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Development and Characterization of Epoxy Resin Based Hybrid Composite Reinforced with Sugarcane Bagasse Ash and E-Glass Fiber

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Abstract: In this research an attempt has been made to develop hybrid composite material using Sugarcane Bagasse ash and E-glass fiber with epoxy resin as matrix for different fiber orientation such as 0°,30° and 45°. Vacuum bag moulding technique is being used to fabricate the composite material. In this study, characteristics of Sugarcane bagasse ash with varied orientation of E-glass fiber and Epoxy Hybrid polymer matrix have been studied. The mechanical properties such as tensile and flexural strength of the Fiber reinforced polymer composites are evaluated and following observations are made. The composites exhibit tensile strength as follows, the highest 204.67 N/$\boldsymbol{mm^2}$ and the lowest 109.278 N/$\boldsymbol{mm^2}$ were observed with 0° and 45° fiber orientation respectively and the flexural strength of 277.52 N/$\boldsymbol{mm^2}$and 211.22 N/$\boldsymbol{mm^2}$were recorded for 0° and 45° respectively.

The results show that, the Tensile and Flexural strength decreases with increasing the degree of orientation of E-glass fiber in the composite. The composite having 5%wt of bagasse ash and 0° orientation of E-glass reinforced with Epoxy resin exhibits better properties among other variations of E-glass orientation.

The tensile and flexural strengths decrease with increase in e-glass orientation because of shear stress induced on the interface of each lamina and in crack propagation is stopped by fibres during the fracture process in 0° fibre orientation specimen, and the contribution of fibres during the fracture process decreases as the degree orientation increases.

Keywords: Room temperature vacuum bag molding (RTVBM), tensile and flexural.

1. INTRODUCTION

1.1 Composite materials

Composite material is defined as the mixture of two or more integrant materials. The materials are necessarily insoluble into each other, the properties of the mixture of materials are superior than the sum of the properties of each material taken individually. The objective of this integration is to derive the finest qualities of the essential materials. There are two types of integral material that surround the matrix and transport the reinforcement materials to keep them in place. To refine the matrix qualities, the reinforcement pass on their different mechanical and physical features.

1.2 Fiber Reinforced Polymer

Fiber reinforced composites are made up of a matrix and fibres. Fiber is the substance used for reinforcement. The fundamental source of strength, whereas matrix material holds all of the reinforcing fibres in place and transfers stresses amongst them. The loads are transferred in length-wise directions by the fibres. To make the production process go more smoothly, filler material is sometimes used.

Usually, fiber reinforcing agents involve asbestos, aluminium oxide, carbon/graphite fibers, glass fibers, natural fiber sets and polyamide. Likewise, common matrix materials contain epoxy, vinyl ester, polyester, phenolic etc.. polyetheretherketone is the most widely used resin material.

1.3 Particle Reinforced Polymer

Particles are utilised to increase the matrix's modulus while also reducing its ductility. Ceramics and glass materials such as small ingot particles, metal particles such as aluminum and other amorphous materials, and polymers are all employed as reinforcement particles. Particles are utilized to make composite materials less expensive. Matrices and reinforcements can be familiar, inexpensive materials and are effortlessly processed. Certain beneficial properties of glasses and ceramics with higher melting temperature, lower density, stiffness, higher strength, corrosion resistance and wear resistance. One of the best electrical and thermal insulators is ceramic. Certain ceramics, magnetic materials, and piezoelectric materials go through specific properties. Ceramics and glassware have a significant disadvantage in that they are brittle by nature. Polymer composite materials have gotten a lot of attention in the engineering world, especially in aircraft. Around the world, research is underway to develop newer composites with various fibre combinations that may be employed in a number of operating circumstances.

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1.4 Natural fiber as reinforcing material

Natural fibre reinforced composite materials have attracted a lot of attention as a possible structural material. Banana, jute, coir, and sisal fibres are valued for their low cost, high specific modulus, light weight, renewability, and recyclability. In contrast to unnatural fibre reinforced composites, composites reinforced with fibres have clearly been the topic of extensive research for lower cost and stronger applications. The interfacial bond between the reinforcing fibres and the resin matrix is a key factor in determining the composites' mechanical properties.

