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Effect of Epoxy modifiers (Bagasse fiber / Bagasse ash / Coal powder /Coal Fly ash) on mechanical properties of Epoxy / Glass fiber hybrid composites

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Abstract

In this Research work, an investigation was made on the mechanical properties of E-glass Reinforced epoxy based composites without and with filler materials (Bagasse fiber **(B.F)** / Bagasse Ash **(B.A)** / Coal powder **(C.P)** /Coal Fly Ash **(C.F.A)**) which acts as epoxy modifiers. Composites filled with 10 wt% concentration of Bagasse Fiber, Bagasse Ash, Coal Powder and Fly Ash from Coal, were fabricated by hand lay-up technique. The fabricated composites are cut in to specimens according to the **ASTM** standards and the mechanical properties like Tensile strength, Flexural strength, Impact strength, Inter laminar shear strength (ILSS) and tensile modules of the specimens were determined. The Test Results shows that composite filled by 10 wt % Bagasse Ash exhibited maximum Tensile strength, flexural strength and Inter laminar shear strength when compared with the other filler composites. The composite filled by 10 wt % coal powder exhibited maximum impact strength and composites filled by 10 wt % Coal Fly Ash exhibited maximum tensile modulus.

Key words: Polymer matrix composites, Glass fiber, flexural strength, Tensile strength, ILSS, Impact strength, tensile modulus

1. Introduction

In the field of material science engineering, development of new composite materials (or) modification of existing composite is the real challenge for most of the Researchers. Polymer matrix composites have good potential to replace the traditional metallic materials because of their advantages like easy processing, productivity, cost reduction etc. over conventional materials. Among the thermosetting polymers epoxy resins are the most widely used for high performance applications because of their excellent mechanical and thermal properties high chemical and corrosion resistance low shrink on curing and the ability to be processed under a variety of conditions [1] .To develop new class of polymer structural materials polymer matrix modification is one of the approaches. The properties of polymers are modified by using carbon fiber and glass fibers as Reinforcements [2]. Glass fiber reinforced epoxy composites give the attractive combination of physical and mechanical properties which cannot be obtained by monolithic materials [3, 4].Mechanical properties of fiber Reinforced composites depends on type of fiber, quantity, fiber distribution and orientation and void content. Besides this the nature of the interfacial bonds and the mechanism of load Transfer of the interphase also play an important role [5].

It is observed from literature that there is a significant improvement on mechanical properties of Epoxy based composites with the addition of micro fillers, which acts as additional Reinforcing components and enhances their mechanical properties and also reduces the processing cost significantly. The properties of these composites depend upon the type, size and weight percentage of the filler material used [6, 7]. The mechanical characterization and comparison of mechanical properties of E-Glass reinforced epoxy based hybrid composites with equal weight % of fillers (modifiers) like Bagasse fiber/Bagasse ash/coal powder/coal fly ash has not been studied hence in this paper E-Glass reinforced particulate (modifiers or fillers) filled epoxy based hybrid composites are prepared and their mechanical properties are studied with 10wt% different fillers. There will be some improvement in mechanical properties if modifiers are added to epoxy. From the test results Bagasse ash modified composites increases the Tensile strength, Flexural strength and ILSS compared to other modifiers, similarly coal powder modified epoxy composite increases the Impact Strength and coal Fly ash modified epoxy composite increases the Tensile modulus compared to other modifiers.

2. Details of Experiment

2.1 Materials required

Bagasse fiber, Bagasse ash, coal powder and coal fly ash particles are used as modifiers. Bagasse fiber and Bagasse ash are collected from KCP sugars and Industries Corporation Limited, Vuyyuru. Coal power and coal fly ash are collected from NTTPS, Vijayawada. Collected fly ash, coal powder and Bagasse ash are cured in a woven at a temp of 105^0C for removal of moisture and then sieved to an average size of 70-80 µm. The epoxy resin Araldite (LY-556), hardener (HY-951) and E-Glass fiber for reinforcement is supplied by kotson engineering corporation, Guntur.

2.2 Fabrication of composite without filler material

A mold of size 400 x 400 x 3 mm^3 is prepared and the work side of the mold was coated with a Releasing agent (PVA). Resin and Hardener were mixed and stirred mechanically in a Ratio of 10:1 by weight. With the help of a brush the mixture of epoxy resin and hardener are applied inside the mold surface after the application of PVA. One layer of E-Glass fiber of size 400X400m^2 is placed in the mold. E-glass sheet is coated with the resin and mild steel Roller is used to remove the entrapped air bubbles and to get uniform distribution of resin and another layer of E-glass fiber is placed on it and the process is continued up to eighth layer and it is cured at room temperature for 24 hours.

