EVALUATION OF MECHANICAL PROPERTIES OF NATURAL FIBER REINFORCED COMPOSITE

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Abstract

Plant based fibre composites may, in future, become materials to replace synthetic fibre polymer based composites and natural fibres owing to their attractive specific properties, low cost, simple processing technologies, eco-friendliness and ability to recycle after use. The quality and performance of plant fibre based composites can further be improved by adopting efficient engineering techniques.

Motivation for the present work has come from the zeal to develop certain biodegradable composite materials for domestic or industrial applications using plant fibres and resins. The wide availability of natural fibres has encouraged the development of natural fibre composites. This thesis aims at introducing new natural fibres for use as fillers in a polymeric matrix, enabling production of cost effective, biodegradable and lightweight composites for load carrying structures. Jute fibre, one such kind, is rich in cellulose, relatively inexpensive and abundantly available. In this study, extraction of jute fibre was carried out and investigations on mechanical properties were determined experimentally.

Fillers were considered as additives. Their major contribution was in lowering the cost of materials by replacing the more expensive polymer. Fillers can improve mechanical properties. Fillers increase the bond between the resin and fiber.

Index Terms: Fabrication, Composite materials, Tensile test.

I.INTRODUCTION

The social and economic developments of human are largely dependent on better utilization of the available resources. Composites are an example for the same. They are engineered from two or more constituent materials with significantly different physical or chemical properties and which remain separate and distinct on a macroscopic level within the finished structure. Fiber Reinforced Polymers or FRPs include Wood comprising (cellulose fibres in a lignin and hemicellulose matrix), Carbon-fiber reinforced plastic or CFRP and Glass-fiber reinforced plastic or GFRP (also GRP). Bricks made of clay and reinforced with straw are an early example of application of composites as used by Israelites. Composite materials have gained popularity (despite their generally high cost) in high performance products such as aerospace components (tails, wings, fuselages, and propellers), boat and scull hulls and racing car bodies. More mundane uses include fishing rods and storage tanks. The synthetic fibres used in the composite material pollute the environment because of their non-biodegradability. During the last decade there has been a renewed interest in the natural fibre as a substitute for glass, motivated by potential advantages such as weight saving, low raw material price and thermal recycling or the ecological advantages of using resources which are renewable. However, increased environmental consciousness particularly on recycling of traditional materials, unprecedented forest resources degeneration and global warming, have led to worldwide efforts to develop natural fibre composites from non-wood resources. On the other hand, natural fibres have their shortcomings and these have to be solved in order to be competitive with glass fibres. Environmentally sustainable lignocellulosic resources are available in different forms of non-wood based fibres and agricultural residues.

Natural commercial fibres include jute, sisal, kapok, kenaf, flax, hemp, ramie etc. Agriculture residues include stalks of most cereal crops, rice husks, coconut fibres, bagasse, peanut shells, and other waste. Most of the recent developments of bio-composites from non-wood lignocellulosic resources have been aimed at improving the quality and performance of the product.

Natural fibres play an important role in developing high performing fully biodegradable 'green' composites, which will be a key material to solve the current ecological and environmental problems. The natural fibre reinforced composite is a lightweight, naturally attractive, cost effective application of renewable materials. It will help to improve cultivation of fibre plants and also economy of the country. Nowadays, wood substitute is found to be commercially cost effective and it plays a major and increasing role as alternative material in the composite industry.

1.1 NATURAL FIBRE

Environmental awareness and an increasing concern with the greenhouse effect have stimulated the construction, automotive and packing industries to look for sustainable materials that can replace conventional synthetic polymeric fibers. Natural fibers seem to be a good alternative since they are readily available in fibrous form and can be extracted from plant leaves at very low costs. Several years ago, nearly all resources for the production of commodities and many technical products, were materials derived from natural textiles. Textiles, ropes, canvas and also paper, were made of local natural fibres. Natural fibres are subdivided based on their origins, coming from plants, animals or minerals. Generally, plant or vegetable fibres are used to reinforce plastic.

