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FABRICATION AND TESTING OF SCREW PINE ROOT FIBRE REINFORCED EPOXY COMPOSITE MATERIAL

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Abstract

The development of environmental friendly materials has been a challenging concern due to the increasing environmental awareness. Natural composites are one such gifted materials which replaces the petroleum based synthetic materials and its related products for the less weight and energy conservation applications. In the present work natural composites were fabricated using chopped Screw Pine root fibres as reinforcement and Epoxy LY556 as matrix with varying fibre volume fraction from 10%, 20%, and 30% by hand lay-up fabrication technique. Composite plates were made by casting in open mould which is made up of wood. The specimens are then cut from the composite plates according to ASTM standards for studying the performance and properties like tensile, flexural, Impact test and water absorption test. The analysis of tensile, flexural and impact properties of these composites revealed that screw pine root fibres can be used as a potential reinforcing agent like other natural fibres such as jute, kenaf hemp, for making low load bearing composites.

1. Introduction

Composite is a structural material that consists of two or more immiscible constituents that are combined at a macroscopic level. One of the constituent is called reinforcing phase and the other in which it is embedded is called matrix phase [1]. Humans have been using composite or composite type materials since Mesopotamian civilization 3400BC, where they used to glue wood strips at different angle to create plywood. Another remarkable invention was made by Mongols during 1200AD. Mongols were horseback archers and their bow was made from a combination of wood, bamboo, bone, horns, cattle tendons and silk bonded with natural pine resin. This increased the accuracy and durability of the bow [2]. The use of wood composite materials dates from centuries ago. In ancient China, wood, bamboo and straw were used to reinforce clay for making walls, and many natural fibre-reinforced clay buildings are still in use. Nowadays one can find composites everywhere around us, from concrete used for building construction to fuselage structure of an aeroplane. Composites have taken over steel because of their excellent strength to weight ratio. Composites are light weight but come with greater mechanical strength. With the

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great advantages comes great difficulties, even though the Glass Fibre Reinforced Plastic (GPRF) are structurally strong their disposal and recycling is a challenging task

Vijay Ramnath, et. al. [3] have investigated the mechanical properties of abaca-jute-glass fibre reinforced epoxy composites. With the centre layer of jute sandwiched between abaca layers, these three layers were then sandwiched between glass fibres. Glass fibres impart strength and surface finish to the composite. It was found that abaca-jute hybrid composite possessed more favourable mechanical strength than abaca fibre composite alone when it comes to tensile and shear properties. Abaca composite showed superior impact and flexural strength when compared to the hybrid. An investigation conducted by Sahu et al.,[4] showed the effect of variation of pineapple and sisal fibres volume fraction in Sisal and Pineapple hybrid composites reinforced with epoxy resin on flexural and impact strength of the whole composite. Hybrid composites were prepared by varying the concentration of sisal and pineapple individually and total fibre volume fraction is kept constant at 20g. Composites were prepared using hand layup method. The test results showed that the composites made by using 50/50 had a maximum impact strength compared to other ratios. Scida et al.,[5] has investigated the influence of hygrothermal aging on mechanical properties of flax fibre reinforced epoxy composite. Study shows that the hygrothermal aging causes a significant reduction in Young's modulus which resulted in decrease of tensile strength of the composite. Further the acoustic emission analysis combined with scanning electron microscopy showed the degradation of flax-fibre in the composite due to hygrothermal aging. Mylsamy and Rajendran, [6] has studied the influence of alkali treatment and fibre length on mechanical properties of short agave fibre reinforced epoxy composites. Composite specimens were prepared by varying the fibre lengths using hand layup and compression moulding technique. Prepared specimens were then subjected to tensile, compression, flexural, impact, machinability and water absorption tests. The results clearly showed superiority in mechanical properties of alkali treated agave fibres when compared to untreated fibre composites. By studying the fractured surfaces it was evident that alkali treatment increased surface area for resin fibre interaction and bonding which had led to increased mechanical properties. As per studies conducted by Ojha et al., [7], [8] which included the use of bio waste such as wood-apple and coconut shells as a reinforcing agent with epoxy as matrix, one can see a new way of recycling bio wastes. The studies show that the wood apple particulate composites are superior to coconut shell powder reinforced particulate composites for the same and weight ratio when tested for tensile, flexural and erosion wear. The author continued the study on wood apple particulate composites and found that carbonizing wood apple shells at a temperature of 800°C improves the mechanical strength further. Dinesh et al. [9] has done an experimental investigation by using an alloy of aluminium i.e. Aluminium 8011, glass flax fibre reinforced with epoxy matrix. Composites are prepared by using compression moulding technique with two different stacking arrangements. One with glass fibres sandwiched between flax fibre sheet, and the other with flax fibre mat sandwiched between glass fibre sheets. Aluminium sheets remained on the outer side in both cases. Then the prepared composites are tested for tensile, compression, and flexural strengths. The results showed that the composite with flax fibre had greater tensile strength than the composite with glass fibre in the centre layer. But for flexural test it was quite opposite, here composite with glass fibre at the centre showed maximum flexural strength. Portella et al., [10] has studied the influence of stacking sequence of cotton and glass fabrics in cotton/glass fibre reinforced with polyester composites on mechanical and dynamic properties. Waste cotton fibres were obtained from the textile industry. Then the composites were prepared by changing the stacking sequence. From the results it was concluded that keeping glass fibre on the outer surface of the composite improves mechanical properties. And it's advisable to keep cotton layer on the outer edge of the composite in order to improve dynamic properties. Pujari et al., [11] has investigated thermal conductivity of composites prepared by using two different plant fibres namely banana and jute as reinforcement with epoxy matrix. Both banana and jute epoxy composites were prepared with the help of hand layup technique. Thermal conductivity of the composites were experimentally investigated by using graded heat flow meter method. Experimental results showed that the increase in the fibre loading decreased the thermal conductivity of the composites. This insulation effect was more in the composites made of banana fibre than jute fibre. The experimental results were in good coordination with theoretical calculation made by using Hashin model and Maxwell model. Sukmawan et al., [12] has evaluated strength of bamboo fibre reinforced with PLA (Poly lactic acid) green composite. These composites were prepared by hand layup technique followed by hot press. Intermolecular interaction between bamboo and poly lactic acid matrix was investigated with FTIR (Fourier transform infrared) analysis. Result showed a great increase in mechanical strength of composite when bamboo fibres were treated with aqueous alkali solution.