2.3 Fabrication of Hybrid composites with natural filler (Bagasse fiber)

Composite laminate is prepared by conventional hand layup technique in a mold of size 400x400x3 mm^3 at room temperature. The composite consists of eight layers of woven E-glass fiber. Bagasse fiber is cut in to the pieces of length 2 to 4cm.10wt% of these pieces of Bagasse fiber are taken in a container or bowl. Poly vinyl alcohol (PVA) is applied on the work side of mold which acts as releasing agent for the composite. After the application of PVA Epoxy and hardener in 10:1 ratio are mixed with each other in appropriate wt% and then a layer of resin is applied on the dried layer of PVA by using the brush, the first layer of E-Glass fiber of size 400X400m^2 is placed on the resin layer, then resin is applied over the glass fiber sheet and $1/6^{th}$ of the Bagasse fiber is pieces are sprinkled uniformly over the glass fiber layer. The second sheet of glass fiber is placed on the Bagasse fiber sprinkled on the first layer of glass fiber; again the resin is applied thoroughly on the second sheet of E-Glass fiber to wet the bottom fibers of glass and Bagasse .this procedure is continued up to the eighth layer of glass fiber with resin coating on it. A plate of 400X400m^2 size is placed over the mold to complete the assembly and the mold is placed under a load of 15 tones to remove entrapped air bubbles and the excess resin which flows out to complete the curing process the mold is left for 24 hours at room temperature.

2.4 Fabrication of hybrid composites (with fillers like Bagasse ash / Coal powder / Coal Fly ash)

Hand lay-up technique is used to fabricate E-Glass reinforced epoxy based particulate filled composites. Those particulate fillers are Bagasse ash/coal powder/coal fly ash with 10wt%.The designation and composition of Epoxy, Glass fiber, Fillers and hardener are fixed and they are shown in Table-1 where C_1 is pure Glass reinforced epoxy composite without filler material.C2 is Glass reinforced epoxy reinforced epoxy composite with Bagasse fiber as filler material.C3, C4 and C5 indicates Bagasse ash, coal powder and fly ash modified FRP composites respectively. Before mixing the fillers (Bagasse ash/coal powder/coal fly ash) with epoxy they are dried at 105^0C in a woven for 2hours.then the fillers are added with epoxy and stirred using a round glass or wooden stirrer for 30 minutes before the mixing of hardener and then hardener is mixed, the same procedure of fabrication of composite without filler is followed in the fabrication of composites with fillers. Mild steel roller is moved on the each layer of the glass fiber to spread the resin uniformly and to remove the air entrapped in the composite. This procedure is repeated up to 8 layers of glass fiber and then composites are cured at atmospheric temperature for 72hours.

Table-1: Designation and Composition of Composites_Raffi

Designation of Composite	Composition
C1	50wt% Glass fiber(G.F) + 50wt% resin (R)
C2	50wt% Glass fiber(G.F)+40wt% Resin(R)+10wt% Bagasse fiber(B.F)
C3	50wt% Glass Fiber(G.F)+40wt% Resin(R) +10wt% Bagasse ash(B.A)
C4	50wt %Glass Fiber (G.F)+ 40wt % resin(R)+10wt% coal powder(C.P)
C5	50wt % Glass Fiber(G.F) + 40wt% resin +10wt% Coal fly ash(C.F.A)

2.5 Specimen preparation

From the molds the fabricated E-Glass reinforced particulate filled epoxy based hybrid composites were taken out and as per ASTM standards they are cut in to the specimens of perfect dimensions from the composite slabs for mechanical characterization (i.e. Tensile test, flexural and impact tests) by using hack saw and various tools in engineering work shop various specimens of shapes and sizes are shown below.