Plant fibers may include hairs (cotton, kapok), fiber sheaves of dicot plants or vessel sheaves of monocot plants, i.e. bast (flax, hemp, jute, and ramie) and hard fibres (sisal, henequen, and coir).A single fibre of all plant based natural fibres consists of several cells. These cells are formed out of crystalline micro fibrils based on cellulose, which are connected to a complete layer, by amorphous lignin and hemicellulose. Many of such cellulose-lignin/hemicellulose layers in one primary and three secondary cell walls stick together to a multiple layer composites. These cell walls differ in their composition and in the orientation of the cellulose micro fibrils. These fibres are composed mainly of cellulose and some lignin and are sometimes called lingo-cellulosic fibers. The natural fibers are classified as shown in Figure 1.1.

1.1.1 Bast Fibres

In general, the bast consists of a wood core surrounded by a stem. Within the stem there are a number of fibre bundles, each containing individual fibre cells or filaments. The filaments are made of cellulose and hemicellulose, bonded together by a matrix, which can be lignin or pectin. The pectin surrounds the bundle thus holding them on to the stem. The pectin is removed during the retting process. This enables separation of the bundles from the rest of the stem. The bast fibres are found in the inner bast tissue of certain plant stems and are made up of overlapping cells, for example flax, hemp, jute, kenaf, ramie.

1.1.2 Leaf Fibres

In general, the leaf fibres are coarser than the bast fibres. Their applications are in manufacture of ropes, and coarse textiles. Among the total production of leaf fibres, sisal is the most important. Its stiffness is relatively high and it is often applied as binder twines. The leaf fibres are a part of the fibro vascular system of the leaves, for example sisal, henequen, palm and abaca.

1.1.3 Seed Fibres

Seed fibers are those that are borne on the seed coats as hairy structures or on the inner walls of the fruit, where each fibre consists of a single, long, narrow cell as in cotton and coir. Cotton is the most common seed fiber and is used for textile all over the world. Other seed fibers are applied in less demanding applications such as stuffing of upholstery. Coir is the fibre of the coconut husk, it is thick and coarse but durable and used to make ropes, mats and brushes.

All vegetable fibers are made up of mainly cellulose and hemi cellouse, lignin, pectin, and wax. All natural fibres are susceptible to microbial decomposition. Natural fibres based on cellulose have a relatively low density, and are relatively stiff and strong. Natural fibres are amenable to modifications as they bear hydroxyl groups from cellulose and lignin. The hydroxyl groups may be involved in the hydrogen bonding within the cellulose molecules thereby reducing the activity towards the matrix. Chemical modifications may activate these groups that can effectively interlock with the matrix. Surface characteristics such as wetting, adhesion, surface tension, porosity, etc. can be improved upon modifications. Alkali treatment of the fibres may lead to major changes in fiber surface roughness.

The irregularities of the fibre surface play an important role in the mechanical interlocking at the interface. The increase in adhesion of the resin onto the fibres happens due to the physical and chemical changes occurred to the fibre treatments. Physical changes may include removal of the waxy layer, changes in the surface roughness, changes in the physical appearance of the fibre and density changes. This may lead to changes in the adhesive strength of the fibre onto the matrix and lead to improve interface properties of the composites.If a natural fibre with an equivalent quality of glass fibre is characterized, then the former can replace the latter by its cheaper cost. Natural fibres are also expected to give less health problems for the people producing the composites.

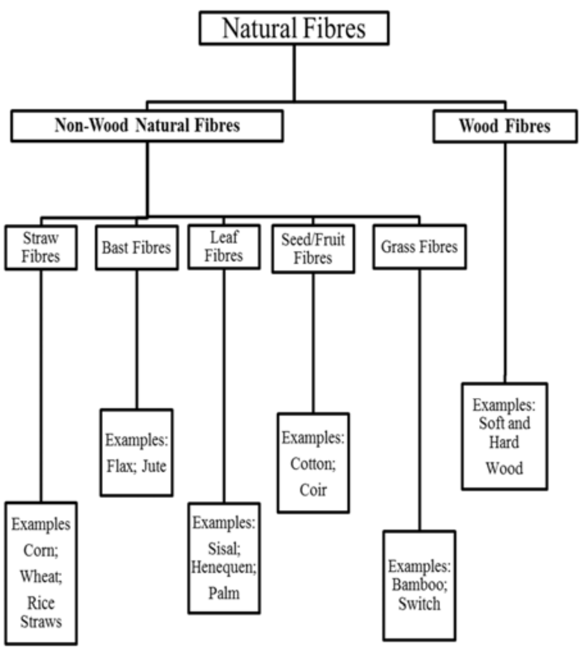


Fig 1Classification of natural fibres

Natural fibres offer several advantages over glass fibres

- Plant fibres are renewable raw materials and their availability is more. When natural reinforced plastics were subjected, at the end of their life cycle, to a combustion process, the released amount of CO_2 of the fibres is natural with respect to the assimilated amount during their growth
- The abrasive nature of natural fibres is much lower compared to that of glass fibres, which leads to advantages with regard to technical, material recycling or processing of composite materials in general.

