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Effect of Fly Ash as Filler on Glass Fiber Reinforced Epoxy Composites

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Abstract: *This study focuses on investigating the influence of percentage variation of filler content on the mechanical properties of glass fiber reinforced epoxy composites using fly ash, a waste by-product from coal combustion in thermal power plants. The CAD model is designed following ASTM D 3039 standards, and three different specimens with varying filler contents (10%, 30%, and 40%) are numerically analyzed using ANSYS 16.0. A pure composite specimen is also included for comparison. The results indicate that the pure composite material exhibits higher strength enhancements compared to the specimens with filler content variations.*

Keywords: Epoxy Composite, Fly ash filler material, FEM, UTM Experimentation

I. INTRODUCTION

Composite materials are extensively employed in the automotive and aerospace industries due to their lightweight nature, making them crucial for improved fuel efficiency. Among these, glass fiber reinforced epoxy composites offer a desirable combination of physical and mechanical properties not achievable in monolithic materials.

Epoxy resins are commonly used as matrices in fiber reinforced composites, prized by structural engineers for their unique balance of chemical and mechanical attributes and versatile processing capabilities. Glass fibers are the preferred reinforcing material in structural applications due to their specific strength properties, widespread availability, and cost-effective manufacturing techniques. Ongoing research aims to further enhance their properties.

To strengthen glass fiber reinforced epoxy composites, various filler materials can be incorporated. These fillers act as additional reinforcing components, contributing to improved mechanical properties. Fly ash, a waste by-product produced from coal combustion in thermal power plants, is one such filler material that can be utilized to enhance the composites' mechanical properties.

Fly ash, classified into Class F and Class C as per ASTM C618, generally comprises oxides rich in silicon (SiO_2), iron (Fe_2O_3), and aluminum (Al_2O_3). Its composition varies based on the source of coal, containing different properties of silica, alumina, iron oxides, calcium, magnesium, along with trace elements like C, Ti, Mg, etc. Fly ash serves as an inert material in composites, reducing material costs, moderately enhancing mechanical properties, and improving processability. Notably, reducing the size of the filler particles leads to better property enhancement by ensuring uniform distribution within the polymer matrix. The fly ash exhibits a combination of properties from spherical particles and those of metals and metal oxides.

II. LITERATURE SURVEY

Baljeev Kumar, Rajeev Garg, and Upinderpal Singh investigated the economic and commercial utilization of fly ash as a filler material in polymer composites.. They found that using fly ash as a reinforcing filler in High-density polyethylene (HDPE) can lead to lightweight composites. The compatibility between fly ash and polymer was enhanced through modification and compatibilization, resulting in significant improvements in the composite properties. However, the full potential of fly ash as a reinforcing filler in polymer composites, particularly in Fly ash/HDPE composites, has not been fully explored.

K. Thomas Paul, S.K. Sathpathy, I Manna, K.K. Chakraborty, G.B. Nando, and others focused on reducing the size of fly ash particles from the micrometer level to the nano level through high-energy ball milling. They achieved a reduction in average particle size from 60 µm to 1480 nm, a significant decrease of approximately 405 times.

S.R. Chauhan, Anoop Kumar, I Singh, and Prashant Kumar conducted studies on the coefficient of friction and dry sliding wear of polymer matrix composites. They discovered that the coefficient of friction decreased with the addition of 10 wt % to 20 wt % of fly ash, while wear resistance increased with the same additions.

R. Satheesh Raja, K. Manisekar, V. Manikandan, and others investigated the effect of fly ash filler size on the mechanical properties of polymer matrix composites. They prepared composite specimens using four different sizes of fly ash filler materials (50 µm, 480 nm, 350 nm, and 300 nm) through CAD molding. Their findings showed that the 300 nm size fly ash filler impregnated polymer composite exhibited better impact energy (14 J) and hardness value (35 Hv) than the other sizes, indicating that reducing the filler size improved the bond between the polymeric matrix and solid fillers.