1.5 Hybrid Composite Materials

Hybrid materials are nanoscale or molecular composites made up of two components. In most cases, one of these substances is inorganic, while the other is organic. These aren't like regular composites, which have parts that are visible. Combining the two native phases at the microscopic level results in a new material with properties that are either identical to the two original phases or have novel properties.

Hybrid composites are those composites that have a mixture of two or more reinforcement fibers. Hybrid composites are generally used when an integration of properties of various types of fibers desired to be succeeded, or when longitudinal as well as oblique mechanical presentation is required.

Hybrid composites include those that combine synthetic and synthetic fibres, unnatural and natural fibres, and natural and natural fibres. Carbon, Kevlar, and glass fibres are popular synthetic fibres used in hybrid composites.

1.6 Vacuum bag molding

With vacuum bagging, the mechanical characteristics of open-mold coatings can be improved. The outer atmospheric pressure exerts force on the vacuum bag by lowering the pressure in the inside component of the bag. With wet lay laminates and pre-impregnated contemporary composites, vacuum bagging is used. The pressure applied to the laminate removes entangled air, excess resin, and the laminate's density. The reinforcement is soaked using hand lay-up, and then the vacuum bag is ascended on the mould and used to thick the laminate and suck out air voids. When moulding pre-impregnated advanced composites, the pre-impregnated material settles on the mould, a vacuum bag is placed, and the mould is warmed up or the mould is placed in a sterilizer that administers heat and external pre-treatment.

The most common method for producing modern composites used in aviation and military components is the pre-impregnated vacuum bag-sterilize approach. Molds are identical to those used in open-mold processes.

A rescue film is placed over the laminate in this new type of vacuum bagging. Polyester fabric, non-woven nylon, or any other material that can absorb excess resin from the laminate. A non-woven fabric's break ply is placed over the bleeder ply, and then a vacuum bag is placed over the entire assembly. Dragging the vacuum from within the bag removes voids and removes extra resin from the laminate by using ambient pressure. The addition of pressure leads in a higher fibre concentration and greater adhesion between sandwich manufacturing layers. When using non-contoured PVC foam sheets in a mould. Vacuum bagging is a solution for ensuring that the core and the outside laminate are properly secondary connected.

1.7 Epoxy resin

Epoxy resin is a two-integral material comprised of epoxy resin and hardener. Epoxy resins have elevated execution, which is broadly used in nourishing, repairing and strengthening numerous structures, specifically in the manufacturing of composite products. Epoxy resin is also used to make powerful moulds. The materials have higher strength and extremely high adhesion properties. Epoxy resin acts as a high electrical insulator, this material is broadly used in producing various electrical components like generators in the electrical industry. It is also used in aerospace and aircraft industry to connect exterior and interior components also uses in the marine industry to recondition different parts of a ship. The main application of epoxy resin is in the production of fiber reinforced polymer composites. Epoxy resin has a high resistance to chemicals such as bases and acids, also high resistance to humidity and water. The resin has less shrinkage than other types of resins such as polyester resin.

1.8 Sugarcane Baggase ash

Sugarcane (Saccharum officinarum) is the wider crop by production quota in the world. A huge amount of wet bagasse is yielded and governance of this residue is of considerable importance from an environmental point of perspective.

The ignition of this bagasse is the most common practice, resulting in the production of a secondary residue that is the sugarcane bagasse ash (SCBA). smoothness, crystalline and the presence of unburned traces are crucial for the production of pozzolanic reactivity and for having superior mechanical performance. Strength of SCBA-based adhesive and concrete is suitable and in various cases 20% substitution of cement can be carried out without remarkable performance loss.