2. Experimental

2.1 Screw pine as Reinforcement Materials

Screw pine root fibres are extracted from the roots of the screw pine tree. Screw pine plants belong to Pandanus family. There are more than 750 species of this plant available on the planet. Screw pine plants are abundantly available in India, Indonesia, and Malaysia etc. Screwpine root fibre have 52 % cellulose content hence they are known to be one of the strong natural fibres Abiral et al., [13].

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Figure 2.1 Fibre extraction process in brief

Screw pine trees have an aerial root system. The roots of the screw pine trees are cut to required length. Then the roots are split in half and exposed to sun light for drying. Complete drying takes about 1 or 2 days. Then the dried fibres are sent between the rollers similar to that of sugarcane juice extractor. To facilitate fibre extraction and to avoid fibre breakage the roots are soaked in water for 2 hours. After extraction of the crude fibres, the fibres are washed under running water to wash away the excess cellulose content. Finally, fibres are dried in sunlight for 2 days.

The extracted crude fibres are to be treated with aqueous alkali solution to reduce affinity of Screw Pine root fibres towards moisture. The presence of moisture content in any natural fibres reduces the strength of the composite. In this study Screwpine root fibres are treated with 5% aqueous NaOH solution to reduce its hydrophilic nature in order to make it compatible with hydrophobic epoxy LY556. Alkali treatment also helps to remove a little bit of hemicellulose, lignin, wax, oil

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from the surface of the fibres. Which intern increases surface area for the Screwpine, this increase in surface area leads to better bonding of the epoxy with fibres. General equation of mercerization with NaOH is as follows.

Fibre – OH + NaOH à Fibre – O – Na + H2O [14]

From the previous study conducted by Deesoruth et al., [15], optimum soaking time for Screwpine root fibres at 5% NaOH concentration is 90 min. Fibres are then removed from the alkaline solution washed with water for an hour to remove traces of NaOH. Fibres can also be treated with mild acidic solution (aqueous HCL) instead of water for better result.

2.2 Selection of matrix material (Resin and Hardener)

Selection of the matrix plays an important role in deciding the strength of the composite. Selection of the matrix also depends on its availability and cost. In this study resin Araldite® LY 556 and hardener Aradur HY 951 are bought from local store “Zenith Industrial Suppliers”, S.P Road, Bangalore which are shown in Figure 4.9. The epoxy and hardener can be chosen in the ratio 10:1 by weight to form an optimal bonding. This epoxy cures at room temperature and does not require any elevated temperature for the cure with a curing time of 24 hours.

