Moreover, during chemical treatment these organic compounds mixed with treating solution and produce large amount of waste water with very high BOD and COD. This highly polluted water cannot be discharged untreated, otherwise it will create huge water pollution problem. Treatment of such highly polluted waste water stream may significantly increase the cost of the composite manufacturing. Moreover, lignin present in waste water cannot easily decomposed by biological processes, and may require more energy incentive physical or chemical water treatment process.

Thus, if composite material is used as commodity product, not as the engineering product and does not require specific mechanical properties. Chemical treatment may not require at all. In this study, the biological and chemical oxygen demand of the waste water produced due to chemical treatment of bagasse are measured, which provides an idea about the energy requirement for treatment of waste water produced from the bagasse chemical treatment, then, the mechanical properties of the composite material with and without treated fibers are compared to investigate the requirement of treatment for different composite applications.

3. OBJECTIVE

Based on the literature survey the following objectives are chosen for this study

1. To determine the footprint of chemical treatment of bagasse fiber for composite preparation on environment.
2. To study the effects of bagasse fiber reinforcement in epoxy metric on its mechanical properties and thermal stability.
3. To determine the actual significance of chemical treatment of bagasse fiber for composite preparation in terms of mechanical properties and thermal stability.

4. MATERIAL SELECTION & METHODOLOGY

4.1 Material Selection

Epoxy is one of the most common resin often used in commodity as well as engineering products. Epoxy can be very easily processed and cured at room temperature. Moreover, it also shows very good mechanical properties. Commercially available Epoxy (Araldite LY556) with HY917 hardener is procured and used as matrix material in this study.

Bagasse is the solid biomass residue of sugarcane biomass (leftover after recovering the juice from the sugarcane juice. Bagasse is widely generated by sugar mills. In this study the raw bagasse was directly collected from a sugar mill. Fiber was initially washed with process water than dried in sun for 6 hr. followed by oven drying (for 24 hr. at 80 ^{o}C) to remove moisture from the fiber. The dried bagasse was then prepared in different length of 3 cm, 5 cm, and some were kept as their original length.

Figure 4.1: Bagasse fiber

Initially, Ethanol was used for neutralization of bagasse. 70% Ethanol solution was taken in (1:2.5) Fibers (kg) to ethanol (liter) ratio for neutralization. Neutralization prevents fiber from ferment. After this bagasse fiber was dried for 6 hours in open air and oven dried at 80°C for 24 hours. Then bagasse was soaked in 5 v/v% NaOH solution for 4 hours at 70°C. The quantity of alkaline solution used for soaking followed a ratio of 15 ml of alkaline solution to1 g of bagasse fibers. With the help of distilled water treated bagasse fiber was rinsed three times and to ensured water pH get 7 by pH meter. The treated sample was first drying in an open air for 6 hours followed by oven drying for 24 hr. at 80 ^oC. The dried bagasse was then prepared in different length of 3 cm, 5 cm, and some were kept as their original length.

4.2. Sample Preparation

4.2.1 Mold Making

1. Silicon resin is used to prepare the specimen.
2. Patri dish is used for making the silicon mold as outer surface controller in which resin is poured to take the shape of mold.
3. Silicon is mixed with hardener in Ratio of 100:4 ml.
4. 3 replicas of specimen are made by wax.
5. Then it will fix on surface of patri dish.
6. And then silicon is pore into patri dish.
7. It will take 24 hours to solidification of silicon, then mold is taken out from patri dish.

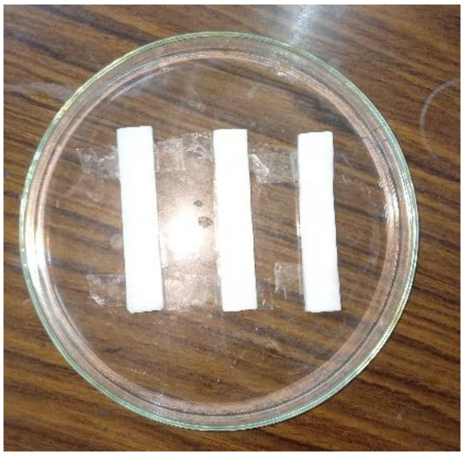


Fig.4.2. Making of mold

4.2.2. Specimen Making

1. After making of mold wax is applied on the surface of mold.
2. Epoxy and hardener is mixed in ratio of 2:1.
3. Then fiber is mixed in it according to the percentage required than pore into mold.
4. Epoxy need 24 hours solidify after that specimen is taken out and trimmed.

Fig.4.3. Sample making

4.3. TEST METHODS

4.3.1. Biological oxygen demand (BOD)

Biological oxygen demand measures the amount of oxygen (DO) required by bacteria in decomposition of organic substance present in water sample. The BOD test determines the effect that organic material present in sample effect DO of water bodies.

A. Seeding This is the process of adding live bacteria in water sample to tested.

B. Apparatus and reagents

1. Incubator
2. BOD bottles
3. Laboratory glassware.
4. Manganese sulphate (MnSO4)
5. Phosphate buffer (KH_2P0_4)
6. Calcium chloride ($CaCl_2$)
7. Ferric chloride solution ($FeCl_3.6H_20$)
8. Hydrochloric acid (HCl)
9. Sodium Hydroxide (NaOH)

D. Procedure

1. Solution of 2 ml magnesium sulphate, phosphate buffer, calcium chloride, and ferric chloride are prepared in 2 liters of distilled water.
2. 2 ml of seed was mixed in dilution water.
3. The pH of sample was neutralized 7 by 1n NaOH or HCl.
4. 0.1 ml of solution of waste stream was taken for experiment.
4. DO of dilution water and sample is checked by dissolved oxygen meter.
6. One set of the bottles of sample and dilution water placed incubator at 20℃ for 5 days.
7. Immediately after the completion of 5 days of incubation, the DO in the sample and dilution water was determined.

4.3.2. Chemical oxygen demand (COD)

Microorganism cannot oxidize or consume all impurities presence in waste water due to their toxic nature. These impurities can be decomposed by chemical oxidation.

Thus, the chemical oxygen demand (COD) is measured according to amount of a specific oxidizing agent that will reacts with water sample in controlled atmosphere.

Chemical oxygen demand (COD) mainly measure the required oxygen required for oxidize the biomass present in sample like potassium dichromate($K_2Cr_2O_7$) and potassium permanganate (KM_nO_4). COD values are always greater than the biochemical oxygen demand (BOD).

A. Apparatus. Digestion vessels; block heater; micro burette; ampule sealer. The heater is required for operating temperature of 150±2°C.

Reflux apparatus (250 – 500 ml).

Condenser

C. Reagents

A. Potassium dichromate (K2Cr2O7; 0.25N)

B. Mercuric sulphate (HgSO4)

C. Sulfuric acid (H2SO4)

D. Ferroin indicator

E. Ferrous ammonium sulphate (Fe (NH4)2(SO4)2.6H2O)

D. Procedure

1. Take 10 ml of distilled water and 1 ml of sample in reflux flax.
2. Add 1 gm of silver sulphate (AgSO4) and mercury sulphate (HgSO4) both.
3. Add 50 ml of N/4 potassium dichromate solution(K2Cr2O7).
4. Mix 30 ml sulfuric acid(H2SO4).
5. Add 50 ml of N/4 potassium dichromate solution.
6. Place sample in culture tube and heat the flask on heating mantle for 24 hours to reflux the contents.
7. After cooling the flask, add 4-5 drops of ferroin indicator and titrate the solution with ferrous ammonium sulphate.
8. Reading was taken when blue green color change reddish blue color.

4.3.3. Thermal Gravimetric Testing

Thermal stability of treated and untreated fibers are analyzed by Thermal gravimetric analysis (TGA) method, experiment were run in nitrogen environment with heating rate of 2 ºC per minute.

4.3.4 Mechanical Testing Tensile Strength (ASTM D 638)

Mechanical properties of different composite samples were measured according to standard ASTM standards as follows

1. Tensile Testing (ASTM D 638)
2. Flexural Testing (ASTM D790)
3. Impact Testing (ASTM D256)
4. Hardness Testing (ASTM D 2240)

5. RESULT AND DISCUSSION

5.1. Biological Oxygen Demand

Table 8.1. Readings of BOD test

Value	Seed Material	Reference sample
Volume used	0.1	0.1
Initial DO	7	2
Final DO	5	4

$$\textbf{BOD} = \frac{D1 - D2 \times 300}{\text{Sample Volume, mL}}$$

Where, D1= Difference in initial DO
D2= Difference in final DO

BOD= 1200 mL/L

5.2 Chemical Oxygen Demand

$$\textbf{COD} = \frac{(B - A) \times N \times 1000 \times 8}{V}$$

Where, A = Titrant used against sample (30 ml)
B = Titrant used against blank (1ml)
N = Normality of titrant (0.25)
V = Volume of the sample (1ml)

COD = 5800 mL/L

Results show that BOD and COD of the waste water stream from bagasse treatment are too high. 1 kg of fibre produces 15 litter of waste water. The difference between the BOD and COD values may be due to the presence of lignin in the waste water. These aromatic compounds are generally hard to decompose by biological processes and requires chemical treatment.

This result indicates that the chemical pre-treatment of bagasse produces the waste water stream with high BOD and COD. This stream may require large amount of energy for treatment, which may significantly increase the fixed and running cost of the plant and adversely affect the economy of the unit.

Therefore, mechanical and chemical properties of the composites with untreated and treated fibres are further analysed to investigate the significance of the chemical pre-treatment of the bagasse.