1.3 MATRIX

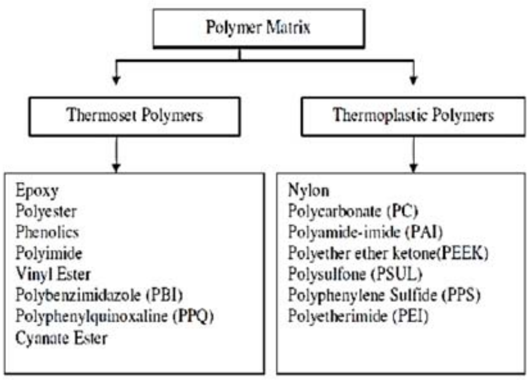
The role of the matrix in a fiber reinforced composite is: (i) to keep the fibres in place, (ii) to transfer stresses between the fibres, (iii) to provide a barrier against an adverse environment, such as chemicals and moisture and (iv) to protect the surface of the fibres from mechanical degradation. The matrix plays a minor role in the tensile load carrying capacity of a composite structure. However, selection of a matrix has a major influence on the compressive, inter laminar shear as well as in plane shear properties of the composite material. Polymer matrix is a long chain molecule containing one or more repeating units of atoms joined together by strong covalent bonds for which classification is the shown in Figure 1.2.

Table 1 Composition of different cellulose based natural fibre (Bledzki and Gassan)

Fibre	Cotton	Jute	Flax	Ramie	Sisal
Cellulose	82.7	64.4	64.1	68.6	65.8
Hemi-cellulose	5.7	12.0	16.7	13.1	12.0
Pectin	5.7	0.2	1.8	1.9	0.8
Lignin	-	11.8	2.0	0.6	9.9
Water soluble	1.0	1.1	3.9	5.5	1.2
Wax	0.6	0.5	1.5	0.3	0.3

Table 2 Mechanical properties of natural fibres as compared with conventional reinforcing fibres (Bledzki and Gassan 1999)

Fibre	Density (g/cm^3)	Elongation (%)	Tensile strength (MPa)	Young's modulus (GPa)
Cotton	1.5-1.6	7.0-8.0	287-597	5.5-12.6
Jute	1.3	1.5-1.8	393-773	26.5
Flax	1.5	2.7-3.2	345-1035	27.6
Hemp	-	1.6	690	-
Ramie	-	3.6-3.8	400-938	61.4-128
Sisal	1.5	2.0-2.5	511-635	9.4-22.0
Coir	1.2	30.0	175	4.0-6.0
Viscose(cord)	-	11.4	593	11.0
Soft wood Kraft	1.5	-	1000	40.0
E-glass	2.5	2.5	2000-3500	70.0
S-glass	2.5	2.8	4570	86.0
Aramide (normal)	1.4	3.3-3.7	3000-3150	63.0-67.0
Carbon	1.4	1.4-1.8	4000	230-240



1.4 NEED FOR NATURAL FIBRE COMPOSITES

The development of natural fibre composites has profited from the policy of a number of (Indian) governments to support the development of technical applications for renewable resources. Establishment of disposal methods for glass fibre reinforced plastics and their recycling laws are important contemporary subjects because many environmental problems have appeared. It is necessary to reduce environmental impacts such as global warming, which are generated by consumption of petroleum, a non-renewable resource. The driving forces of natural fibre composites are (i) cost reduction, (ii) weight reduction and (iii) marketing (application of renewable materials). The use of natural fibre reinforced polymer represents an attractive and suitable method for replacing. Natural fibres are low cost, renewable and high specific strength and its composites are used for fabricating some products such as furniture and architectural materials. Recently, they have gained widespread use in the automobile industry.

1.5 SCOPE OF THE PRESENT WORK

In this thesis the relation between the structure and the mechanical properties of untreated and alkali treated jute fibres and their reinforced polyester composites were carried out with the following objectives.