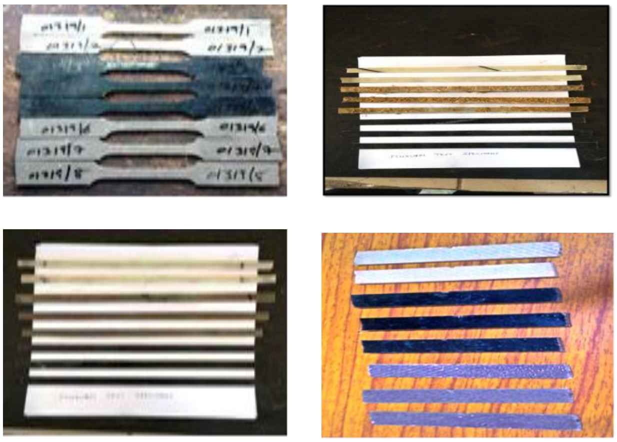

Figure1: Tensile test, Flexural Test and Impact Test specimens

2.6 Material Test Details

2.6.1 Tensile strength and tensile modulus

The dog bone type specimen with end tabs is used for tensile test as per ASTM- D 638- III standard. The dimension of the samples for the test is 246mmx29mmx3.14mm.The test is performed on FIE40 UTN-40 machine. Sixteen number of specimens with and without fillers are used to test the tensile strength and their mean value is taken as their Tensile strength for each composite with a particular filler material.

2.6.2 Flexural and Inter laminar shear strength

The short beam shear test is conducted on the samples to calculate ILSS. The test is conducted as per the ASTM D-290-2003 standard for the prepared samples. The dimension of the samples for the test is 246mm x 15 mm x 3mm. universal testing machine UTE-60T, MCS, SI: 170/0507 is used for the Test. The cross head speed is maintained at 10mm/min and the test is conducted for sixteen specimens to get the values of inter-laminar shear strength (ILSS) and Flexural strength.

The ILSS equation is

$$\textbf{ILSS} = \frac{3P}{4bd}$$

Here, p is the maximum load applied, b is the width of specimen and d is the thickness of the specimen. The same value of p is used to calculate the flexural strength also. A span of 52mm is used for obtaining both ILSS and Flexural strength. Flexural strength is calculated by using the equal.

$$\textbf{Flexural Strength} = \frac{3PL}{2bd2}$$

2.6.3 Impact strength

Impact tests are done as per ASTM D 256 using an impact tester. The size of the specimen for Impact test is 64x 12.0 x 3.25 mm^3 and the depth under notch is 10.2mm. The machine is adjusted such that the blade on the free hanging pendulum just barely contacts the specimen. The testing conditions may be assumed as Ideal. The specimens are clamped in a square support and the struck at their central point by a hemispherical bolt. The values of Impact energy of different specimens are recorded directly from the dial Indicator.

2.6.4 Specimens after test

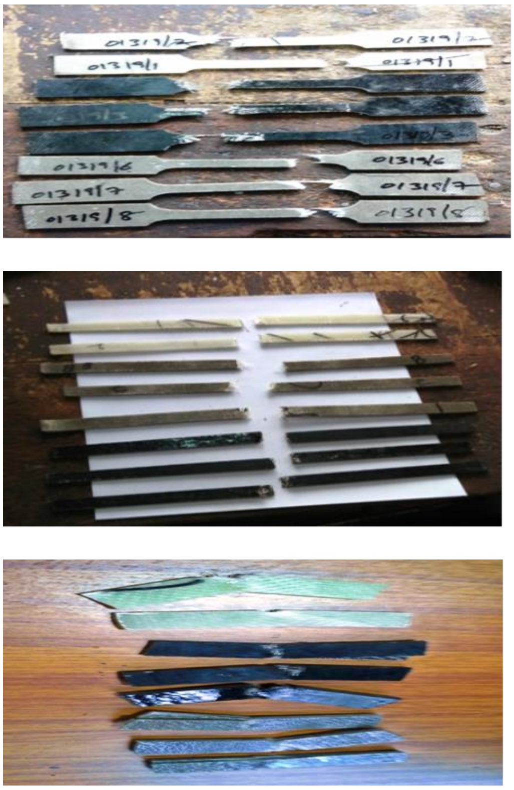

Figure2: Tensile test, Flexural Test and Impact Test specimens after test (from top to bottom)

3. Results and Discussion

3.1 Tensile strength

Table 2 shows the Experimental results of Tensile strength

Table 2: Tensile strength for composites_ Raffi

Designation	Composition	Tensile strength (MPa)	Mean value of Tensile strength (MPa)
C1	50%G.F+50%R	214.379 298.701 248.751 256.926	252.18925
C2	50%G.F.+40%R+10%B.F	58.487 82.164 85.041	75.230
C3	50%G.F+40%R+10%B.A	196.237 211.015 239.012	**215.421**
C4	50%G.F+40%R+10%C.P	194.160 190.363 160.836	181.786
C5	50%G.F+40%R+10% (C.F.A)	188.333 175.130 161.937	175.133

The Tensile strength of the epoxy based hybrid composites depends upon the fiber length, modulus of the fibers, strength of the fibers, matrix fiber interaction, chemical stability of the matrix fiber and strength of the matrix.