5.3. Thermal Gravimetric Analysis (TGA)

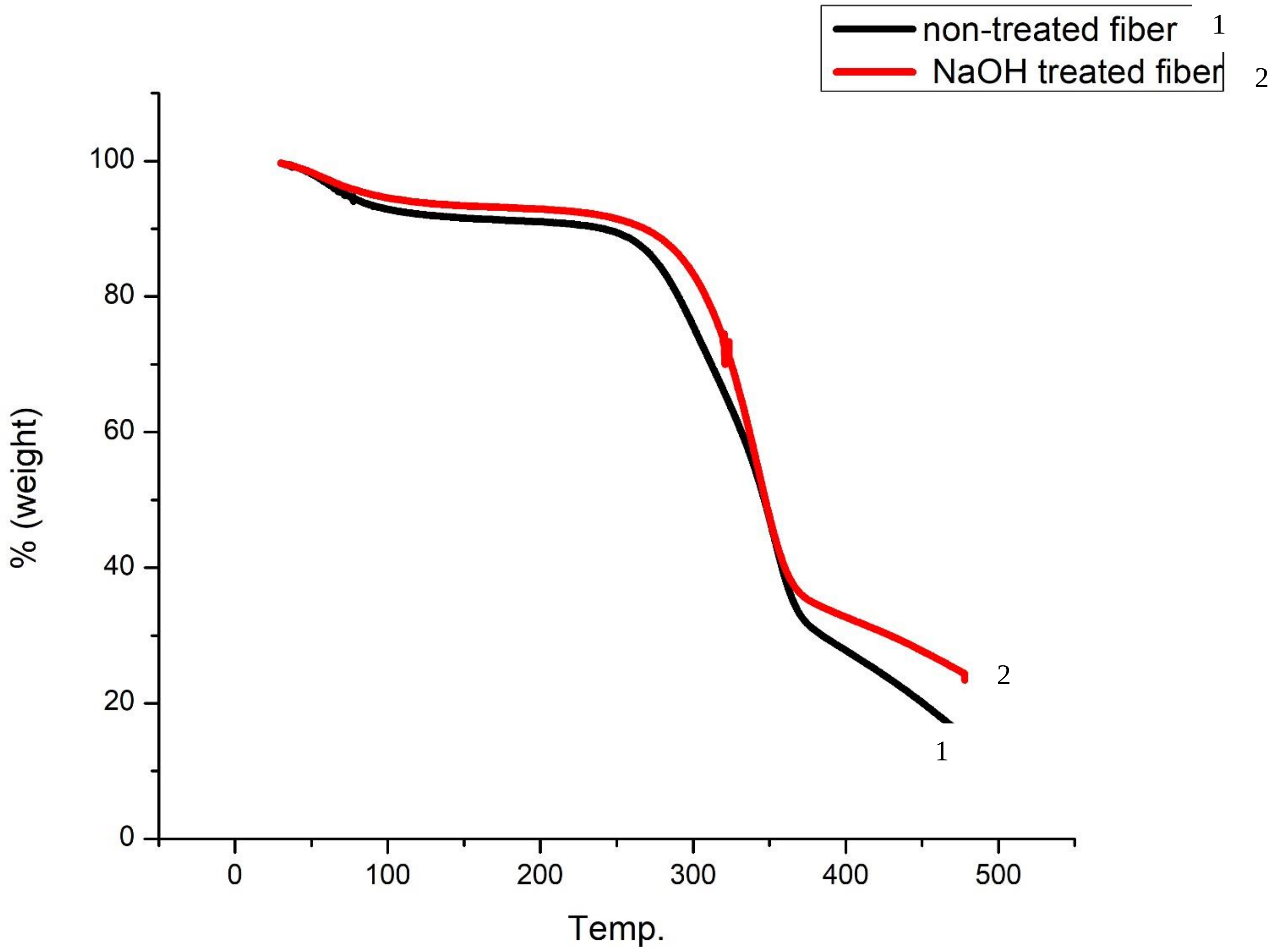


Fig.5.1. TGA graph of Non-treated and Treated Fiber.

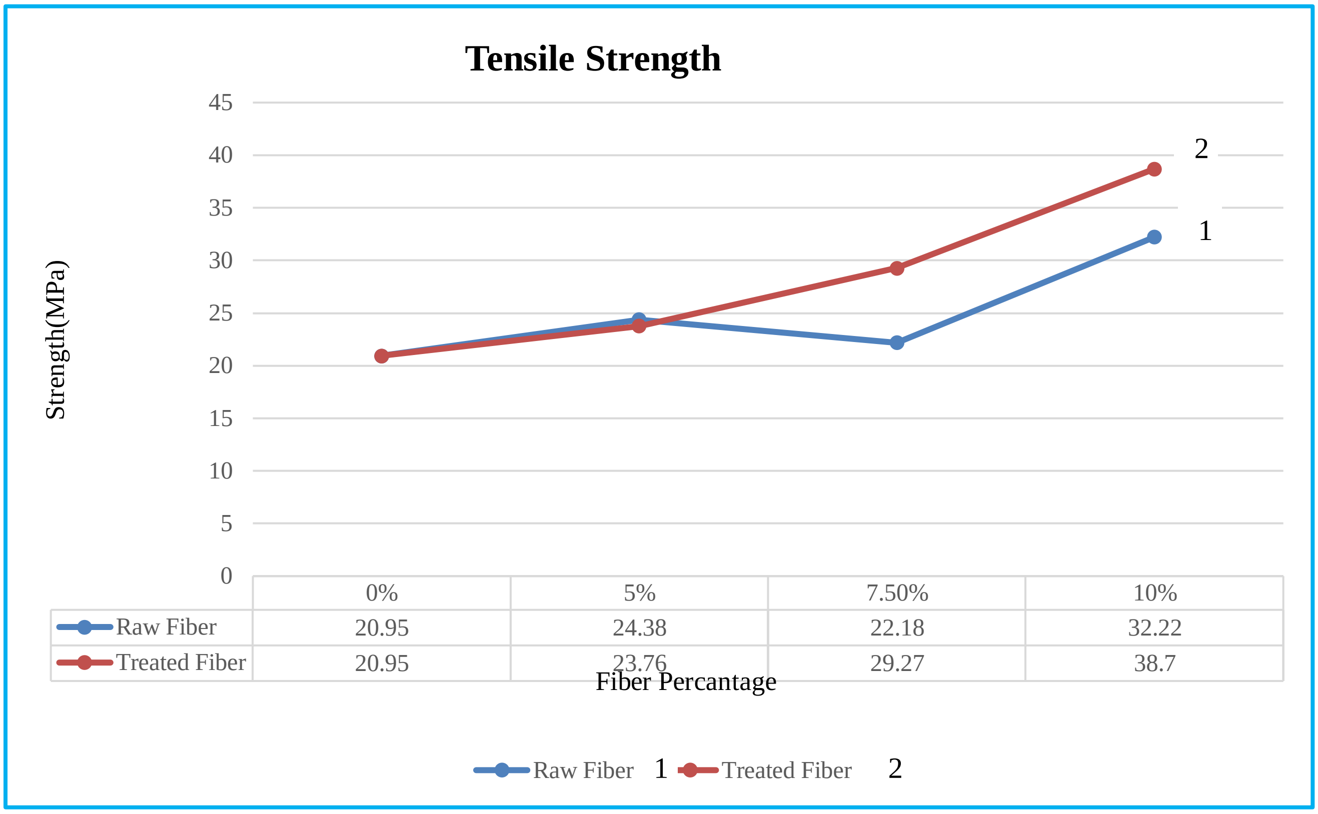
TGA results show that the treated fibers are thermally more stable as degradation temperature (253℃) of treated fibers are slightly higher than the degradation temperature (274℃) of untreated fibers. However, both samples are stable at the room temperature. Thus, these results show that chemical treatment is not required if the bagasse based composite material is processed and used at temperature range from 0 ℃ to 250℃ temperature.

Results also show that untreated bagasse contains more inorganic minerals in comparison to treated chemically treated bagasse sample. However, it may not affect the end use of composite material, if they are not used in adverse chemical environment.

5.4. Tensile strength of composites

The tensile strength for composite gradually decreased with an increase in fiber percentage loading. Strength of material is due to reinforcement of composite in to epoxy matrix, strength is also depending on bonding strength of fiber and epoxy interface. Increase in strength due to fiber strength which work as strength modifier.

5.4.1. Comparison of tensile strength of raw and treated fiber composite



	0%	5%	7.50%	10%
Raw Fiber	20.95	24.38	22.18	32.22
Treated Fiber	20.95	23.76	29.27	38.7

Fig 5.2. Comparison of tensile strength of raw and treated fiber composite (Raw fiber 1 and Treated fiber 2)

2

5.4.2. Comparison of tensile modulus of raw and treated fiber composite

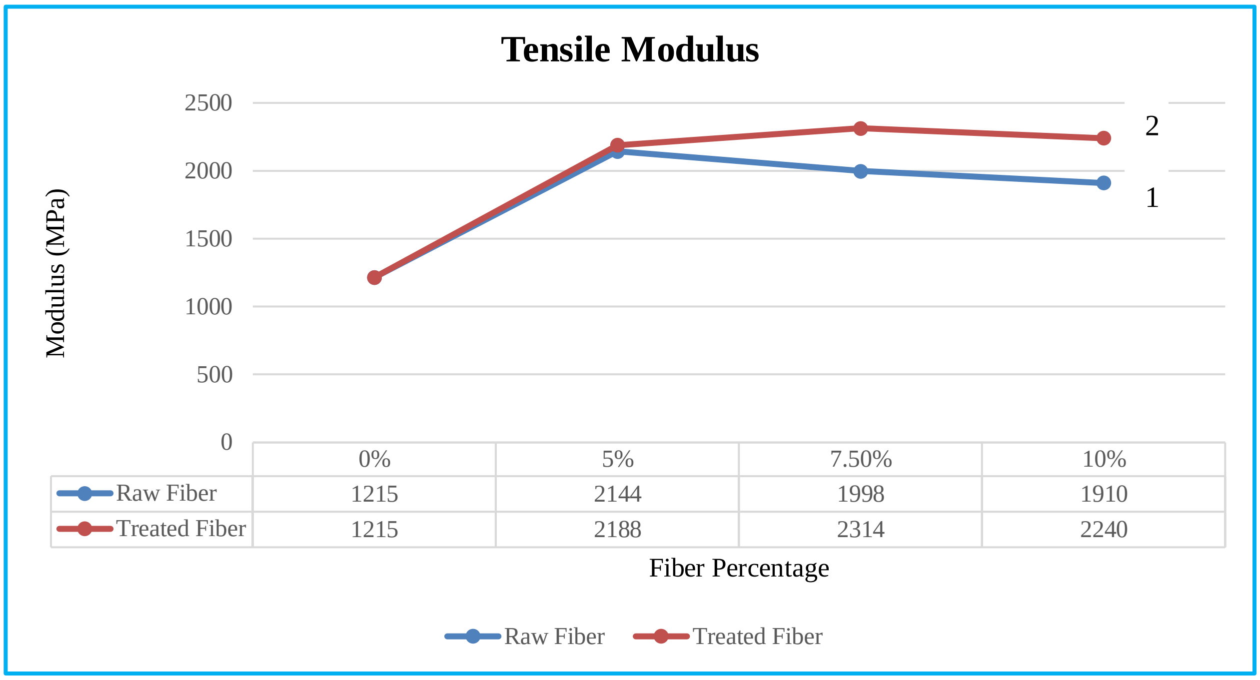


Fig 5.3. Comparison of tensile modulus of raw and treated fiber composite (Raw fiber 1 and Treated fiber 2)