- To do a detailed study of the physical, chemical and mechanical properties of jute fiber and also the surface morphology of the fiber
- To design and fabricate a mould
- To make the chopped Jute fiber (treated and untreated) reinforced polyester composite samples
- To study the performance of the chopped Jute fiber reinforced polyester composites by analyzing the tensile, compressive, flexural and impact properties, moisture absorption, dynamic mechanical property, machinability and morphology
- To investigate the mechanical properties (tensile, flexural and impact), Fourier transform infrared spectroscopy and scanning electron microscopy of the continuous/short Jute/glass fiber reinforced polyester hybrid composites.

II. FABRICATION OF COMPOSITES

2.1 FIBRE

The fibre extracted from the trees is collected at jute bags manufacturing unit. The fibre is dried in sun light for two weeks and then soaked in water for one week. The wetted fibre is washed with distilled water thoroughly and again dried for one week. The dried fibre is combed to free the fibres. The extraction process took place 30-40 days.

Fig 2 Extracted jute fiber

2.2 ALKALI TREATMENT

Alkalization is a common pre-processing technique used on base natural fibre to remove hemicellulose, fats and waxes that may reduce the interfacial strength when processed into composite form. The surface modification consisted of alkali treatment of fibre with varying concentration of NaOH. It was found that with varying NaOH concentration, the fibre property changes. The raw fibres were treated and immersed with 10% sodium hydroxide solution and then washed with very dilute hydrochloric acid (HCl) to remove the residual alkali. Then, the fibres were rinsed with cold water twice or thrice. The rinsed fibres were dried at room temperature for 2 to 3days.

2.3 PREPARATION OF COMPOSITE

Wax polish is applied on the surfaces of the base plates and poly vinyl alcohol (PVA) is applied with a brush and allowed to dry for few minutes to form a thin layer.

These two items will help in easy removal of the laminate from the base plates. PVA also provides a glossy finish to the surfaces of the laminate. The unsaturated general purpose iso polythene resin is taken along with 2% of accelerator- Cobalt napthanate and catalyst- methyl ethyl ketone peroxide (MEKP). The catalyst initiates the polymerization process and the accelerator speeds up this process. Initially the accelerator is added and next the catalyst is added. The contents are thoroughly stirred and then placed on the base surface and spread uniformly with the brush. It is always preferable to add lesser quantity of accelerator than the specified amount of accelerator to avoid solidification of the contents before they are placed and spread on the glass plate. Then the top base plate that was already applied with the wax and PVA is placed and a weight of about 1000 N is placed over for about 5 hours.

Figure 3 Fiber soaked with 10 % NaOH solution

Fig 4 Fiber washed in distilled water and HCL solution

1

2

Fig 5 Jute fiber (1) Raw and (2) alkali treated

2.4 SPECIMEN PREPARATION

The specimen of untreated chopped Jute fibre reinforced Polyester composite with two different fibre lengths such as 8mm and 10mm were prepared in the laboratory using hand layup and compression mould technique. Similarly, the specimen of alkali treated chopped Jute fibre reinforced Polyester composite with two different fibre lengths such as 8mm and 10mm were prepared. The specimens were prepared with three different fibre resin ratio of 5:95, 10:90 and 15:85 by manual stirring for a sufficient time to scatter the fibres in the matrix. These samples were cured for 24 hours at room temperature and then taken off the mould, since a good interfacial bond is required for effective stress transfer from the matrix to the fiber.

Fig 6 Chopped Jute fiber reinforced Polyester composites

III TESTING OF COMPOSITES

3.1 PRELIMINARY

Various sample composite sheets are moulded using different additives to the basic ingredient, i.e., **Polyester**. Different additives are: accelerator- Cobalt napthanate & Catalyst treated jute short fiber (TF), untreated jute short fiber (UTF). The variety of composites produced and respective ingredients are indicated in the following table.