Due to the excellent particle dispersion in matrix and strong interface adhesion between filler and polymer, it is observed that the hybrid composite filled by 10wt% **Bagasse ash** exhibits maximum tensile strength of 215.421MPa compared to other filler composites and lower than the unfilled composites.

Due to the presence of ceramic particles in coal powder which gives the good bonding strength in between polymer filler and fiber, it is observed that composites filled by 10wt% coal powder exhibits better tensile strength compared to composites filled by other fillers like coal fly ash and Bagasse fiber

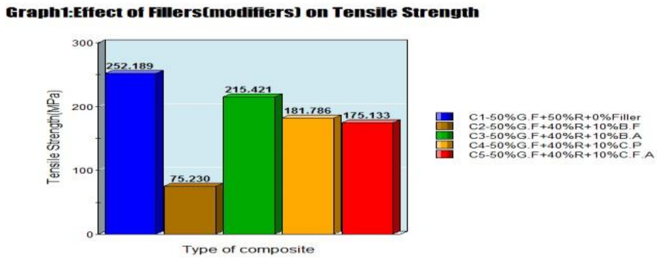

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Figure3: Graph for type of composite VS Tensile strength

The unfilled composite exhibited maximum tensile strength of 252.189 MPa when compared with the filler composites. The declines in Tensile strength of particulate filled composites when compared with the unfilled composites are because of

- Presence of pores at the interface between filler particles and the matrix. The interfacing adhesion may be too weak to transfer the tensile stress.
- In the matrix base stress concentration results due to the irregular shaped particulates.

3.2 Tensile Modulus

Table 3 shows the Experiments results of tensile modulus

Table 3: Tensile modulus for composites_ Raffi

Designation	Composition	Tensile modulus (MPa)	Mean value of Tensile modulus (GPa)
C1	50%G.F+50%R	6510.76 6123.37 6244.157	6.292
C2	50%G.F.+40%R+10%B.F	457.48 815.01 894.02	0.722
C3	50%G.F+40%R+10%B.A	6896.32 6179.72 6836.85	6.637
C4	50%G.F+40%R+10%C.P	6045.99 6504.06 4445.57	5.665
C5	50%G.F+40%R+10% (C.F.A)	8909.59 7693.2 6868.36	**7.823**

The tensile modulus of **coal fly ash** modified epoxy composite is more compared to Bagasse fiber/Bagasse ash/coal powder modified epoxy composites and unfilled composite. The graph of Type of composite VS tensile modulus is shown below.

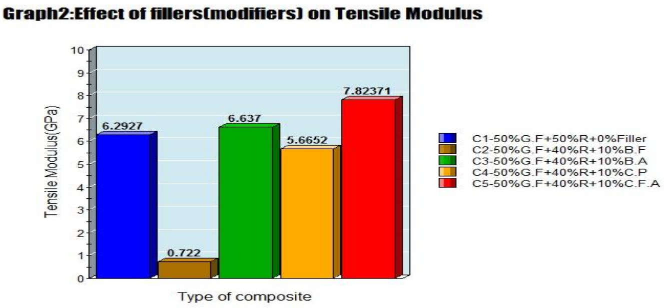

Figure4: Graph for type of composite VS Tensile modulus

3.3 Flexural Strength and ILSS

Table 4 : Flexural Strength for composites_ Raffi

Designation	Composition	Flexural Strength (MPa)	Mean value of Flexural Strength (MPa)
C1	50%G.F+50%R	955.53 1000.86 890.95 1054.2	975.38
C2	50%G.F.+40%R+10%B.F	110.02 110.21 117.14	112.45
C3	50%G.F+40%R+10%B.A	860.22 734.28 806.02	**800.1733**
C4	50%G.F+40%R+10%C.P	839.69 691.4 720.55	750.54
C5	50%G.F+40%R+10% (C.F.A)	735.51 674.98 668.72	693.07

