International Journal of Advance Research in Science and Engineering
Volume No.07, Special Issue No.(02), March 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

EXPERIMENTAL INVESTIGATION ON MECHANICAL PROPERTIES OF FLAX FIBER REINFORCED COMPOSITIES WITH EPOXY

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ABSTRACT

Generally, glass, cotton and carbon fibers are most widely used materials in composite. In this study it has been aimed to use flax fibers in composite materials and to study the mechanical properties of the samples. The research was carried out with 100% flax fibers at different reinforcement ratios to produce hand lay-up composite material. Fibers/matrix interface bonding in the composites was improved by the De-waxing process of flax fiber prior to composite fabrication. The prepared composite was tested to study the mechanical properties of the composite such as tensile strength, impact strength, flexural strength, water absorption and hardness. The mechanical tests results indicated flax fibers as an alternative natural fiber source for developing reinforced composite for various industries.

Keywords: Carbon Fibres, Flax Fibres, De-Waxing process.

I. INTRODUCTION

As a result of the increasing demand for environmentally friendly materials and the desire to reduce the cost of traditional fibres (i.e.) carbon, glass, aramid, jute, hemp etc. reinforced petroleum-based composites, new bio-based composites have been developed. The evolution of composite materials has replaced most of the conventional materials of construction in automobile, aviation industry etc. fibre reinforced composite have been widely successful in hundreds of applications where there was a need for high strength materials. There are thousands of custom formulations which offer FRPs a wide variety of tensile and flexural strengths. Researchers have begun to focus attention on NFC (i.e. bio – composites), which are composed of natural or synthetic resins, reinforced with natural fibres. Natural fibres exhibit many advantageous properties: they are low density material yielding relatively lightweight composites with high specific properties. These fibres also over significant cost advantages and ease of processing along with being a highly renewable resource, in turn reducing the dependency on foreign and domestic petroleum oil. Recent advances in the use of natural fibre when compared with traditional materials such as metals, the combination of high strength and lower weight has made FRP an extremely popular choice for improving a product design and performance. Natural fibres have been used as reinforcing materials for over 3000 years, in combination with polymeric materials. The study of fibre reinforced plastics began in 1908 with cellulosic materials in phenolics, later extending to urea and melamine and reaching commodity status with glass fibres reinforced plastics (Jawaid et al 2011). However, glass fibres do have some disadvantages; they are non-renewable and give problem with respect to ultimate disposal as they cannot be thermally recycled by incineration and are left behind as a residue. They are also very abrasive which leads to an increased wear of processing equipment such as extruder and moulds. With respect to health they cause skin irritations during handling of fibre products during processing of fibre reinforced parts. Nowadays, there is a growing interest in the development of new materials which ensure optimal utilisation of natural resources, and particularly of renewable resources. Increased pressure from environmental activists and stringent laws has resulted in renewed interest in sustainable composites focusing on renewable raw materials. In this context, there is a growing interest in use of natural fibres such as flax, straw, hemp, ramie and jute etc as reinforcements in composites. Natural fibres can be considered as naturally occurring composites consisting mainly of cellulose fibrils embedded in lignin matrix. These cellulose fibrils are aligned along the length of the fibre, irrespective of its origin. It appears that such an alignment renders maximum tensile and flexural strengths, in addition to providing rigidity in that direction (Satyanarayana et al 1990). These fibres can be found in great amount in nature and are already harvested in many countries of the world. Their primary advantage is their renewal time. Although these fibres are abundantly available in developing countries such as India and Bangladesh, most application is still rather conventional such as matting, carpet backing, packing materials and ropes etc. The natural fibres are categorised into three groups: vegetable, animal hair and mineral fibres (John and Thomas 2008). The theoretical mechanical properties of cellulose reinforced composites are impressive because of the strength and stiffness of crystalline cellulose (Duchemin et al 2009). Of the natural fibres, bast fibres, defined as fibres obtained from the outer cell layers of the stems of various plants are more likely to be adopted as reinforcements over the other cellulosic fibres because of their specific mechanical properties and low density (Summerscales et al 2010). This combination of interesting mechanical properties together with their environmentally friendly character has triggered extensive research activates by research institutions, academicians and automobile industry, as environment friendly alternative for the use of glass fibres.