5.4.3. Comparison of tensile strain of raw and treated fiber composite

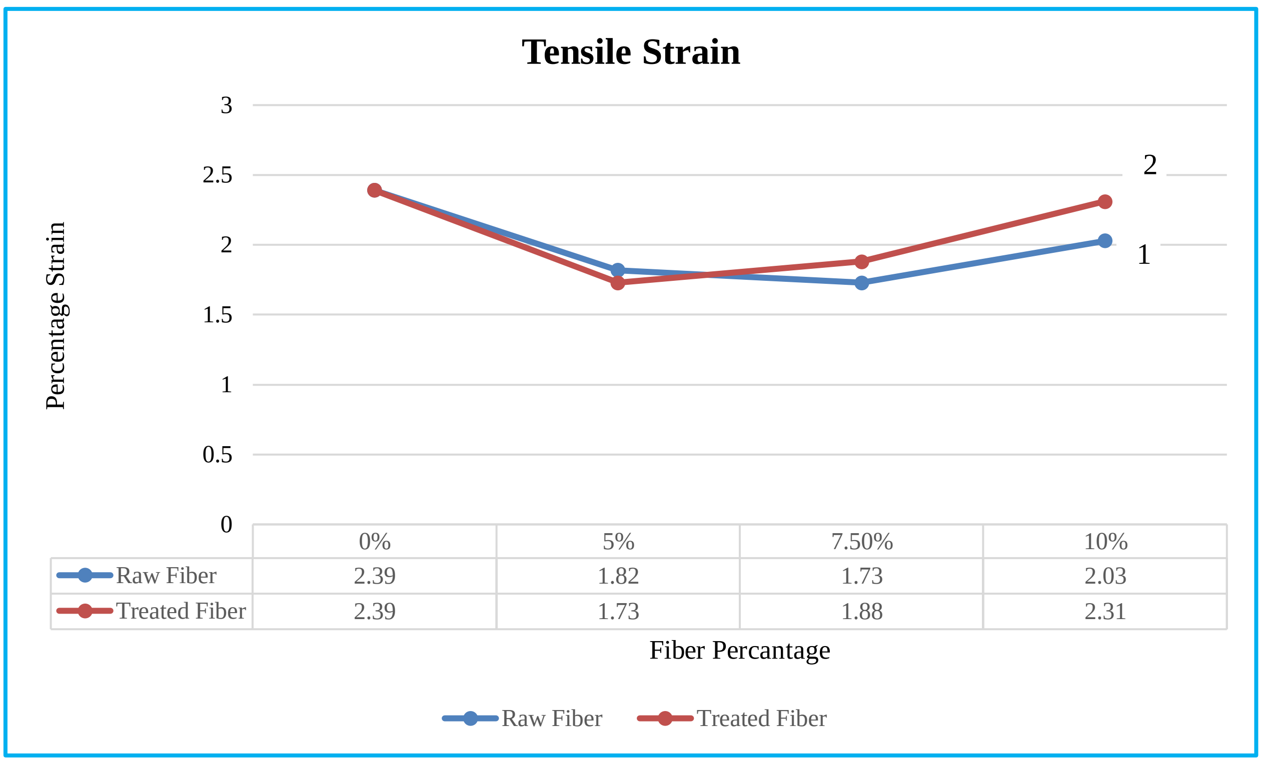


Fig 5.4. Comparison of tensile strain of raw and treated fiber composite (Raw fiber 1 and Treated fiber 2)

Tensile test results of treated fiber are better, it gives higher strength to composite in every aspect. Treated fibers gives better reinforcement to composite than untreated fiber. Tensile strength of treated fiber composite is more than 20% higher than untreated fiber composite. Modulus of treated fiber composite is 15% higher also.

Elongation of treated fiber is also high than raw fiber composite that's mains composite will much flexible and ductile. As results, toughness of composite will also high that's another a good aspect for the treated fiber composite.

Untreated and treated fibres are further analysed to investigate the significance of the chemical pre-treatment of the bagasse in respect to flexural, impact and hardness properties of the composites.

5.5. Flexural Strength of Composites

Flexural strength and modulus of Epoxy/bagasse composites is different at different fiber loading. The result showed that the flexural strength increases with increased treated fiber and decrease in untreated fiber loading.

5.5.1. Comparison of Flexural strength of raw and treated fiber composite

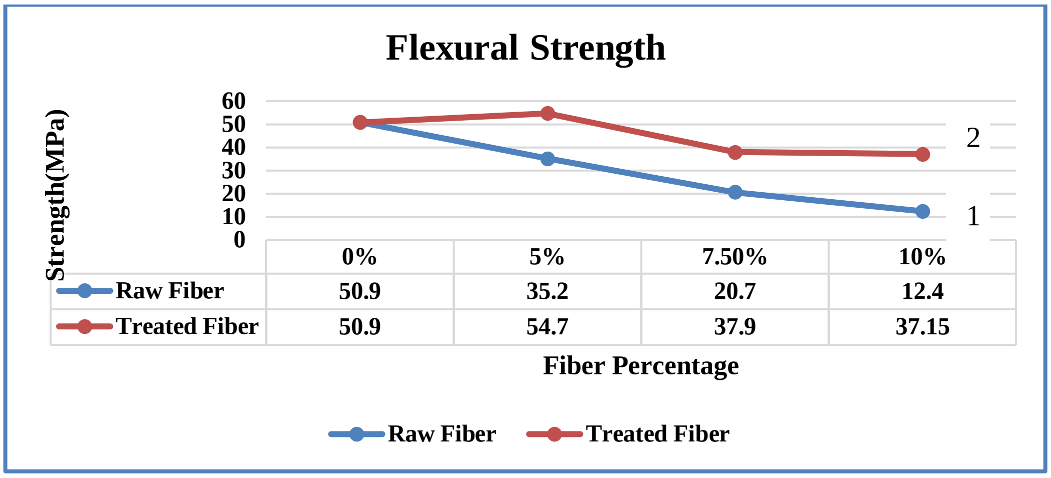


Fig 5.5. Comparison of Flexural strength of raw and treated fiber composite. (Raw fiber 1 and Treated fiber 2)

5.5.2. Comparison of flexural modulus of raw and treated fiber composite

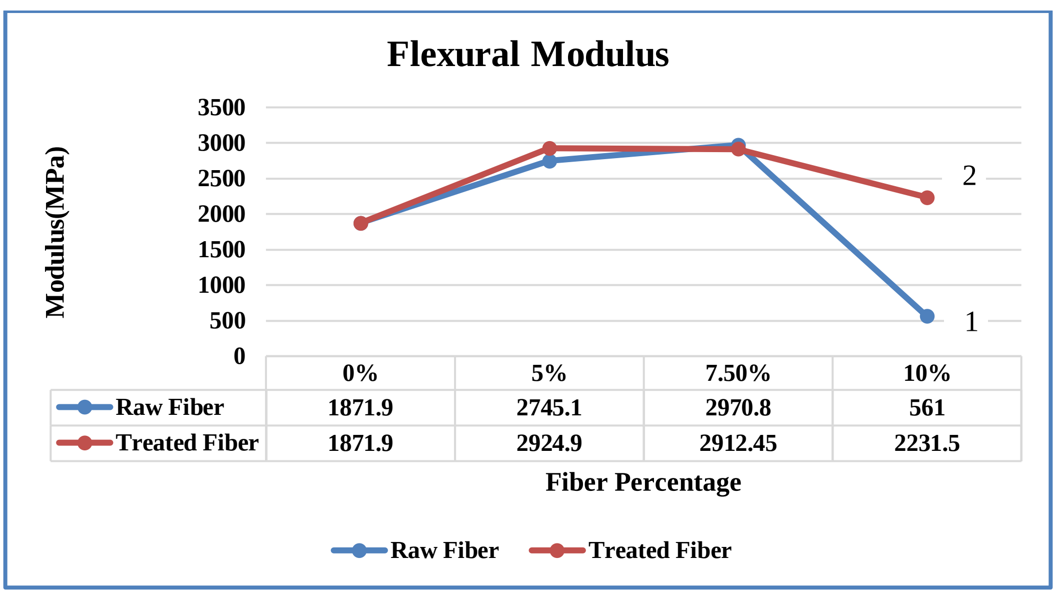


Fig 5.6. Comparison of flexural modulus of raw and treated fiber composite. (Raw fiber 1 and Treated fiber 2)

As per results of flexural properties of both types of composite, flexural strength of composites is decrease as increase in fiber percentage. However, strength of treated fiber composites are found higher than strength of raw fiber based composites. Flexural modulas are found nearly same for both types of composite materials

5.6. Impact strength of composite

The Impact strength of composite is increase when adding small amount of fiber (up to 5%) because it resists to moment of dislocation. If percentage of fiber is increasing further the impact strength is decrease gradually.