Table 2 Composition of Materials

Fibre length in mm	Sample no	Fibre Type	Resin in wt Grams	Fibre wt Grams	MEKP & Cobalt Naphthalene in wt grams
8	S_{11}	UTF	50	0	2
	S_{12}	UTF 5%	47.5	2.5	2
	S_{13}	UTF 10%	45	5	2
	S_{14}	UTF 15%	42.5	7.5	2
10	S_{21}	UTF	50	0	2
	S_{22}	UTF 5%	47.5	2.5	2
	S_{23}	UTF 10%	45	5	2
	S_{24}	UTF 15%	42.5	7.5	2
10	S_{31}	TF	50	0	2
	S_{32}	TF5 %	47.5	2.5	2
	S_{33}	TF10 %	45	5	2
	S_{34}	TF15 %	42.5	7.5	2

3.2 PREPARATION OF SPECIMENS

The specimens are prepared for each test, i.e., tensile test as per ASTM D638. The dimensional details of each type of specimen.

3.3 TENSILE TEST

Tensile testing of specimen prepared according to ASTM D 638, was carried out using electronic tensile testing machine (fig 4.3) of cross head speed of 5mm/min and a gauge length of 50mm. The tensile modulus and elongation at the break of the composites were calculated from the load displacement curve. At least five specimens were tested for each set of samples and the mean values were reported.

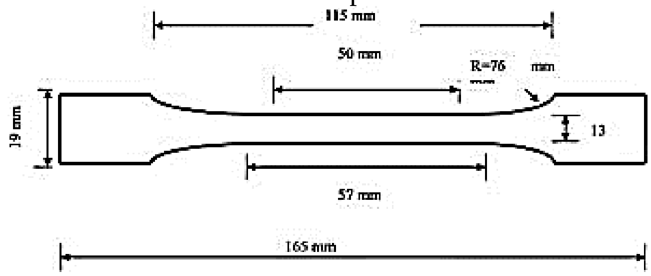


Fig 7 Dimensions for Specimens Tensile

Fig 8 Dimensions for Specimens Tensile

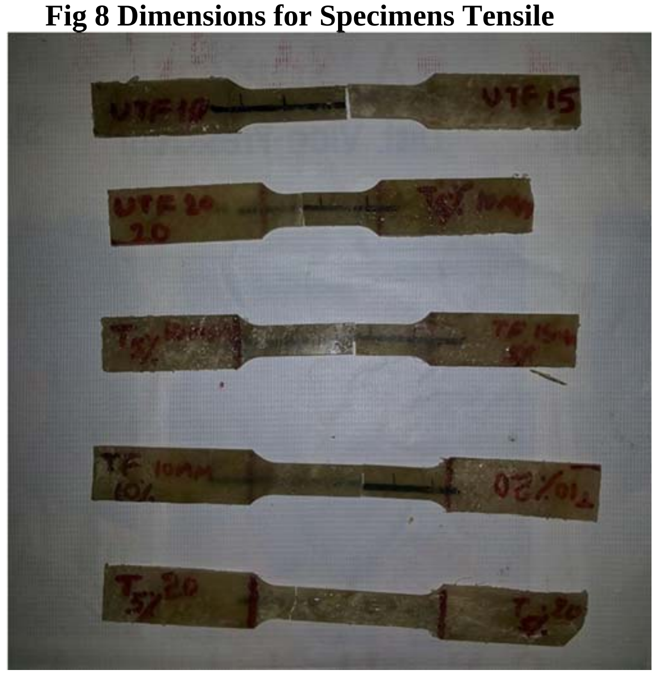


Fig 9 Tensile Test Specimens after Testing

3.4 MOISTURE ABSORPTION

Moisture absorption test has carried out for 24hrs and 48 hrs. Firstly the specimens are dried for 2 hrs in oven at 50^{O}.After the specimens are kept in distilled water for 24 and 48 hours. The change in weight is calculated using measuring device.

Fig 10 The specimens are dried in oven

Fig 11 The specimens are immersed in water

IV. RESULTS AND DISCUSSIONS

4.1 ANALYSIS OF CHOPPED JUTE COMPOSITES

The short fibre reinforced composite consists of short fibres dispersed into matrix material. The low cost, ease of fabricating complex parts, and isotropic nature are enough to make the short fibre composites, the materials of choice for large scale production. Consequently, the short fibre reinforced composites have successfully established its place in lightly loaded component manufacturing. The most widely used short fibre reinforced composites is randomly oriented short fibre reinforced composites due to comparatively easy production process.