Pervaiz et al (2003) studied the environmental performance of hemp based natural fibre mat thermoplastics (NMT) by quantifying their carbon storage potential and Co2 emissions and comparing the results with commercially available glass fibre composites. A comparative life cycle analysis shows that a net saving of 50,000 MJ (~ 3-ton Co2 emissions) per ton of thermoplastic can be achieved by replacing 30% glass fibre reinforcement with 65% hemp fibres. Further, the results shows that use of natural fibres in thermoplastics have great potential to act as sustainable sink for atmospheric carbon dioxide and at the same time save non-renewable resources.

Mohanty et al (2001) concluded that natural fibres needed much lower energy compared to synthetic fibres. Van dam et al (2000) in a comparative study on environmental implications of manufacture of polypropylene, high density polyethylene and polyurethane fibres relative to natural fibre based products concluded that jute fibre

production requires less than 10% of the energy used for polypropylene fibres. When the use of fertilizers was included in the calculations, the energy requirement for polypropylene fibre production
increased to about 15%. However, the data are for jute fibres produced without powered mechanical assistance and environmental impacts other than energy use were not considered. Further, natural fibres are advantageous over glass fibre since they buckle rather than break during processing and fabrication. In addition, cellulose possesses a flattened oval cross section that enhances stress transfer by presenting and effectively higher aspect ratio (John and Thomas 2008).

Besides the advantages mentioned above, the natural fibre composite also possess some disadvantages such as poor compatibility between hydrophobic polymer matrix and hydrophilic fibres which leads to formation of weak interfaces, resulting in poor mechanical properties (Wambua et al 2003).

Fig. 01 – Top and Bottom pattern

II. EXPERIMENTAL PROCEDURE

The experimental setup requires materials such as Two iron patterns, flax fibres, epoxy resin, hardener for Epoxy resin, liquefied wax, four pattern cornered bolt and nuts, polythene covers, tools and burette. Primarily mold is prepared for the required dimensions and it is covered with plastic sheet over the top of it. The first step is to mix the resin and the hardener.

Table. 01

Sample Code	Epoxy Matrix Weight %	Flax Fiber Reinforcement Weight %
FFRPE1	95	5
FFRPE2	90	10

The ratio is usually given by the supplier and can be found on the containers of the hardener or resin. The portions are measured by weight to volume required but it is important to follow these proportions exactly as this is a complete chemical reaction and all components must react completely for maximum strength of the matrix. The mixing is performed in the mixing containers with the mixing stick, which is carried out slowly so as to not entrain any excess air bubbles in the resin. An estimate of the amount of resin needed can be based on weight of Flax fibre. The chemical proportion of the components are shown in Table 01.

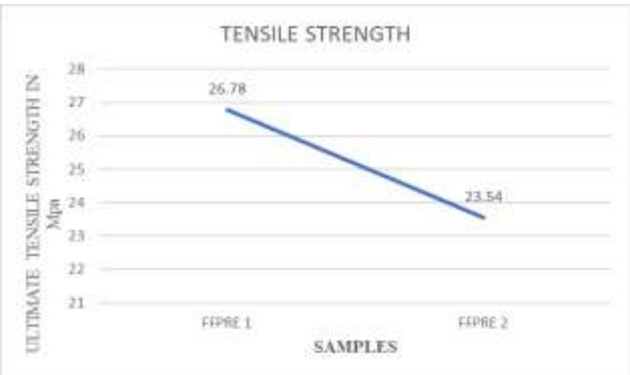
Table 02.

Sample	Epoxy Mass	Epoxy Density	Total Mass	Flax Mass	Flax Density	Total Mass	Total Sum(Kg/M^3)	Volume of Box M^3	Mass (Density Sum * Vol)
A	B	C	D=B*C	E	F	G=E*F	H=D+G	I	J=H*I
1	0.95	1250	1187.5	0.05	1.45	0.0725	1187.5725	0.0009	1.068
2	0.9	1250	1125	0.1	1.45	0.145	1125.145	0.0009	1.012

It is assumed that 50% volume of resin/50% volume of fiber and then use the density of the reinforcement to arrive at the weight of the resin. The first layer of fiber reinforcement is then laid. This layer is wetted with resin and then softly pressing using a brush or a roller. If the fiber is not completely wet,

Figure 01.

more resin can be added over the top and spread around. At this stage a second layer of flax fiber is added and special care must be taken to eliminate all air bubbles possible. This can be accomplished by either rolling any air bubbles out with a small hand rolling tool or brushing out the air bubbles with a paint brush. This step is repeated until the desired thickness is obtained. As the flax fiber layers are added to build laminates and total part thickness the individual layers may be oriented at varying angles to accomplish specific strength in the direction of the reinforcement weave- this is called ‘clocking’. The fabricated part is then cured in atmospheric temperatures (i.e. 30-40 deg.). After the completion of curing process, the part is cleaned in order to further proceed it .