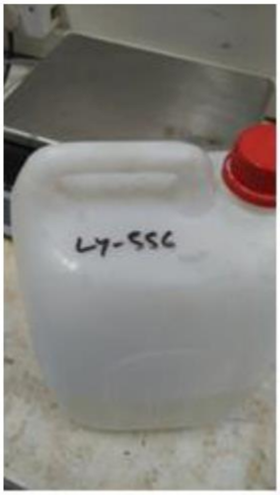

Figure 2.2 Epoxy and Hardener

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2.3 Mould Preparation

A 20 mm thick wooden slab measuring 200mm by 200mm with 5mm beadings along the four sides is used in the preparation of the mould. Beadings help to ensure both epoxy and fibres are contained and also help to keep the composites free from contamination during the curing time.

Figure 2.3 Wooden Mould

3. Preparation of composite

Composite specimens were prepared using compression moulding method by varying the weight percentage of the fibres from 10 % – 30% in steps of 10%. In the beginning the mould was cleaned with acetone to remove wax and dirt. Then a thin coat of wax was applied on the bottom surface, all four sides of the mould and the cover plate which will be in contact with the composite. This is to avoid sticking of epoxy to the surfaces and ease of removal of the composite itself. Resin Araldite® LY 556 and hardener Aradur HY 951 are mixed in the ratio 10:1 in a clean bowl. Chopped fibres are then added to matrix and mixed thoroughly (figure 3.1). This mixtures must be poured in to the mould within 10-15 minutes of the mixing otherwise the matrix would start hardening.

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Figure 3.4 Preparation of composite

Figure 3.5 Pressure applied on the mould

Then the mixture is evenly spread to fill the mould cavity. Cover plate is placed on the mould and the moderate pressure is applied on the surface of the cover plate. This can be seen in Figure 3.2. Then the composite is left for curing for 24 hours.
After the curing time specimens were retrieved from the mould. Mould is cleaned for further use. Screwpine/Epoxy composite sheets were then marked to dimension as per ASTM standard. Vertical power bandsaw was used for cutting the specimens. Since surface finish from the band saw was coarse, edges needs to be smoothed with sandpaper. In the beginning sandpaper of grade CAMI grade 80 was used followed by sand paper of CAMI grade 180 to get good surface finish at the edges [16].

4. Mechanical Tests

After the fabrication of the test specimen they were subjected to different mechanical tests as per ASTM standards. The standards followed were ASTM-D 638, ASTM-D 790-03, and ASTM-D 785-08 for tensile test, flexural test, and hardness test respectively. To obtain statistically significant observations for each volume fraction and condition, triplicate specimens are tested to evaluate mechanical properties.

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Figure 4.6 Tensile test specimen

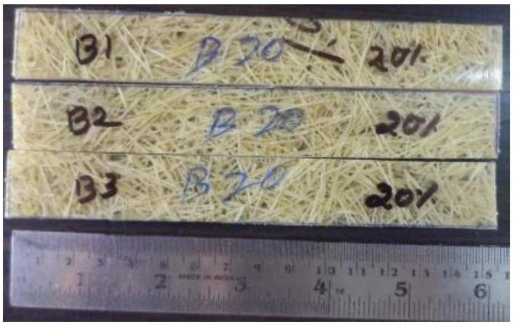

Figure 4.7 Flexural test specimen

Figure 4.8 Izod impact test specimen

4.1 Tensile test of composite specimen

In Tensile testing, test specimens are subjected to controlled tension until fracture. From this test it is possible to deduce maximum tensile strength, young's modulus, maximum elongation, reduction in area and poison ratio. Tensile tests are usually conducted at the speed of 5mm/min to 500mm/min using the lowest speed that ruptures the specimen within 0.5 to 5 minutes at room temperature (304K). During testing speed of 2mm/min was taken for convenience.
Tensile test was carried out according to ASTM D638 standard. In a computerized universal testing machine Kalpak Universal Testing Machine KIC-2-1000-C of capacity 100KN Figure 4.9. Composite tensile specimens were fixed firmly between the jaws of computerized universal testing

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machine Figure 4.10. Tensile force was applied on the specimen with a gradually increasing load until the specimen breaks or fractures.

Figure 4.9 Kalpak CUTM

Figure 4.10 Tensile specimen

4.2 Three-point flexural test of composite specimen

Three-point flexural test was conducted according to ASTM-D 790-03. Testing was carried on the same Kalpak Universal Testing Machine KIC-2-1000-C of capacity 100KN which was used for testing tensile specimens. Specimens were placed between two supporting rollers separated at a distance of 100mm (span length). And a third roller was lowered till it touches the mid span. A gradually increasing bending force was then applied on the specimen until it fractures.