4.1.1 Tensile properties

The effects of the alkali treatment on the tensile performance of the Jute fibre polyester composites with different fibre percentage were investigated. All the graphs display a linear Hook's law. The engineering stress, true stress and tensile modulus decrease, while the elongation at break increases with the increase of the fibre lengths of the composite. Surface modification of the fibre by alkali treatment improves chemical bonding and helps to withstand high tensile load by the composites made of them. 10% increase in tensile load exhibited by all the alkali treated fibre composite samples can be related to the enhanced mechanical interlocking of the fibre and the resin. The load verses elongation curves was plotted between treated and untreated fibres. Different fibre lengths were chosen i.e. 8mm, 10mm.

Fig 12 shows the graph is plotted between tensile force and different fiber weight. The graphs show that the tensile force increases with weight of fiber.

Fig 12 shows the graph is plotted between tensile force and fibre percentage. The graph shows that the tensile force increases with percentage of fiber. The composite with 15% fibre percentage shows good results compare to other.

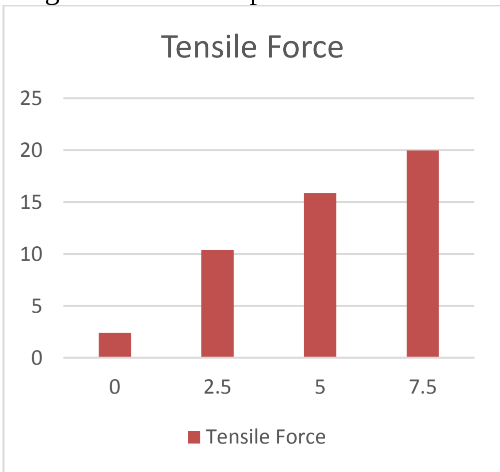


Fig 11 Tensile force vs fiber weight, UTF length 8mm was plotted

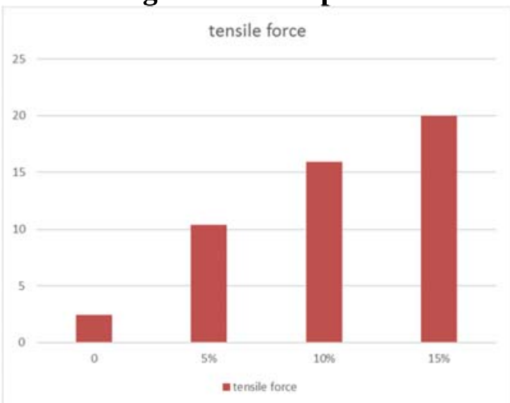


Fig 12 Tensile force vs fiber %, UTF length 8mm was plotted

Fig 13 shows the graph is plotted between tensile force and fiber percentage. The graph shows that the tensile force increases with percentage of fiber. The composite with 5% fiber percentage shows good results compare to other.

Fig 14 shows the graph is plotted between tensile force and fiber percentage. The graph shows that the tensile force increases with alkali treatment.

The composite with 15% fiber shows good results compare to other.

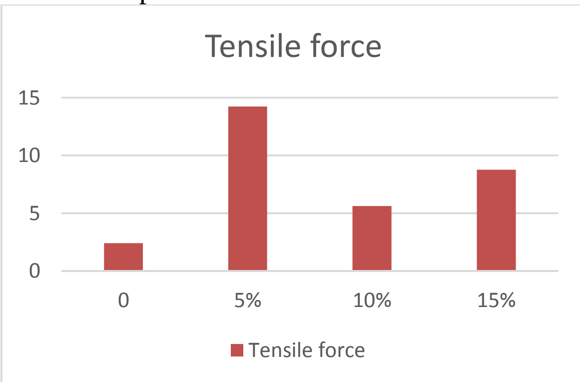


Fig 13 Tensile force vs fiber %, UTF length 10mm was plotted

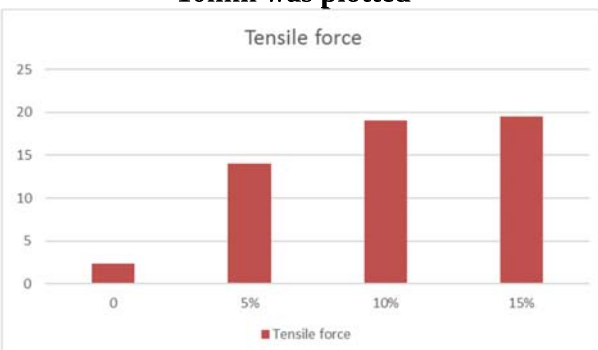


Fig 14 Tensile force vs fiber %, TF length 10mm was plotted

Fig 15 shows the graph is plotted between tensile force and fiber percentage. The graph shows the comparison between treated fiber and untreated fiber. The graph shows that the tensile force increases with alkali treatment. The composite with 15% fiber shows good results compare to other.