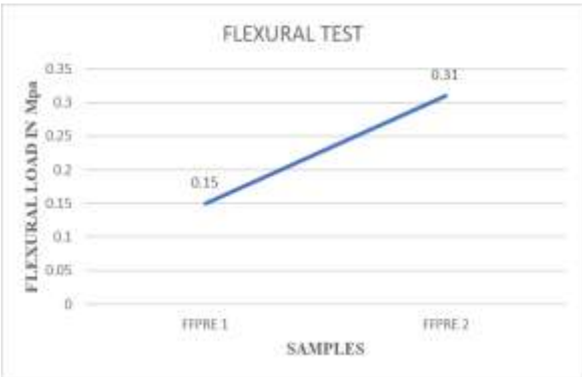


Figure 02.

III. RESULTS & DISCUSSION

3.1 Tensile Test

The test is carried out with 4 specimens of each sample and average value is plotted in the Figure 01 Shown below The Ultimate Tensile strength for the Composite fibre is obtained as 26.78 MPa and 23.54 MPa for the samples 1 and 2 respectively. The tensile strength of flax/Epoxy composites at different percentage of flax fibre are depicted in the graph. It is clear

that the tensile strength of the composites decreases with increasing percentage of flax fibre. By addition of 5% fibre, the strength was found to be decreased to 6.4% for sample 2 when compared to sample 1.

3.2 Flexural Load Test:

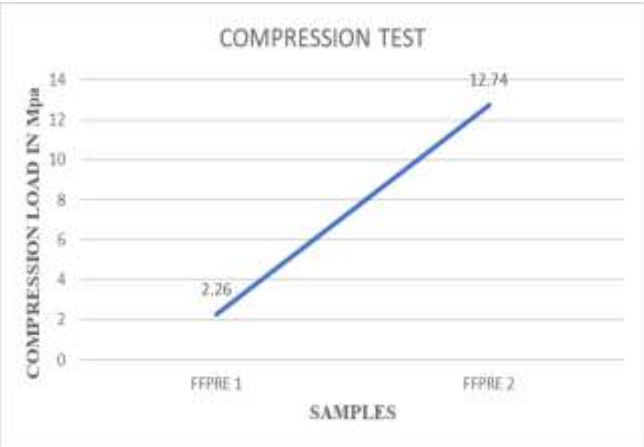
The test is carried out with 4 specimens of each samples and the average value is plotted in the above graph. It is evident that 10% flax fiber reinforced polyester composites showed the maximum flexural strength of 1150 MPa

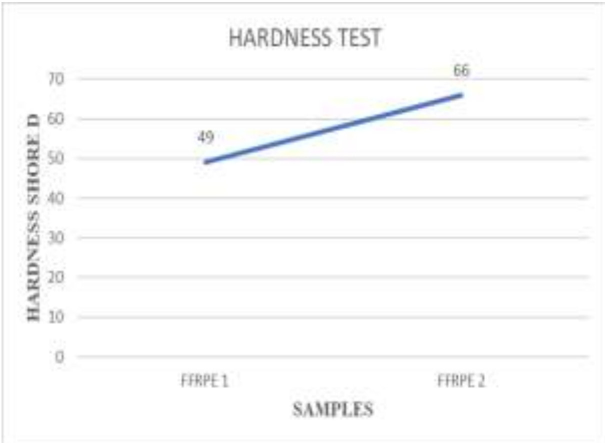
Figure 03.

over 60 MPa showed by 5% treated flax reinforced epoxy composites. The maximum force resisted by the flax polyester composite before failure was 2.48KN. The 10% flax fiber reinforced polyester composites were found to have 90 % increase in the flexural strength than the 5 % reinforced epoxy composites. The Figure 02. Represents the plot for various samples and load conditions.