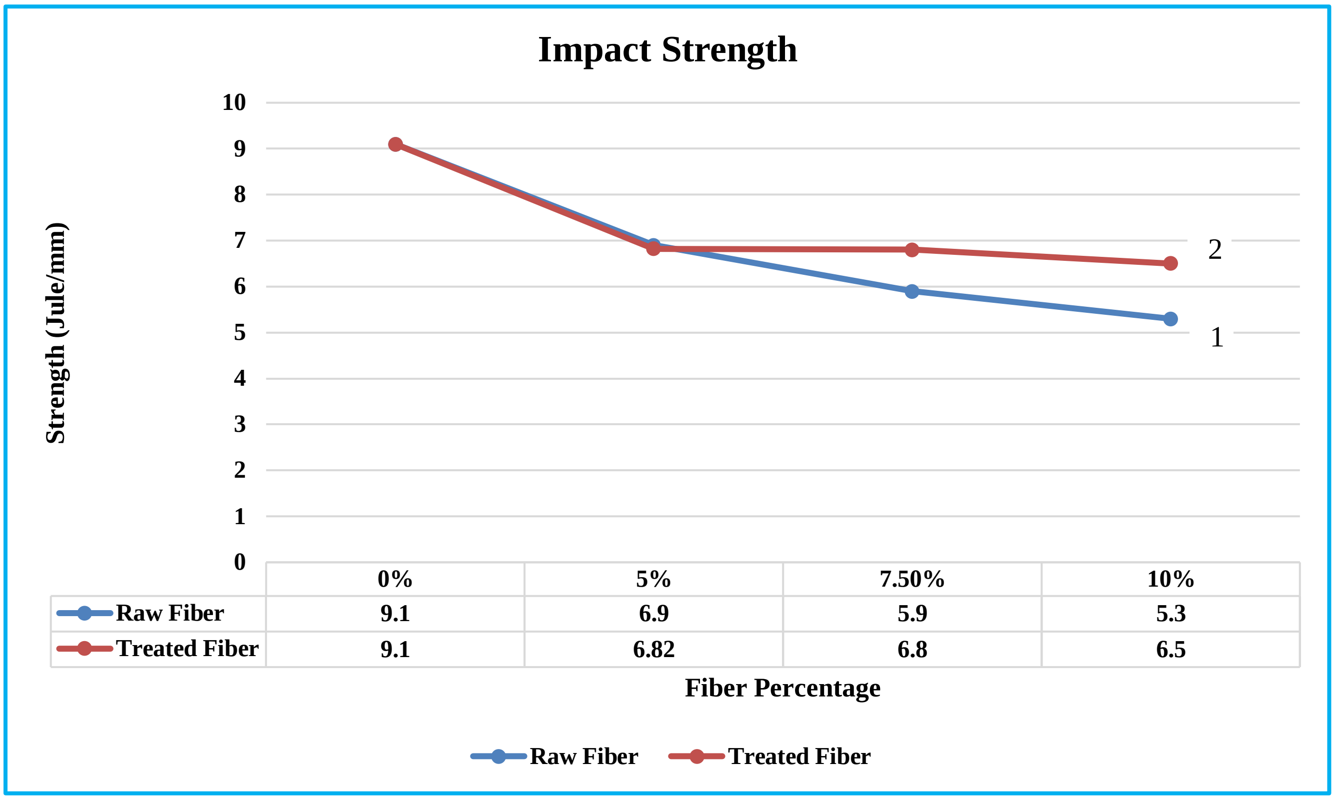


Fig 5.7. Impact strength of raw and treated fiber composites. (Raw fiber 1 and Treated fiber 2)

Results of impact strength shows that, strength of composite is decreased in both fiber composite. However, chemical treatment only improves impact strength slightly as the impact strength of both types and samples are found nearly same.

5.7. Hardness of composites

It is observed that the fiber exhibited better hardness compared to raw ones at all filler. Further, there was considerable decrease in the hardness for the composites.

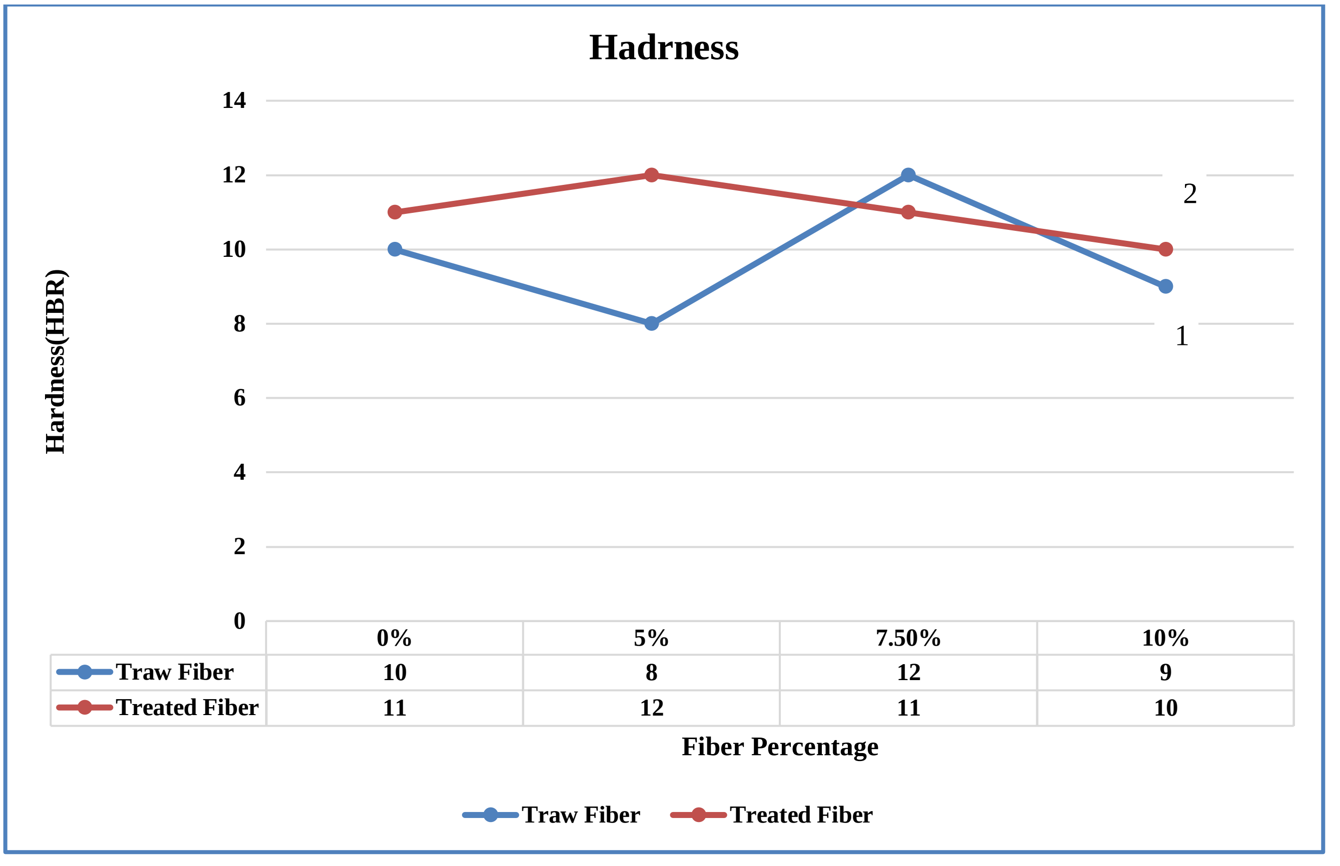


Fig 5.8. Hardness of raw and treated fiber composites. (Raw fiber 1 and Treated fiber 2)

Results shows that Hardness of composite is not get affected in significant amount, maximum strength is fund at 5% in treated and 7.5% in raw fiber composite. Results also show that chemical treatment does not improve the hardness of the composite material. Hardness will not affect the end application because fibers are having much wear resistance than pure epoxy.

6. CONCLUSION

This Study showed that chemical treatment of bagasse for removal of hemicellulose and lignin will generate large amount of waste water stream which has very have BOD and even around 5 times more COD. Thus, such waste water may require large amount of energy to treat it. On the other hand, tensile and flexural properties of composite made by treated fibers are higher than the mechanical properties of the composites made by untreated fiber. However, Chemical treatment does not affect the flexural modulus, impact and hardness properties of the composite material. Moreover, TGA test shows that both types of composite materials are nearly equally stable at room temperature. Thus results suggests that the composites made with epoxy/untreated bagasse fiber have significantly good properties for manufacturing the various commodity products, and chemical treatment of fibers is not required in this case.

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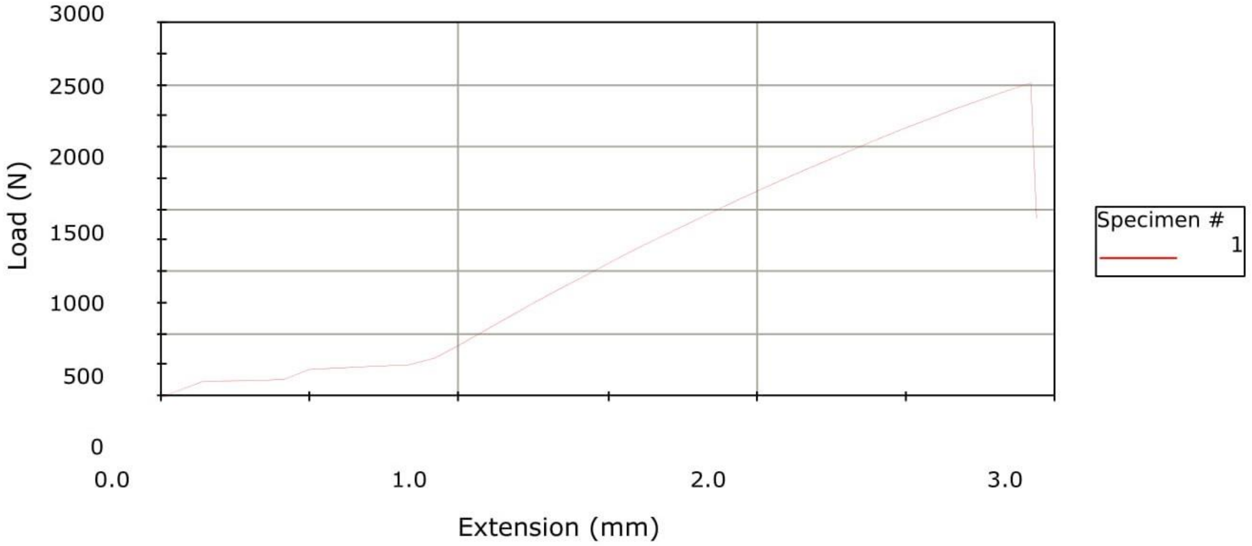
APPINDEX

1. Test results of tensile properties

(1) 10% Raw fiber Composite (Sc. no. 1817-19), Tensile Properties.