1.9 E glass fiber

Glass fibres are mostly used to reinforce polymers. High-strength (HS) glass, E-glass, and corrosion resistant (CR) glass are the best forms of glass fibres. The “E” comes from the fact that the first large artificial composite reinforcing was created for electrical insulation applications. E-glass fibres are the most widely utilised fibrous reinforcements by a wide margin. This is because to its inexpensive cost and rapid improvement when compared to other fibres. Multifilament bunches are used to make glass fibres. Glass fibre reinforced polymer matrix composites are often utilised as thermal and electrical insulators due to their low thermal and electrical conductivities.

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1.10 Material characterization

When it comes to materials science, characterization refers to the broader and more widespread practise of examining and measuring the material's structure and properties. This is the most basic procedure in materials science; without it, no scientific understanding of engineering materials can be established. The term's definition varies widely; some definitions limit its application to techniques that study the microscopic structure and properties of materials, while others apply it to any materials examination process as well as macroscopic techniques like density calculation, mechanical testing, and thermal analysis. The scale of structures observed in materials characterization spans from angstroms, as in imaging chemical bonds and individual atoms, to centimetres, as in imaging coarse grain structures in metals.

A universal testing machine (UTM), also known as a universal tester, materials test frame, or materials testing machine, is a machine that is used to test the tensile and compressive strength of materials. The tensile testing machine was originally known as a "tensometer." The "universal" element of the term refers to its adaptability in performing various common tensile and compression tests on components, materials, and structures.

1.10.1 Tensile Test

Tensile strength testing is a destructive engineering and materials science test in which a controlled tension is given to a specimen until it fails entirely. This is possibly the most extensively used mechanical testing method. Before failure, the working of the sample is intended to be elastic. Failure is expected to come in an unexpected and volatile manner.

1.10.2 Flexural Test

Flexural tests are commonly used to determine a material's flexural modulus or flexural strength. Flexural strength is a calculation used in engineering to determine how much a sample will bend when a load is applied. The flexural strength of that given sample is represented by the greatest recorded force.

II. MATERIALS AND METHODOLOGY

2.1 Material selection

Fabric determination might be a significant task to design and make the novel cutthroat composites, having the top tier properties and features. Inside the research work, most outrageous consideration has been taken in choosing the legitimate materials in mastermind to meet the objectives of the ask about project. Inside and out investigation in critical spaces of innovation and hi-tech applications, elite composites are attractive to meet the practical necessities. Therefore, synthetic fibrous reinforcement was marked with high-quality epoxy resin to meet the requirements.

Details of elements of hybrid composites are as follows:

- Sugarcane Bagasse ash powder form.
- E-Glass Fiber (190GSM) in fabric form.
- Epoxy Resin LY 556 and Hardener HY 951.

Sugarcane Bagasse ash

Sugarcane bagasse ash is an agricultural crop, whose residue after extracting the juice is called as bagasse. Sugarcane is a natural agricultural and renewable resource. Chemically, sugarcane bagasse ash contains about 50% of cellulose, 25% of hemicellulose and 25% of lignin. In this study sugarcane bagasse is used in a powder form. Inclusion of sugarcane bagasse ash increases the strength of the material while developing the composite material.

E-Glass Fiber

Glass fibers are generally use for fibrous reinforcement, it has adequate strength, stiffness and ease in manufacturing. It retains stronger for high stress and shorter time frames. Based on the chemical composition and constituents with silica sand while leads to produce different types of glasses, viz., A-glass, AR-glass, C-glass, D-glass, E-glass, ECR-glass, Rglass, S-glass and SR-glass.

Among these types of glass fibers, E-glass fibers were choosed to manufacture FRP composites in bidirectional Plain and twilled woven fabric form.

E-glass is also electrical glass, which is Alkali free, highly electrically resistive glass made with alumina-calcium borosilicates. They are naturally used for the applications where high strength and electrical resistivity is the requirement. It is the most commonly used fiber in the fiber reinforced polymer composite industry.

Epoxy Resin LY 556 and Hardener HY 951.