3.3 Compression Test

The test is carried out with 4 specimens of each sample and average value of the overall test is plotted in the Figure 03. The Compression load for the Composite fibre reinforcement is obtained as 2.26 KN and 12.74 KN for the samples 1 and 2 respectively. The sample 2 is enhances as better mechanical properties for the composite material. The tests showed that the composites made with fibre resin weight percentage were very good with





the impact stress as it showed very better values form the tests performed. The fibre provides strength for the composite material, as the flax

fiber percentage in the composite is only 5-10

Figure 04.

percentage. The Flax Epoxy composite seems to have a better impact strength than the first sample with 69.86 %. The reason being natural fiber contains higher cellulose content and lower micro fibril angle results in higher work of fracture in impact testing.

3.4 Hardness Test

The test is carried out with 4 specimens of each samples and average value is plotted in the above graph. The Hardness for the Composite fibre reinforcement is obtained as 49 and 66 for the samples 1 and 2 respectively. Sample 2 provides better mechanical properties for the composite material compared to sample 1. The results were found to be in close conjunction with each other. In the test

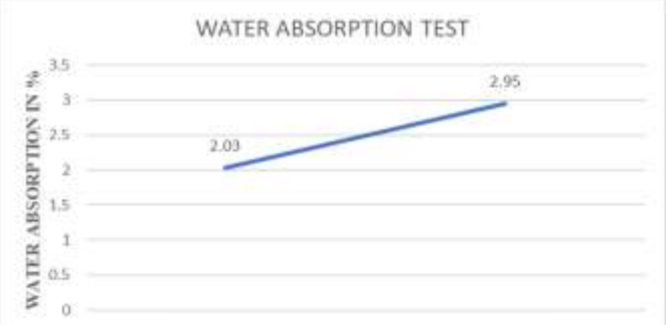


Figure 05.

conducted the hardness value was found for flax fiber reinforced Epoxy composites. This shows that the changes in resins amount have no considerable effect on the hardness of the composite and it mainly depends on the type of fiber used as the reinforcement. The 10% reinforced flax fiber composites showed better results than the 5% reinforced composites.

3.5 Water Absorption Test

Table 03.

S. No	Type of Test	Sample Ffre1	Sample Ffre2
1	Tensile Strength in (Mpa)	26.78	23.54
2	Flexural Load in (Kn)	0.15	0.31
3	Impact Load in (Kn)	2.26	12.74
4	Hardness	49	66
5	Water Absorption (In %)	2.03	2.95

The test is carried out with each sample and average value is plotted in the above graph 05. The Water absorption for the Composite fibre reinforcement is 2.10% and 2.58% for the samples 1 and 2 respectively. Sample 1 is enhanced with better mechanical properties for less water absorption than sample 2 for the composite materials.

IV. CONCLUSION

Flax fibres are cost-effective materials have specific mechanical properties which have potential to replace glass fibres as reinforcement in composite. Their main Disadvantage is the variability in their properties. Environmental effects (e.g. high relative humidity) will degrade the tensile properties of flax fibres. A suitable chemical treatment (e.g. Silane) can increase the tensile strength and strain of the flax fibres. The tensile strength and modulus of flax fibres decrease with an increase in fibre length, fibre diameter and gauge length. Flax fibres at the mid-span and tip in the stem with high content of cellulose should be considered as the raw materials. Improving the poor environmental- and dimensional stability of lingo cellulosic materials is an effective way to modify the mechanical properties of these materials. The tensile properties of flax fibres scatter significantly with the change in fibre diameter, gauge length. An appropriate treatment (e.g. Duralin treatment or drying cycle treatment) can be selected to achieve a higher and more uniform strength with less scatter. Flax fibre with thermoplastic, thermoset and biodegradable polymer matrices exhibit promising mechanical properties. A major limitation of using flax fibres as reinforcement in composites is the incompatibility which results in poor fibre/matrix interfacial bonding and thereby reduces the tensile properties. The selection of suitable manufacturing process and physical/chemical modification can improve the mechanical properties of flax composites. Flax composites have the potential to be the next generation materials for structural application for infrastructure, automotive industry and consumer applications. Future work on flax composites should be focused on understanding the environmental assessment, durability, further improving the mechanical properties and moisture resistance. Additionally, novel manufacturing processes and surface modification methods should be further developed.

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