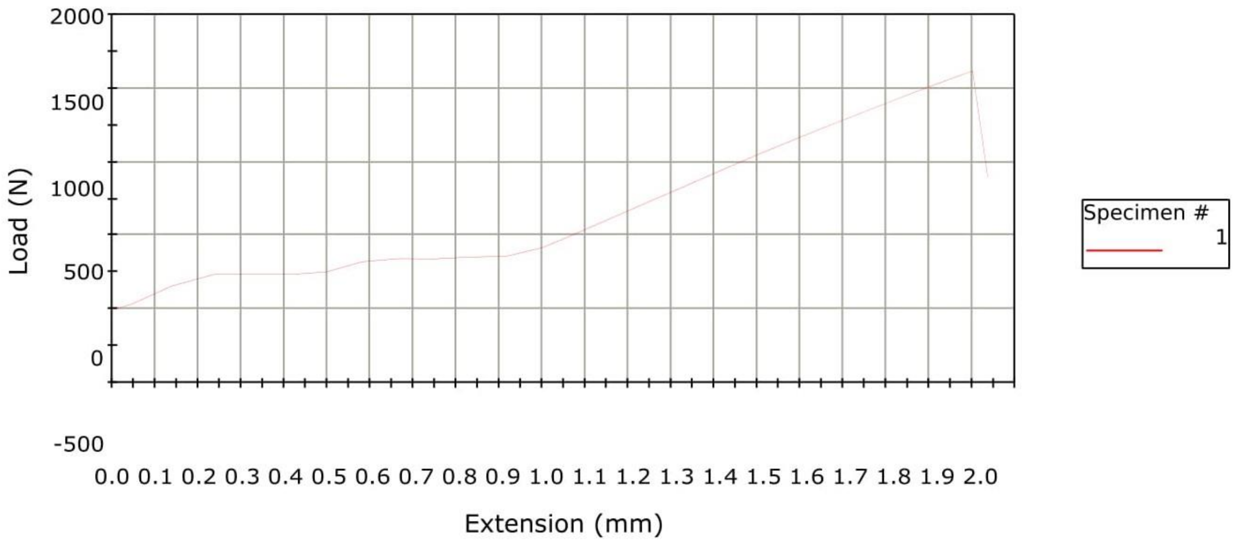


	Maximum Load (N)	Tensile stress at Maximum Load (MPa)	Tensile strain at Maximum Load (%)	Tensile extension at Maximum Load (mm)
1	2511.808	32.222	2.036	2.91665
Coefficient of Variation	-----	-----	-----	-----
Maximum	2511.808	32.222	2.036	2.91665
Mean	2511.808	32.222	2.036	2.91665
Minimum	2511.808	32.222	2.036	2.91665
Standard Deviation	-----	-----	-----	-----

	Modulus (Automatic) (MPa)	Tensile stress at Yield (Zero Slope) (MPa)	Load at Yield (Zero Slope) (N)
1	1910.559	-----	-----
Coefficient of Variation	-----	-----	-----
Maximum	1910.559	-----	-----
Mean	1910.559	-----	-----
Minimum	1910.559	-----	-----
Standard Deviation	-----	-----	-----

Fig 11.1 Tensile properties of 10% raw fiber composite.

(2) 7.5% Raw Fiber Composites, Sc. no. 1818-19 Tensile Properties.

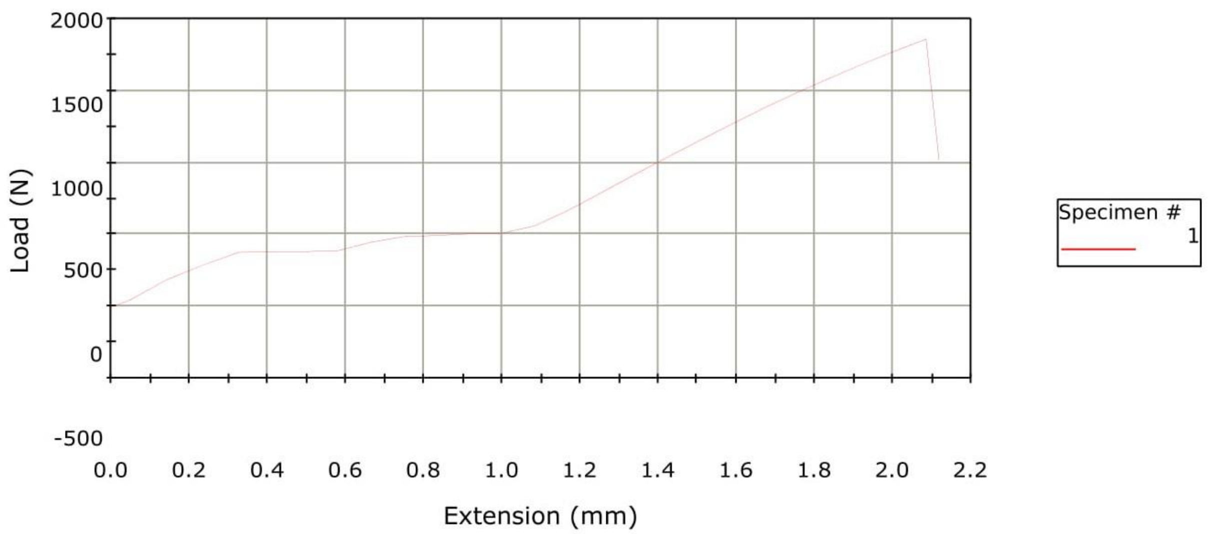


	Maximum Load (N)	Tensile stress at Maximum Load (MPa)	Tensile strain at Maximum Load (%)	Tensile extension at Maximum Load (mm)
1	1613.783	22.178	1.739	2.00002
Coefficient of Variation	-----	-----	-----	-----
Maximum	1613.783	22.178	1.739	2.00002
Mean	1613.783	22.178	1.739	2.00002
Minimum	1613.783	22.178	1.739	2.00002
Standard Deviation	-----	-----	-----	-----

	Modulus (Automatic) (MPa)	Tensile stress at Yield (Zero Slope) (MPa)	Load at Yield (Zero Slope) (N)
1	1998.513	-----	-----
Coefficient of Variation	-----	-----	-----
Maximum	1998.513	-----	-----
Mean	1998.513	-----	-----
Minimum	1998.513	-----	-----
Standard Deviation	-----	-----	-----

Fig 11.2 Tensile properties of 7.5% raw fiber composite.

(3) 5% Raw fiber Composite, Sc. no. 1819-19 Tensile Properties.

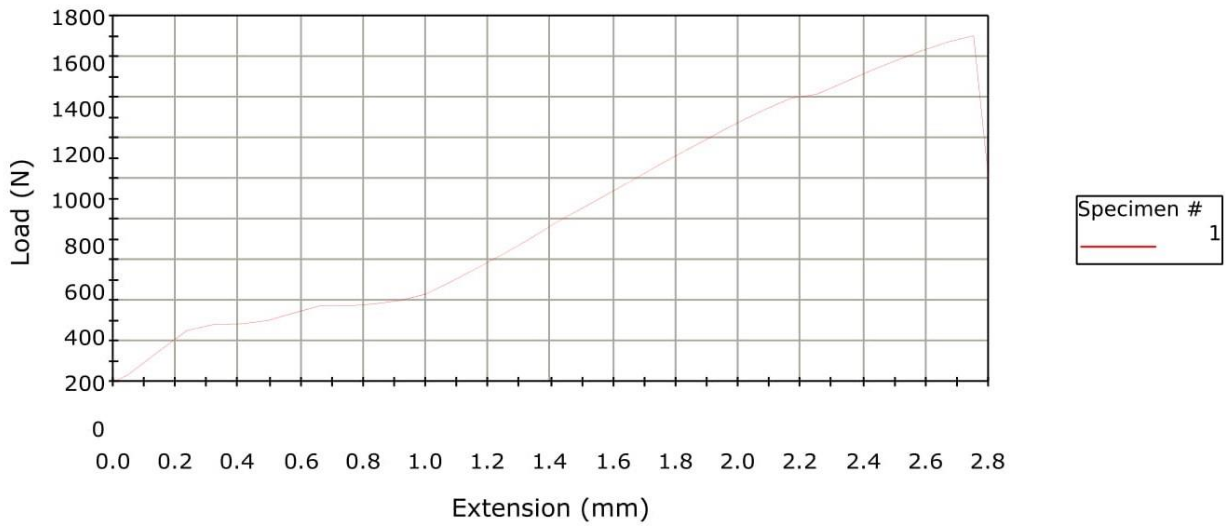


	Maximum Load (N)	Tensile stress at Maximum Load (MPa)	Tensile strain at Maximum Load (%)	Tensile extension at Maximum Load (mm)
1	1852.804	24.385	1.812	2.08336
Coefficient of Variation	-----	-----	-----	-----
Maximum	1852.804	24.385	1.812	2.08336
Mean	1852.804	24.385	1.812	2.08336
Minimum	1852.804	24.385	1.812	2.08336
Standard Deviation	-----	-----	-----	-----

	Modulus (Automatic) (MPa)	Tensile stress at Yield (Zero Slope) (MPa)	Load at Yield (Zero Slope) (N)
1	2144.835	-----	-----
Coefficient of Variation	-----	-----	-----
Maximum	2144.835	-----	-----
Mean	2144.835	-----	-----
Minimum	2144.835	-----	-----
Standard Deviation	-----	-----	-----

Fig 11.3 Tensile properties of 5% raw fiber composite.

(4) Pure Epoxy, (Sc.no. 1820-19) Tensile Properties.