Table 5 : Inter Laminar Shear Strength(ILSS) for composites_ Raffi

Designation	Composition	ILSS (MPa)	Mean value of ILSS (MPa)
C1	50%G.F+50%R	28.390 30.025 27.842 30.8150	29.268
C2	50%G.F.+40%R+10%B.F	9.679 9.80 10.2836	9.921
C3	50%G.F+40%R+10%B.A	28.868 26.970 28.133	**27.99**
C4	50%G.F+40%R+10%C.P	26.966 23.866 24.734	25.188
C5	50%G.F+40%R+10% (C.F.A)	25.389 23.754 23.598	24.247

From the Table 4 and Table 5 of flexural and inter-laminar shear strength (ILSS) Results, it is observed that Bagasse ash modified epoxy composites exhibited more flexural strength and INTER LAMINAR SHEAR STRENGTH of 800.173MPa and 27.990MPa respectively. This may be because of finer particle size of less than 10 microns of Bagasse ash which gives better adhesive strength compared to other fillers

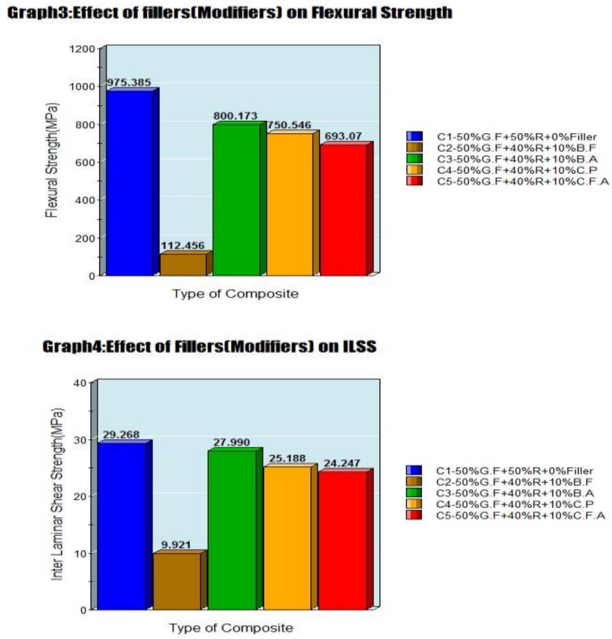

Figure5: (a) Graph for type of composite VS flexural strength (b) Graph for type of composite VS ILSS

3.4 Impact Strength

Table 6: Impact Strength for composites_ Raffi

Designation	Composition	Impact Strength (MPa)	Mean value of Impact Strength (MPa)
C1	50%G.F+50%R	3.6 4.3 6.0 5.0	4.725
C2	50%G.F.+40%R+10%B.F	3.5 5.5 5.8	4.933
C3	50%G.F+40%R+10%B.A	4.6 5.4 5.4	5.1333
C4	50%G.F+40%R+10%C.P	6.4 5.8 4.6	**5.6**
C5	50%G.F+40%R+10% (C.F.A)	4.8 3.4 3.8	4

Table 6 shows the results of impact strength of various composites. From those results it was observed that impact strength of **coal powder** modified epoxy composites is (5.6J) more when compared with the Bagasse fiber/Bagasse ash/coal fly ash modified composites. It may be because of more hardness of coal powder compared to other filler materials.

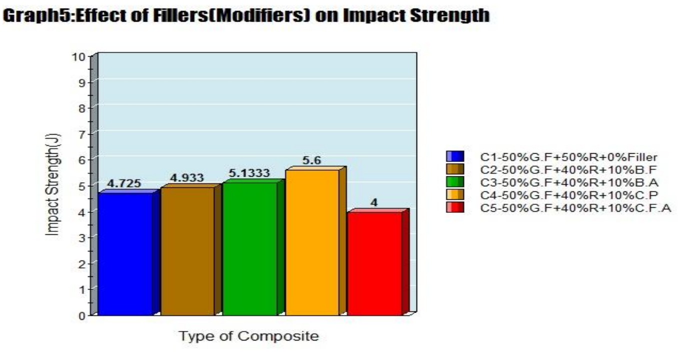

Figure6: Graph for type of composite VS Impact strength

4. Conclusions

Fabrication of E-glass reinforced epoxy based composites with or without fillers is possible by simple hand lay-up process.

The mechanical properties like tensile strength, flexural strength and ILSS more in Bagasse ash modified epoxy based composites compared to Bagasse fiber/coal powder/coal fly ash modified composites.

Impact strength of coal powder modified composite is more compared to Bagasse fiber/Bagasse ash/coal fly ash modified composites.

Tensile modulus of coal fly ash modified epoxy composites is more compared to Bagasse fiber/Bagasse ash/coal powder modified composites.

5. Acknowledgments

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