Epoxy resin is one of the most optimal thermoset polymer, it is been using since form 19th century as a matrix material for fiber reinforced polymer composites, due to its excellent mechanical, chemical and thermal properties, enabling it to sustain in extreme operating conditions and high stress areas, therefore epoxy resin is popularly been known as matrix material in FRP composites. Epoxy is the family of resins which has various grades and sub classes, based on their applicability the resins are chosen. The LY556 epoxy is a high quality resin having excellent bonding characteristics and mechanical properties. LY556 can be cured in both hot and cold temperatures. It has a low viscosity that leads in reinforcing materials and makes it easier to impregnate. The LY556 is a staple in the aerospace industry. The industry relies on this high-quality resin. The LY556 works well with fibre glass.

Properties of Epoxy resin LY556 with hardener HY951 are as follows:

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- Low viscosity resulting in high flow, thus strengthen the interlaminar bonding, easy impregnation of reinforcement materials for preparation of composites laminates.
- This combination leads to Long plot life (of 2hrs for 100ml at ambient temperature) allowing longer time for heavy and big projects.
- High resistance against thermal expansion (glass transition temperature) after ambient cure: 60 ˚c after post-cure at 120 ˚c. Enabling composites to withstand extreme operating conditions.
- Excellent mechanical and dynamic properties after post curing of epoxy with laminates under very cold and elevated temperatures.

2.2 Fabrication Technique

Composites laminates were manufactured by hand layup process and vacuum bag molding technique. The prime objective of using these techniques is, the hand layup process is only process where high reinforcement to matrix ratio can be obtained under fully controlled conditions, because of the direct human interference in the fabrication process, also in this process, there are significantly less chances of resin starvation or interlaminar debonding, as the optimum/ required wetting or resin can be applied on the reinforcement fibers resulting in high strength to density ratio.
Pre-fabrication and fabrication process includes the following sequential steps:

- Selection of matrix and reinforcement materials by considering its properties and characteristics.
- The following set of composite sheet was manufactured. Sugarcane bagasse ash, E glass fibre and Epoxy resin LY 556 with hardener HY951.
- Adopting the manufacturing process, by considering the feasibility and availability of facilities and advantage of using the process.
- Hand layup process and Room temperature vacuum bag molding (RTVBM) technique are selected for the fabrication of composites.
- Calculate the reinforcement to matrix ratio by considering weight fraction and volume fraction (70:30 volume fractions).
- Calculate the degree of hybridization by integrating the E glass, viz 0^o, 30^o, 45^o orientation and 5% of sugarcane bagasse ash with epoxy resin.

III. EXPERIMENTATION

The composite laminates were fabricated as mentioned in the table. i.e., with different variation of e-glass fibre with 5%wt of sugarcane bagasse ash and epoxy resin as matrix material.

Table : Laminates designation of hybrid composites

Composite laminates	Fibre orientation	Thickness	Bagasse ash	Fibre layer composition
Bidirectional e-glass / Sugarcane bagasse ash	0^o 30^o 45^o	2.5mm	5%wt	G+B+G+B+G+B+G+B+G+B

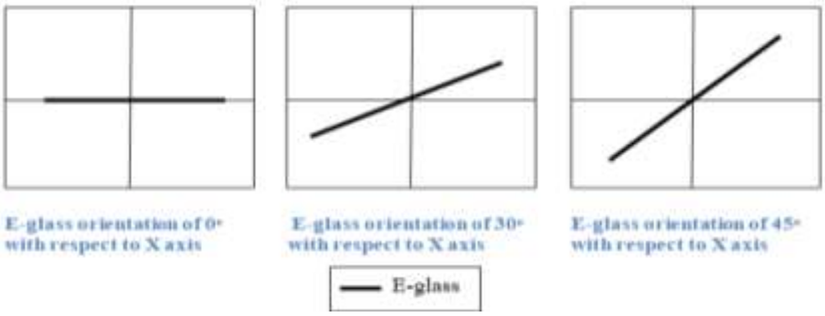

Fig: Orientation of e-glass

Characterization

The present work is being carried out to study the mechanical properties like tensile strength and flexural strength of the sugarcane bagasse ash and Eglass reinforced hybrid composite. All the tests have been conducted as per the ASTM standards.