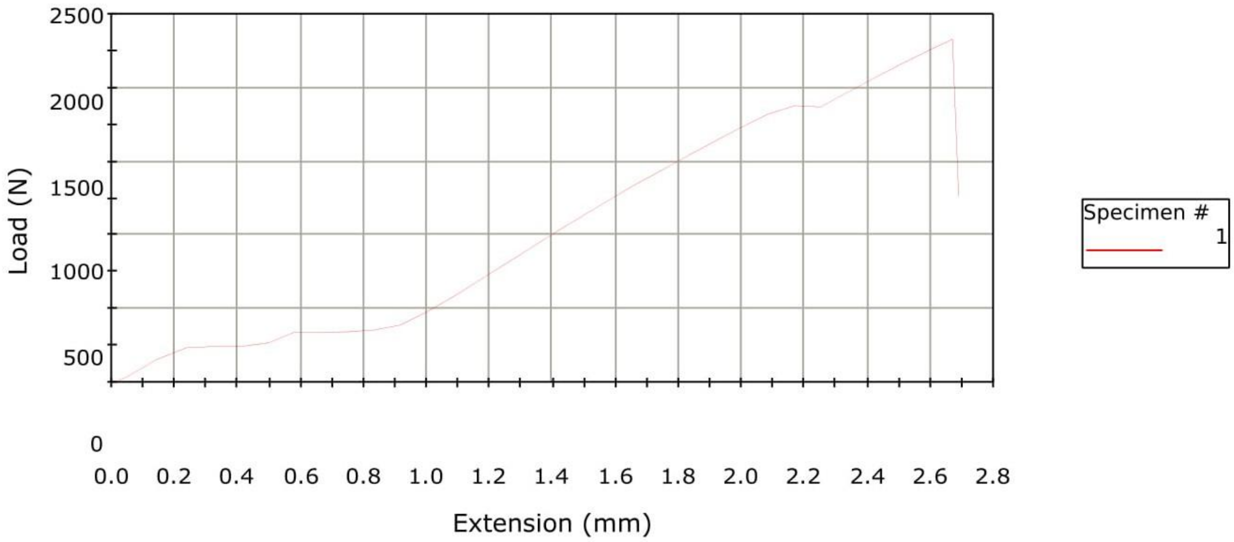


	Maximum Load (N)	Tensile stress at Maximum Load (MPa)	Tensile strain at Maximum Load (%)	Tensile extension at Maximum Load (mm)
1	1700.028	20.952	2.391	2.75002
Coefficient of Variation	-----	-----	-----	-----
Maximum	1700.028	20.952	2.391	2.75002
Mean	1700.028	20.952	2.391	2.75002
Minimum	1700.028	20.952	2.391	2.75002
Standard Deviation	-----	-----	-----	-----

	Modulus (Automatic) (MPa)	Tensile stress at Yield (Zero Slope) (MPa)	Load at Yield (Zero Slope) (N)
1	1215.260	-----	-----
Coefficient of Variation	-----	-----	-----
Maximum	1215.260	-----	-----
Mean	1215.260	-----	-----
Minimum	1215.260	-----	-----
Standard Deviation	-----	-----	-----

Fig 11.4 Tensile properties of pure epoxy.

(5) 10% Treated fiber Composite (Sc.no. 1821-19), Tensile Properties.

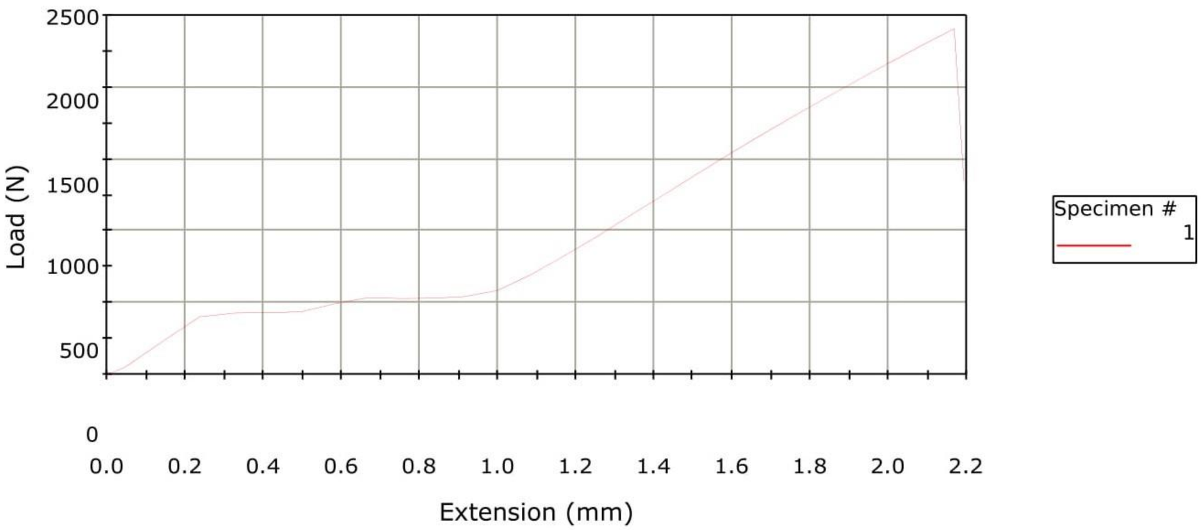


	Maximum Load (N)	Tensile stress at Maximum Load (MPa)	Tensile strain at Maximum Load (%)	Tensile extension at Maximum Load (mm)
1	2324.634	38.705	2.319	2.66673
Coefficient of Variation	-----	-----	-----	-----
Maximum	2324.634	38.705	2.319	2.66673
Mean	2324.634	38.705	2.319	2.66673
Minimum	2324.634	38.705	2.319	2.66673
Standard Deviation	-----	-----	-----	-----

	Modulus (Automatic) (MPa)	Tensile stress at Yield (Zero Slope) (MPa)	Load at Yield (Zero Slope) (N)
1	2240.087	-----	-----
Coefficient of Variation	-----	-----	-----
Maximum	2240.087	-----	-----
Mean	2240.087	-----	-----
Minimum	2240.087	-----	-----
Standard Deviation	-----	-----	-----

Fig 11.5 Tensile properties of 10% treated fiber composite.

(6) 7.5% Treated fiber Composite (Sc.no. 1822-19), Tensile Properties.

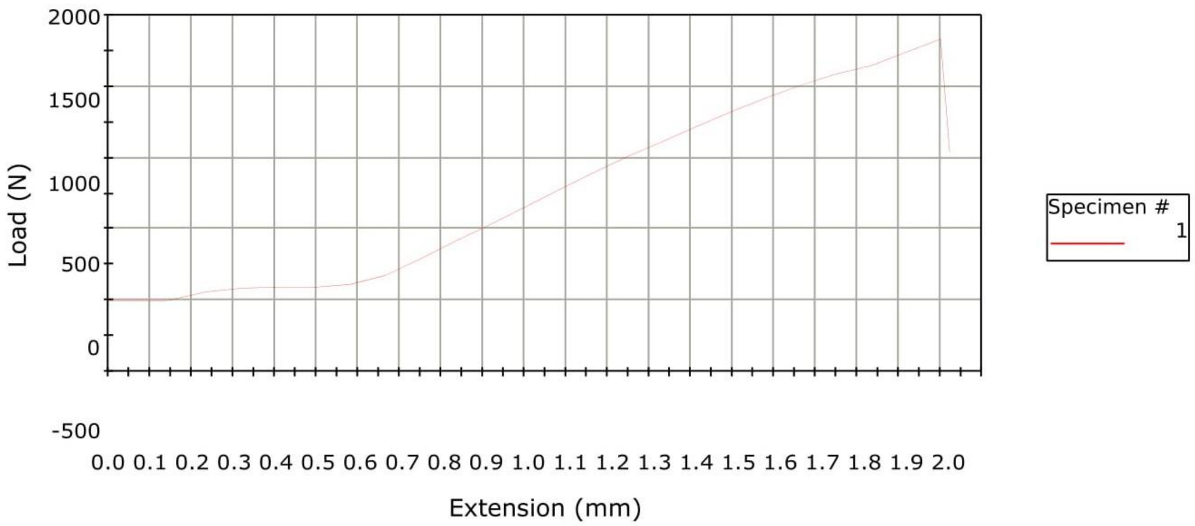


	Maximum Load (N)	Tensile stress at Maximum Load (MPa)	Tensile strain at Maximum Load (%)	Tensile extension at Maximum Load (mm)
1	2403.848	29.276	1.884	2.16665
Coefficient of Variation	-----	-----	-----	-----
Maximum	2403.848	29.276	1.884	2.16665
Mean	2403.848	29.276	1.884	2.16665
Minimum	2403.848	29.276	1.884	2.16665
Standard Deviation	-----	-----	-----	-----

	Modulus (Automatic) (MPa)	Tensile stress at Yield (Zero Slope) (MPa)	Load at Yield (Zero Slope) (N)
1	2314.850	-----	-----
Coefficient of Variation	-----	-----	-----
Maximum	2314.850	-----	-----
Mean	2314.850	-----	-----
Minimum	2314.850	-----	-----
Standard Deviation	-----	-----	-----

Fig. 11.6 Tensile properties of 7.5% treated fiber composite.

(7) 5% Treated fiber Composite (Sc.no. 1823-19), Tensile Properties.