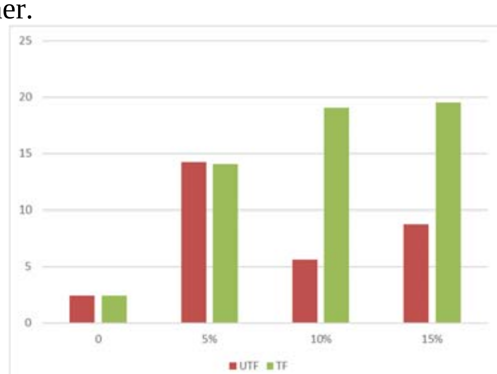


Fig 15 Tensile force vs fiber %

4.1.2 Moisture Absorption Properties

Fig 16 The graph is plotted between change in weight and fiber %. The composite with 15% untreated fiber shows good results compare to other.

Fig 17 The graph is plotted between change in weight and fiber %. The composite with 15% treated fiber shows good results compare to other.

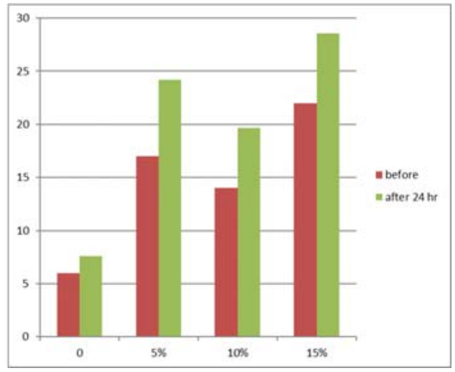


Fig 16 Change in wt vs fibre% (UTF, Length 10mm) was plotted

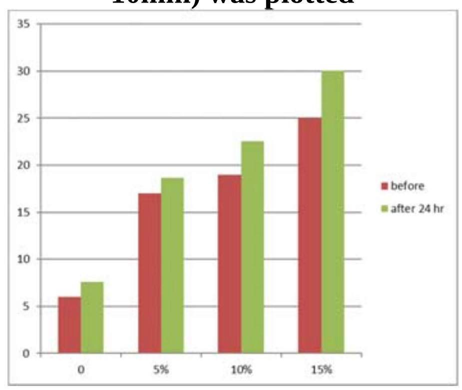


Fig 17 Change in wt vs fibre% (TF, Length 10mm) was plotted

V. CONCLUSION

- Agro climatic factors, environmental factors and harvesting period are found to influence the qualities of natural plant fibres. Thus in this study, length and weight distribution of the Jute fibre were analyzed. On an average, the fibre length was found to be more than one meter and also the maximum weight distribution was found to be between 0.9 m and 1.4 m.
- The chemical composition of both raw and alkali treated Jute fibres were studied. According to the current observation, the cellulose content of Jute fibre was rich when compared to the other natural fibres. It was also found that the alkali treatment reduced the hemicellulose, lignin and wax content of the fibres. The alkali treated fibre thus was found to be in an attractive colour and smooth surface texture than the raw one.
- The composite with alkali treated fibres exhibited a slightly higher tensile strength than the one with untreated

fibres. Fibre surface modification by alkali treatment improved the fibre-matrix interaction.

- The density of Jute fibre was found to be lower than that of the synthetic fibres available and so this fibre can be preferred to manufacture lightweight composite materials in the near future. Another added advantage is that the Jute fibre is biodegradable.
- The tensile force analysis of both the raw and alkali treated fibres were performed with varying factors. The treated fibres were found to have more tensile force than the raw fibres.

SCOPE FOR FUTURE STUDY

Fibre technology, high performance adhesives, and fibre modifications can be applied in the manufacture of structural natural fibre composites with uniform densities, durability in adverse environments, and high strength. Thus,

- Fabrication of lightweight composite with improved fuel efficiency for application in automotive industry can be possible.
- Nano fibres can be synthesized from Jute fibre and composites with efficient mechanical properties can be prepared.

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