Tensile Test

Tensile testing is on a very basic level a materials science test where in which a laminate is subjected to a strain until crack. In the present study, the tensometer is used for tensile test for the hybrid composited samples. All the specimens

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are examined as per ASTM D3039 standard (sample dimension is 250x25x2.5mm^3) to know the tensile force, tensile modulus and percentage of elongation. The orientation of e-glass is with respect to x axis.

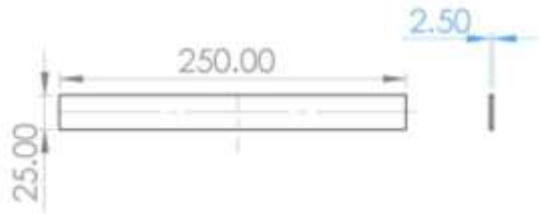
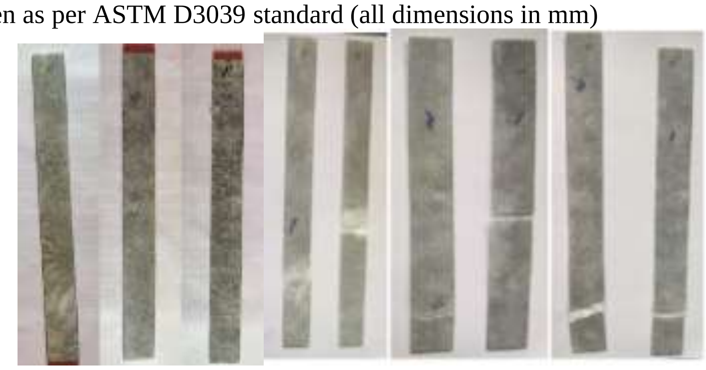


Fig: Tensile test specimen as per ASTM D3039 standard (all dimensions in mm)



(a) (b)

Fig: (a) Specimens before Tensile test, (b) Specimens after Tensile test (0°, 30°, 45° respectively)

Flexural Test

The bend test technique fundamentally measures the conduct of materials that is subjected to basic load stacking. Flexural quality is set as the most extraordinary pressure in the uttermost fiber. This is figured at the surface of the laminate on the pressure side. Flexural modulus is processed from the slant of the stress vs deflection bend.

Static and fatigue flexural properties such as flexural strength and modulus are determined by ASTM D790 standard test method. In this test, a composite beam specimen of rectangular cross-section is loaded in three-point mode. Sample is cut into flat shape of size (12.7x125x2.5mm^3), in accordance with ASTM standards.

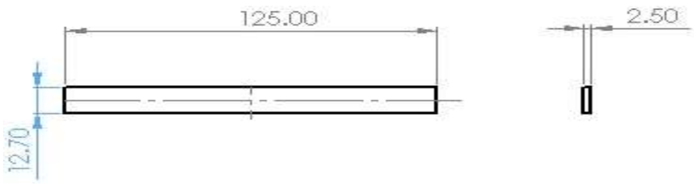
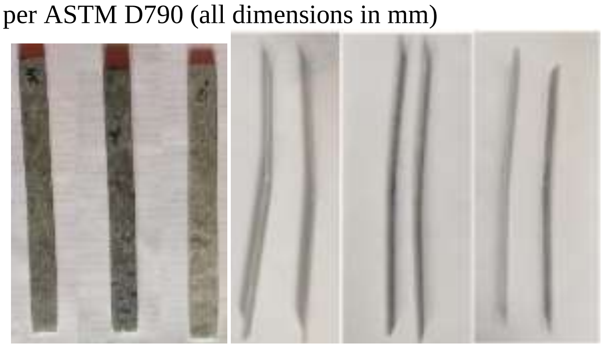


Fig: Flexural test specimen as per ASTM D790 (all dimensions in mm)



(a) (b)

Fig: (a) Flexural test samples before test, (b) Flexural test samples after test (0°, 30°, 45° respectively)

IV. RESULTS AND DISCUSSIONS

The fabricated composites were tested for mechanical properties like tensile test and flexural test. The details of the materials required, fabrication technique and test parameter used in characterization are given.