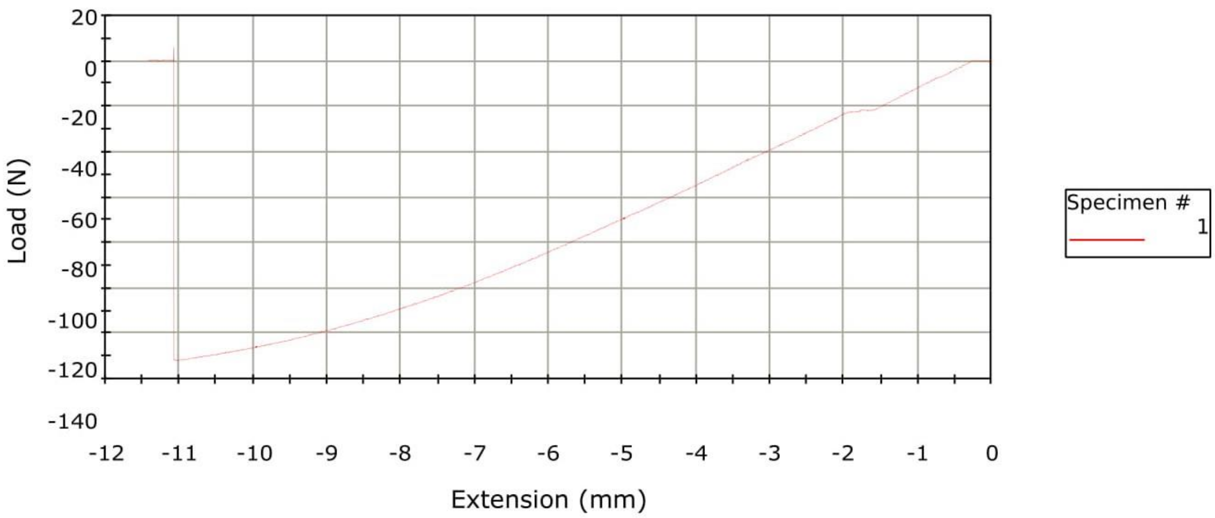
	Maximum Load (N)	Tensile stress at Maximum Load (MPa)	Tensile strain at Maximum Load (%)	Tensile extension at Maximum Load (mm)
1	1827.267	23.758	1.739	1.99996
Coefficient of Variation	-----	-----	-----	-----
Maximum	1827.267	23.758	1.739	1.99996
Mean	1827.267	23.758	1.739	1.99996
Minimum	1827.267	23.758	1.739	1.99996
Standard Deviation	-----	-----	-----	-----

	Modulus (Automatic) (MPa)	Tensile stress at Yield (Zero Slope) (MPa)	Load at Yield (Zero Slope) (N)
1	2188.672	-----	-----
Coefficient of Variation	-----	-----	-----
Maximum	2188.672	-----	-----
Mean	2188.672	-----	-----
Minimum	2188.672	-----	-----
Standard Deviation	-----	-----	-----

Fig 11.7 Tensile properties of 5% treated fiber composite.

11.2 Test reasults of flexural properties

(8) 0% Fiber Pure Epoxy (Sc.no. 1824-19), Flexural Properties.

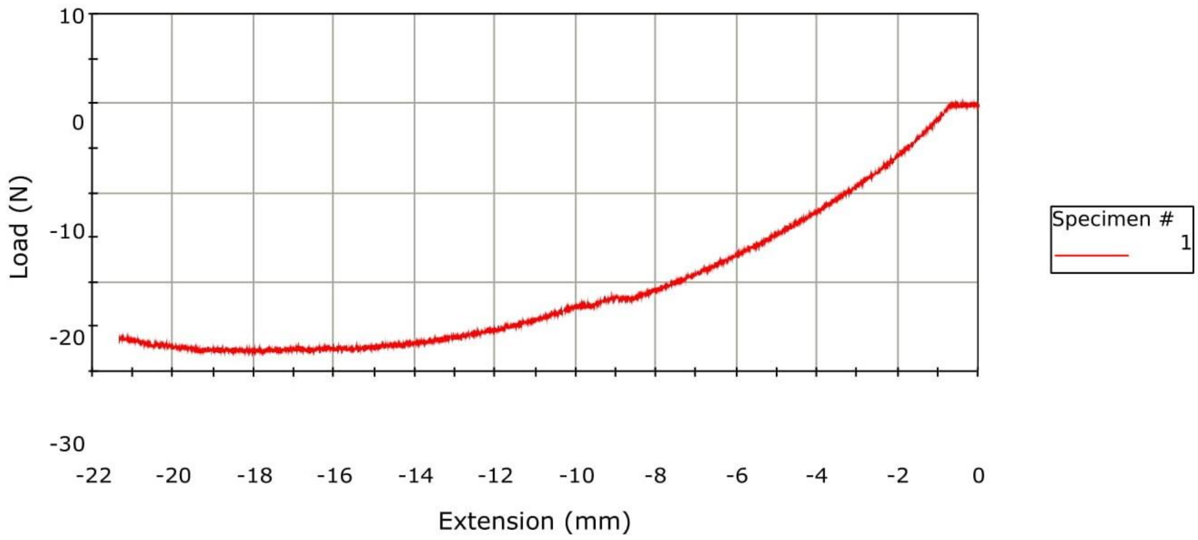


	Maximum Load (N)	Flexure stress at Maximum Load (MPa)	Maximum Flexure load (N)	Modulus (Automatic) (MPa)
1	5.833	-2.255	131.733	1871.976
Coefficient of Variation	-----	-----	-----	-----
Maximum	5.833	-2.255	131.733	1871.976
Mean	5.833	-2.255	131.733	1871.976
Minimum	5.833	-2.255	131.733	1871.976
Standard Deviation	-----	-----	-----	-----

	Flexure stress at Maximum Flexure load (MPa)
1	50.938
Coefficient of Variation	-----
Maximum	50.938
Mean	50.938
Minimum	50.938
Standard Deviation	-----

Fig 11.8 Flexural properties of pure epoxy.

(9) 10% Raw Fiber Composite (Sc. no. 1825-19), Flexural Properties.

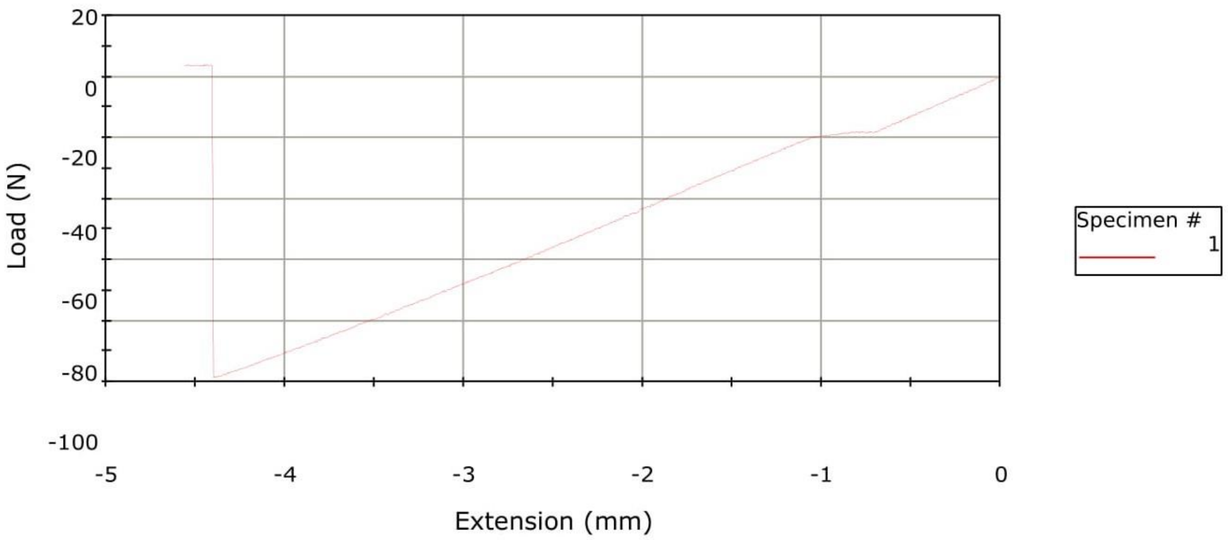


	Maximum Load (N)	Flexure stress at Maximum Load (MPa)	Maximum Flexure load (N)	Modulus (Automatic) (MPa)
1	0.207	-0.092	27.912	561.383
Coefficient of Variation	-----	-----	-----	-----
Maximum	0.207	-0.092	27.912	561.383
Mean	0.207	-0.092	27.912	561.383
Minimum	0.207	-0.092	27.912	561.383
Standard Deviation	-----	-----	-----	-----

	Flexure stress at Maximum Flexure load (MPa)
1	12.423
Coefficient of Variation	-----
Maximum	12.423
Mean	12.423
Minimum	12.423
Standard Deviation	-----

Fig 11.9 Tensile properties of 10% raw fiber composite.

(10) 5% Raw Fiber Composite (Sc.no. 1826-19), Flexural Properties.

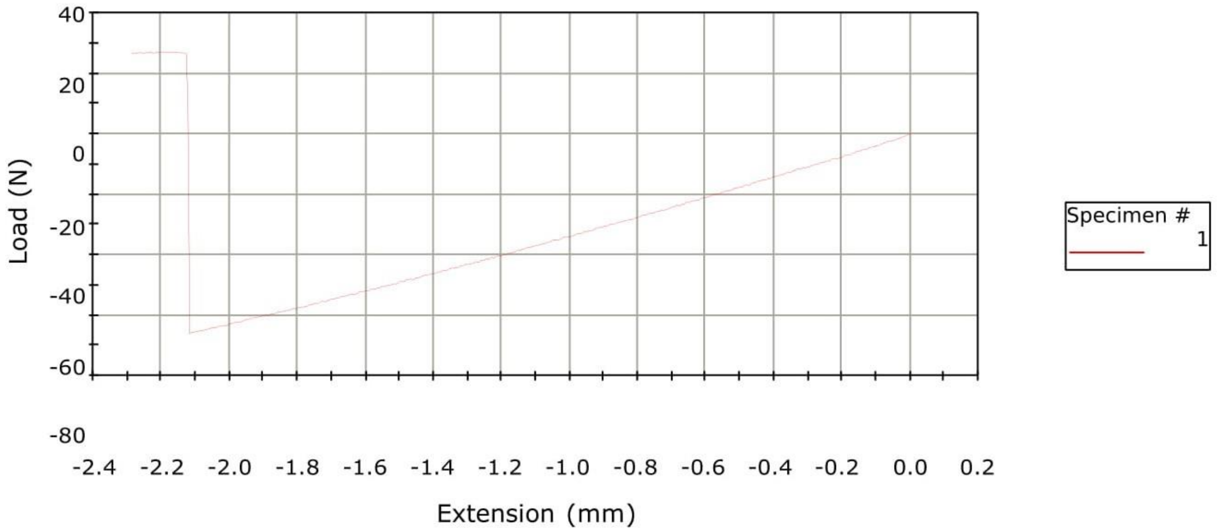


	Maximum Load (N)	Flexure stress at Maximum Load (MPa)	Maximum Flexure load (N)	Modulus (Automatic) (MPa)
1	3.829	-1.370	98.364	2745.007
Coefficient of Variation	-----	-----	-----	-----
Maximum	3.829	-1.370	98.364	2745.007
Mean	3.829	-1.370	98.364	2745.007
Minimum	3.829	-1.370	98.364	2745.007
Standard Deviation	-----	-----	-----	-----

	Flexure stress at Maximum Flexure load (MPa)
1	35.201
Coefficient of Variation	-----
Maximum	35.201
Mean	35.201
Minimum	35.201
Standard Deviation	-----

Fig 11.10 Tensile properties of 5% raw fiber composite.