JitendraGummadi, G. Vijay Kumar, and Gunti Rajesh prepared samples with five different particle sizes of fly ash and varying percentages of fly ash in polypropylene. They conducted bending tests on the specimens using a tensometer and found that the addition of fly ash improved flexural modulus and flexural strength while decreasing percentage elongation at break. The finest particles exhibited the best flexural strength at all concentrations.

PatilDeogonda, Vijaykumar N. Chalwa, and others utilized TiO2 and ZnS as filler materials in Glass Fiber Reinforced Plastic (GFRP) laminated composites and observed that the tensile, bending, and impact strength increased with the addition of filler materials. However, the ZnS-filled composite performed better than the TiO2-filled composite, and both fillers made the material harder and more brittle, resulting in reduced impact toughness.

S.D. Saravanan, M. Senthil Kumar, and their team studied the effect of mechanical properties on rice husk ash reinforced Aluminum alloy (AlSi10Mg) matrix composites. They used different weight fractions of rice husk ash to develop metal matrix composites and found that the tensile strength, compression strength, and hardness increased with an increase in weight fraction, while the ductility decreased.

Based on the literature survey, the project aims to prepare different composite specimens by varying the percentage of fly ash and conducting tensile tests on a Universal Testing Machine (UTM).

III. DESIGN AND ANALYSIS

A. Material Specification:

The materials used to prepare the specimen are E-Glass fiber, Epoxy resin (LY556), Hardener (HY951)

Material : Epoxy, Glass Fiber, Fly Ash

Young's Modulus: 5000 - 35000 MPa

Poisson's Ratio: 0.24 - 0.4

Density: 1800 - 1850 kg/m^3

Table 1: Filler Material Specimen Details

	E-Glass mat		
Sr. No.	*Glass fiber content %*	*Epoxy*	*Filler content in % (fly ash)*
1	60	40	-
2	50	40	10
3	30	40	30
4	20	40	40

Table 2: Test specimen detail

Test specimens	ASTM	Size
Tensile test specimen	D-3039	250x25x2.5 mm.

B. CAD Model:-

To prepare the CAD model of specimen ANSYS 16.0 Design modeler is used.

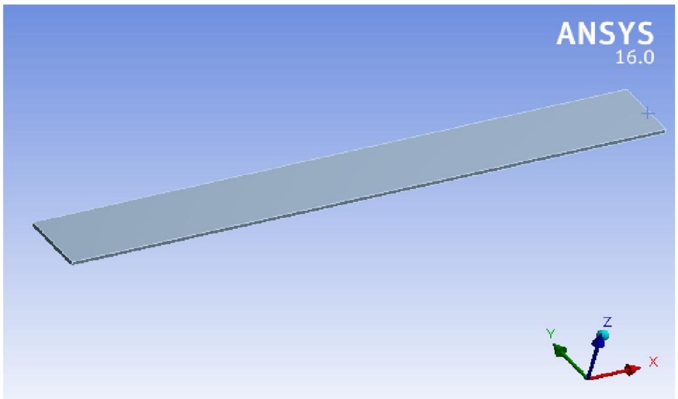

Fig1. CAD Model of specimen

C. Discretization or Meshing:-

A hexahedron element with a standard program controlled mesh is employed for discretizing the model. The mesh consists of 2640 nodes and 1890 elements. .