Tensile Test

The tensile test is generally conducted on flat specimens using standard test method as per ASTM D 3039. This test is performed in Tensometer. For each test two composite laminates were tested and average value is taken for analysis.

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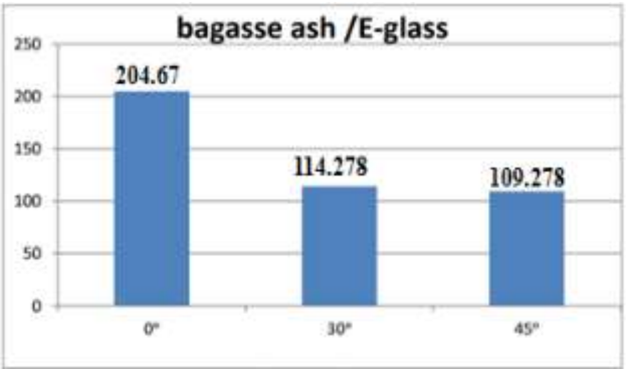
The tensile strength of sugarcane bagasse ash and e glass fiber hybrid composite has been conducted. The experimental results have been presented in table.

Table: Tensile test results for bagasse ash/E glass hybrid composites

Composite laminate	Fibre Orientation	Load at break(N)	Elongation at peak(mm)	Tensile strength(N/mm^2)
Sugarcane bagasse ash/E-glass fibre	0°	13881.5	8.335	204.670
	30°	8676.5	6.924	114.278
	45°	6359.5	6.866	109.278



X axis : E-glass Orientation

Y axis : Tensile strength (N/mm^2)

Fig: Tensile strength for sugarcane bagasse ash/Glass Hybrid composites

The change in tensile strength for composites containing different orientation of E glass fibre with 5%wt of bagasse ash is shown in Fig 6.1. The highest 204.67 N/mm^2 and the lowest 109.278 N/mm^2 were observed with 0° and 45° respectively. The shear stress induced at the interface of each lamina is the major reason for drop in the tensile strength [12]. Figure gives stress vs strain graph for composites containing different orientation of E glass fibre with 5%wt of bagasse ash reinforced with epoxy resin.