(11) 7.5% Raw Fiber Composite (Sc.no. 1827-19), Flexural Properties.

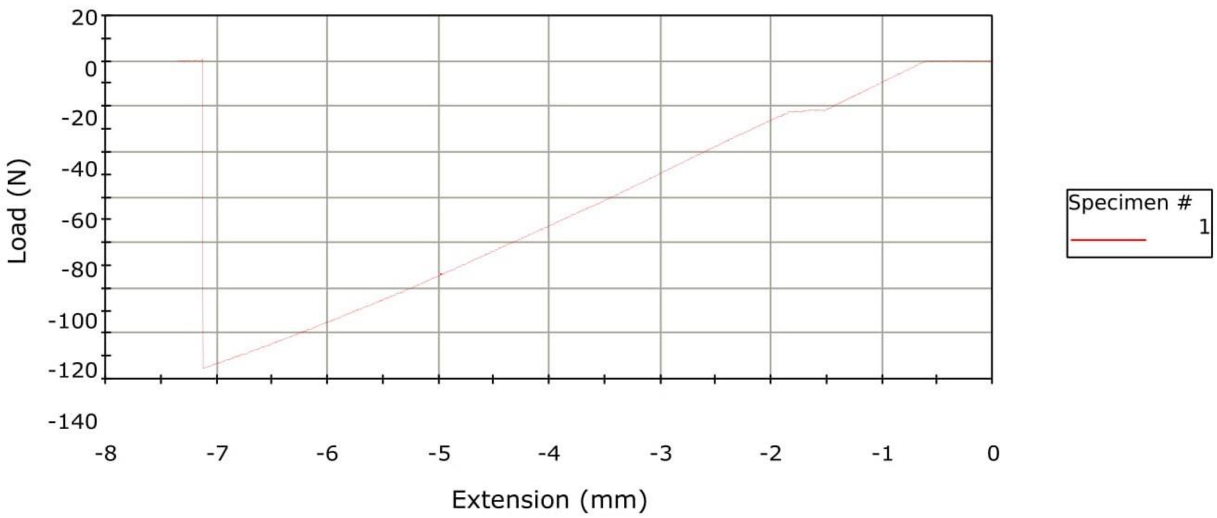


	Maximum Load (N)	Flexure stress at Maximum Load (MPa)	Maximum Flexure load (N)	Modulus (Automatic) (MPa)
1	26.989	-8.495	65.818	2970.861
Coefficient of Variation	-----	-----	-----	-----
Maximum	26.989	-8.495	65.818	2970.861
Mean	26.989	-8.495	65.818	2970.861
Minimum	26.989	-8.495	65.818	2970.861
Standard Deviation	-----	-----	-----	-----

	Flexure stress at Maximum Flexure load (MPa)
1	20.716
Coefficient of Variation	-----
Maximum	20.716
Mean	20.716
Minimum	20.716
Standard Deviation	-----

Fig 11.11 Tensile properties of 7.5% raw fiber composite.

(12) 5% Treated Fiber Composite (Sc. no. 1828-19), Flexural Properties.

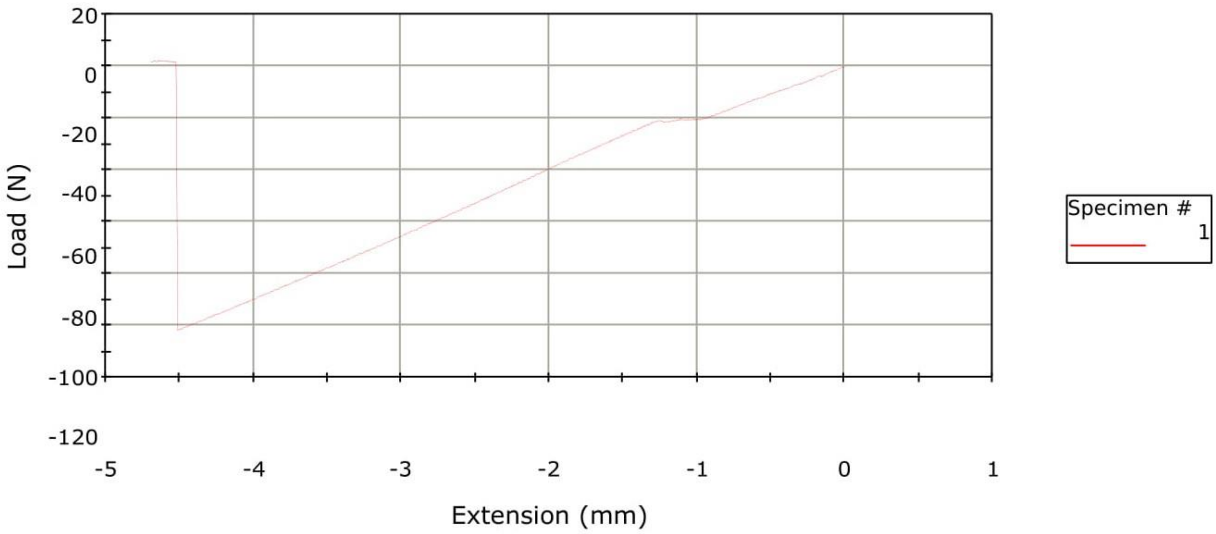


	Maximum Load (N)	Flexure stress at Maximum Load (MPa)	Maximum Flexure load (N)	Modulus (Automatic) (MPa)
1	0.972	-0.394	134.939	2924.944
Coefficient of Variation	-----	-----	-----	-----
Maximum	0.972	-0.394	134.939	2924.944
Mean	0.972	-0.394	134.939	2924.944
Minimum	0.972	-0.394	134.939	2924.944
Standard Deviation	-----	-----	-----	-----

	Flexure stress at Maximum Flexure load (MPa)
1	54.751
Coefficient of Variation	-----
Maximum	54.751
Mean	54.751
Minimum	54.751
Standard Deviation	-----

Fig 11.12 Tensile properties of 5% Treated fiber composite.

(13) 7.5% Treated Fiber Composite (Sc. no. 1829-19), Flexural Properties.

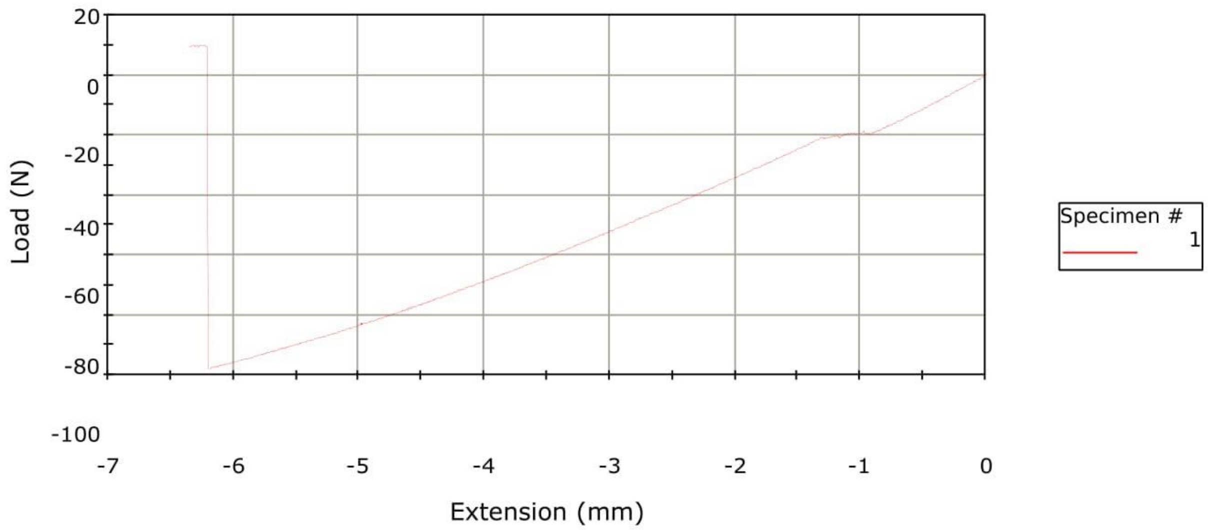


	Maximum Load (N)	Flexure stress at Maximum Load (MPa)	Maximum Flexure load (N)	Modulus (Automatic) (MPa)
1	2.211	-0.825	101.630	2912.449
Coefficient of Variation	-----	-----	-----	-----
Maximum	2.211	-0.825	101.630	2912.449
Mean	2.211	-0.825	101.630	2912.449
Minimum	2.211	-0.825	101.630	2912.449
Standard Deviation	-----	-----	-----	-----

	Flexure stress at Maximum Flexure load (MPa)
1	37.943
Coefficient of Variation	-----
Maximum	37.943
Mean	37.943
Minimum	37.943
Standard Deviation	-----

Fig 11.13 Tensile properties of 7.5% Treated fiber composite.

(14) 10% Treated Fiber Composite (Sc.no. 1830-19), Flexural Properties.



	Maximum Load (N)	Flexure stress at Maximum Load (MPa)	Maximum Flexure load (N)	Modulus (Automatic) (MPa)
1	9.787	-3.721	97.713	2231.555
Coefficient of Variation	-----	-----	-----	-----
Maximum	9.787	-3.721	97.713	2231.555
Mean	9.787	-3.721	97.713	2231.555
Minimum	9.787	-3.721	97.713	2231.555
Standard Deviation	-----	-----	-----	-----

	Flexure stress at Maximum Flexure load (MPa)
1	37.151
Coefficient of Variation	-----
Maximum	37.151
Mean	37.151
Minimum	37.151
Standard Deviation	-----

Fig 11.14 Tensile properties of 10% Treated fiber composite.