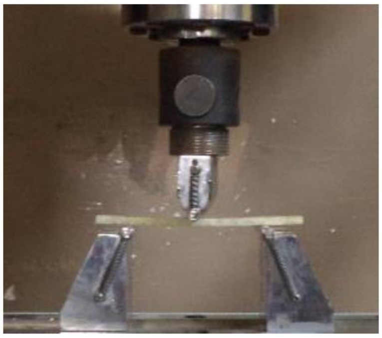

Figure 4.11 Specimen during flexural test

Tensile tests are usually conducted at the speed of 5mm/min to 500mm/min using the lowest speed that ruptures the specimen within 0.5 to 5 minutes at room temperature (304K). During testing speed of 2mm/min was taken for convenience. Three point bending tests were conducted at room temperature. The flexural test specimen was placed onto two supports having a span of length 100 mm. Test was conducted at the speed of 2mm/min. Hardness test was conducted on all specimen to evaluate the hardness of the specimen at room temperature.

4.3 Izod impact test for composite specimen

Izod impact test are used to determine the impact strength of the materials. A pivoting arm is placed at a certain height. The arm will have a potential energy. When this pivoting arm is released, it swings down like a pendulum and hits the specimen. After hitting the specimen it raises to a height. The difference in height gives the potential energy difference, which was absorbed by the specimen. Izod impact test was conducted based on ASTM-D 256-A standard.

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Figure 4.12 Izod impact test

5. Result and discussion

5.1 Tensile Test

Composite specimens were prepared by varying weight ratio of the fibre from 0% to 30% in steps of 10%. Tensile tests were conducted on prepared Screwpine reinforced epoxy composite specimens as per ASTM D638. Stress v/s strain behavior for each weight ratio of the composite is show in the graph below.

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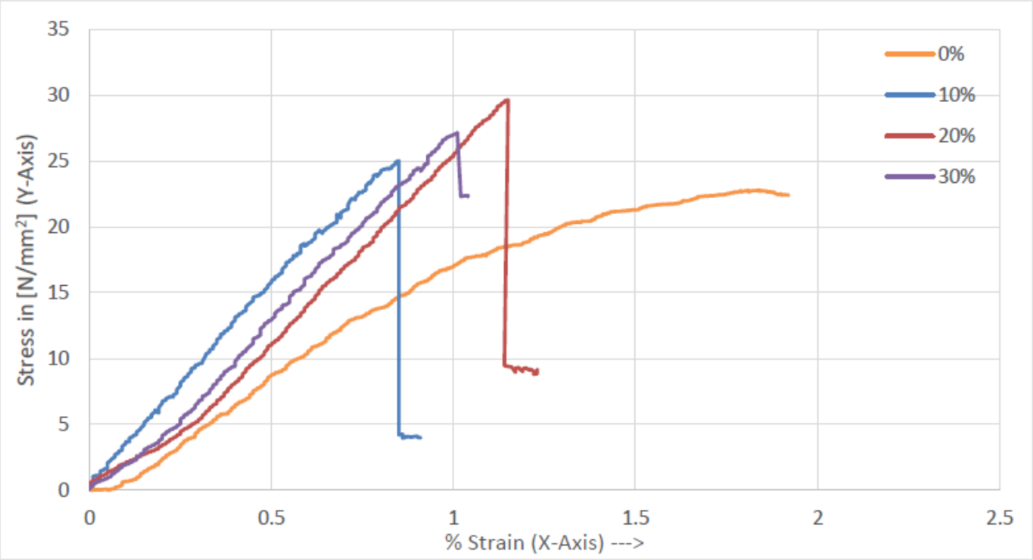

Figure 5.13 Stress in N/mm2 V/s Strain for 0-30% weight ratio of the fibre

From the tests conducted on the Screwpine reinforced epoxy composites it can be concluded that, tensile strength of the composite specimen was observed to increase with addition of the fibres until 20% of the weight percentage of the fibre. Beyond which it was observed to decrease. This is mainly because of the reason that the fibres were supporting and holding the matrix until 20%. But as the fibre quantity increased the bonding required to hold the fibres and matrix reduces which will result in weak bonding. These kind of composite materials cannot be used be used in the fields where the toughness is prominent.

5.2 Three point flexural test

Screwpine reinforced epoxy composites were prepared by varying the weight percentage of the fibres. Composite specimens are then tested for three point flexural strength as per ASTM-D 790-03 standard. Test results and photographs of the each test specimens before and after the flexural tests are documented and discussed in following paragraphs.