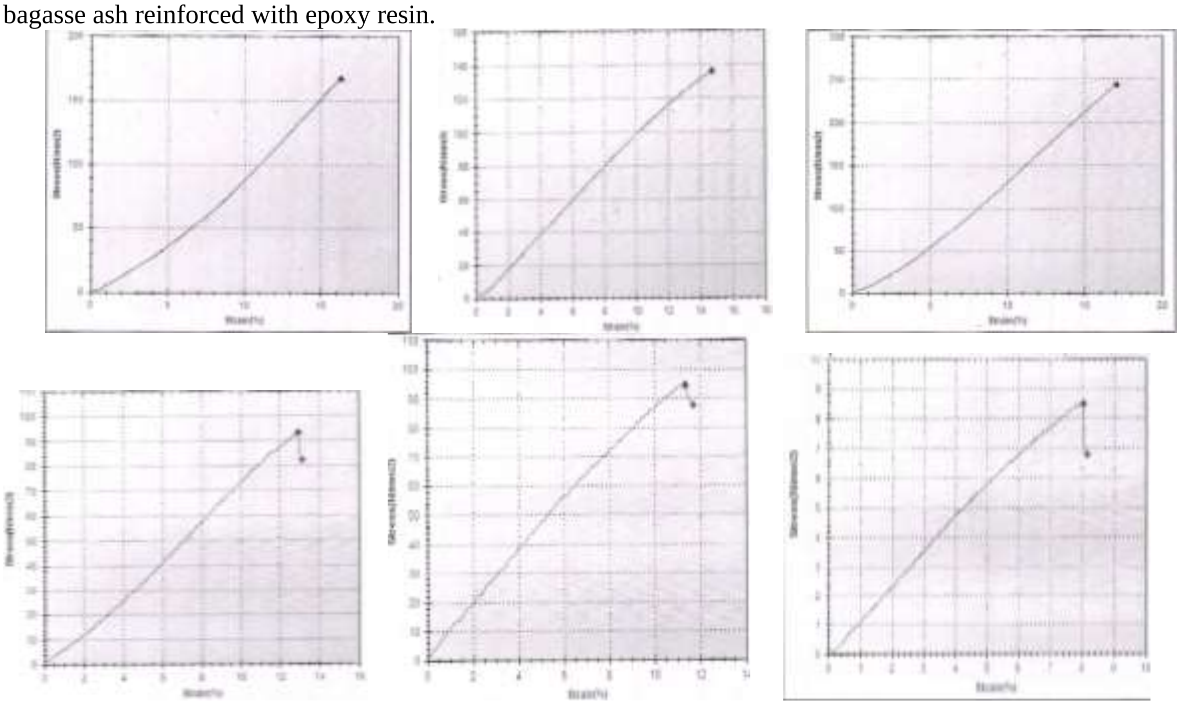


Fig: Stress vs Strain graphs for 0°, 30°, 45° orientation of E-glass, two samples of each composite laminate is taken and variations are shown.

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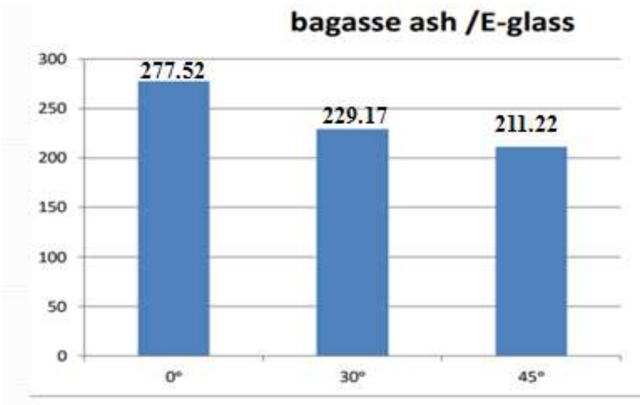
Flexural Test

The flexural test for different hybrid composites are performed as per the ASTM standards at the test speed of 5mm/min. Two specimens of each variation of the hybrid composites were taken for testing and average of the values are taken for analysis.

The flexural strength value of the composite was comprehensively studied by means of three point bending flexural test.

Table: Flexural test results for bagasse ash/ E-glass hybrid composites

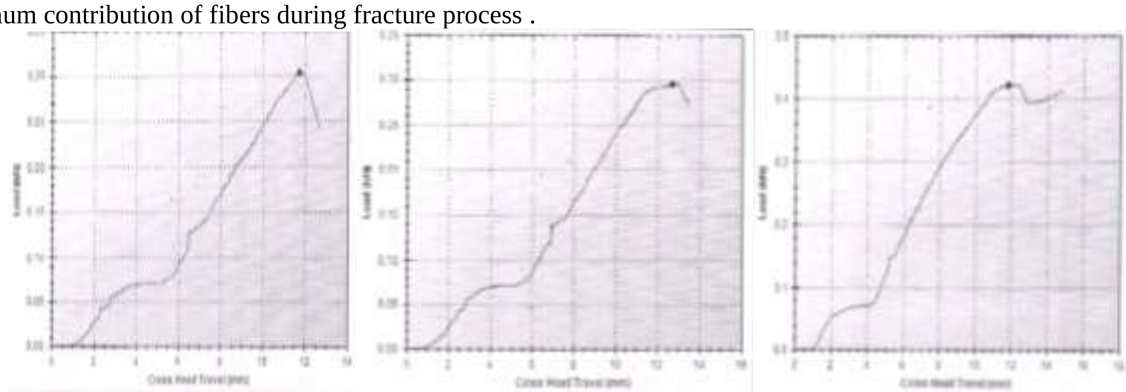
Composite laminate	Fibre Orientation	Load at peak(N)	Deflection at peak(mm)	Flexural strength(N/mm^2)
Sugarcane bagasse ash/E-glass fibre	0º	298.5	12.484	277.52
	30º	407.0	12.246	229.17
	45º	210.0	16.007	211.22



X axis : E-glass Orientation
Y axis: Flexural strength (N/mm^2)
Fig: Flexural strength for bagasse ash/ E glass hybrid composites

The flexural strength of 277.52 N/$mm^2$and 211.22 N/mm^2 were recorded for 0º and 45º respectively. The flexural strength decreases with increasing the angle of E-glass orientation. Figure gives load vs cross head travel graph of bagasse ash/ E-glass hybrid composites.

The flexural strength decreases with increasing the orientation of E-glass fiber. This is because in 0º fiber orientation specimen the crack propagation is arrested by fibers during fracture process and as degree orientation increases there is a minimum contribution of fibers during fracture process .



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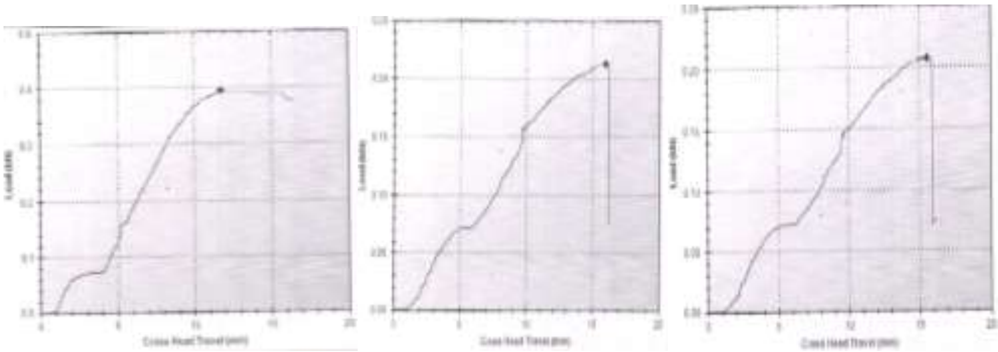

Fig: Load vs Cross head travel graph of 0°, 30°, 45° orientation of E-glass, bagasse ash/ E-glass hybrid composites.

V. CONCLUSIONS

In this study, hybrid composite was developed with Epoxy as a matrix material and E-glass and bagasse ash as reinforcement materials. The characterization results revealed that the tensile strength and flexural strengths were improved with the addition of 5%wt of sugarcane bagasse ash compared to composite made of e-glass and epoxy resin. The tensile and flexural strengths decreases with increase in e-glass orientation because of shear stress induced on the interface of each lamina and crack propagation is stopped by fibres during the fracture process in 0° fibre orientation specimen, and the contribution of fibres during the fracture process decreases as the degree orientation increases.

1. In this investigation, characteristics of Sugarcane bagasse ash, varied orientation of E-glass, Epoxy Hybrid polymer matrix have been studied and following conclusions are drawn.
2. During fabrication and post fabrication, the composite laminates were systematically processed and cured as per the recommendations of the resin manufacturer for LY 556 Epoxy resin.
3. The composite exhibit good characteristics in tensile and flexural loadings, since E-glass is known for its high strength and stiffness.
4. It is noted that, the composite exhibit tensile strength as follows, the highest 204.67 N/mm^2 and the lowest 109.278 N/mm^2were observed with 0° and 45° respectively and the flexural strength of 277.52 N/$mm^2$and 211.22 N/mm^2were recorded for 0° and 45° respectively.
5. Observation made that, the Tensile and Flexural strength decreases with increasing the degree of orientation of E-glass fiber in the composite.
6. The composite having 5%wt of bagasse ash and 0° orientation of E-glass reinforced with Epoxy resin exhibits better properties among other variations of E-glass orientation.

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