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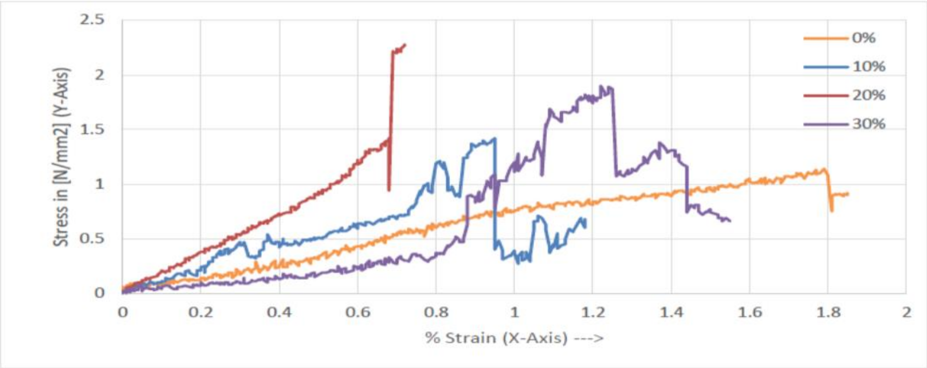

Figure 5.14 Stress in N/mm2 V/s Strain for 0-30% weight ratio of the fibre

The flexural tests show the same trend as that of the tensile test. Three point flexural strength of the Screwpine reinforced epoxy composite specimen was found to increase with the addition of fibres until 20% of the weight ratio of the fibre. Beyond which it was observed to decrease. This is mainly because of the reason that the fibres were supporting and holding the matrix until 20%. But as the fibre quantity increased the bonding required to hold the fibres and matrix reduces which will result in weak bonding. The waviness of the graph is mainly due to the vibrations caused by the individual fibres breakage.

5.3 Izod Impact Test

Izod impact test was carried out on the Screwpine reinforced epoxy composites as per ASTM-D 256-A standard. The result showed a constant increasing trend throughout. This is because of the presence of the random oriented fibres in the V-notch area which will hinder crack propagation.

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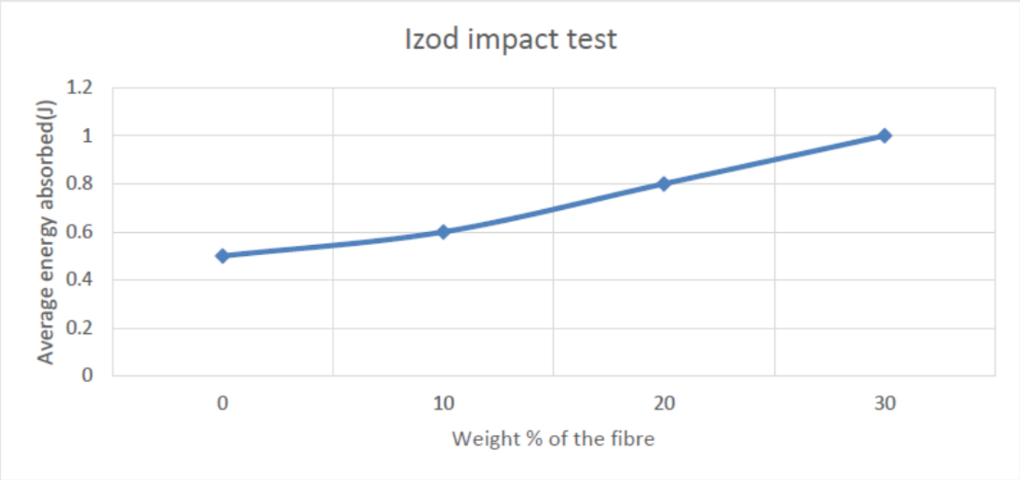

Figure 5.15 Izod impact test

Izod impact test was conducted on the Screwpine reinforced epoxy composite specimen to measure the impact strength of the composites. Impact test was carried on the composite samples prepared by varying the weight percentage of the fibre from 0 to 30% in steps of 10%. Energy absorbed by the composite samples were found to increase with increase in weight percentage of the fibre. This behaviour is because of the random orientation of the fibre in region of the V-notch. Random orientation of the fibre cause hindrance for crack propagation which results in the improved impact strength.

6. Conclusion

On the basis of experimental investigation, it can be concluded that, addition of screw pine fibres increased the strength of the composite till 20%, beyond which the matrix required for the binding of fibre becomes less leading to decrease in mechanical strength. Further research work needed to be carried out in the development of natural fibre reinforced composites. This is crucial if new improved materials are to be developed for safe usage against crack growth and environmental pollution.

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