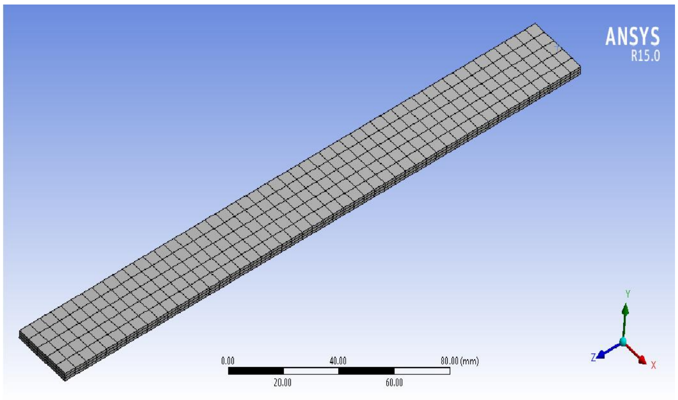

Fig2. Discretization of specimen

D. Boundary Condition & Loading:-

To apply tension on specimen one end is made to fix and another end is applied with tension load.

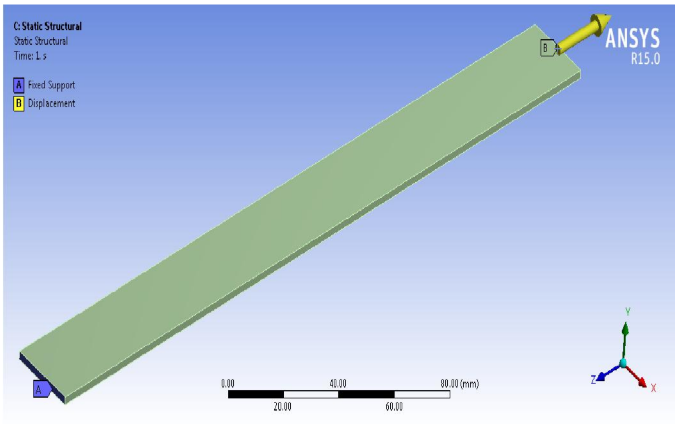

Fig3. Boundary conditions and loading on specimen

E. Orientations:-

Given orientations are on X-axis = Normal directions, Y-axis = Transverse directions, Z-axis = Fiber directions.

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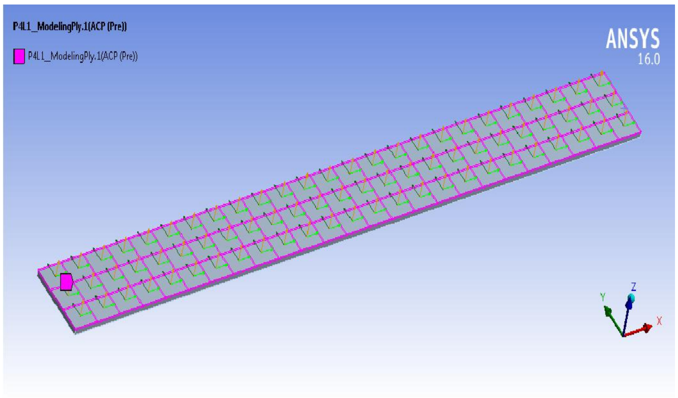

Fig4. Orientations of specimen

F. Plies:-

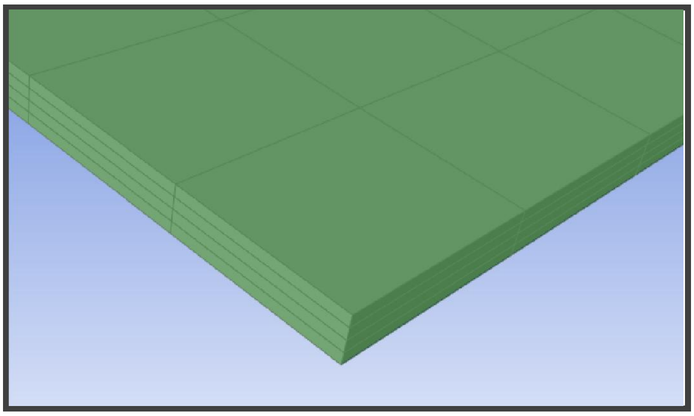

Fig5. Plies of specimen

4. Finite Element Analysis

Normal Stress Plot:-

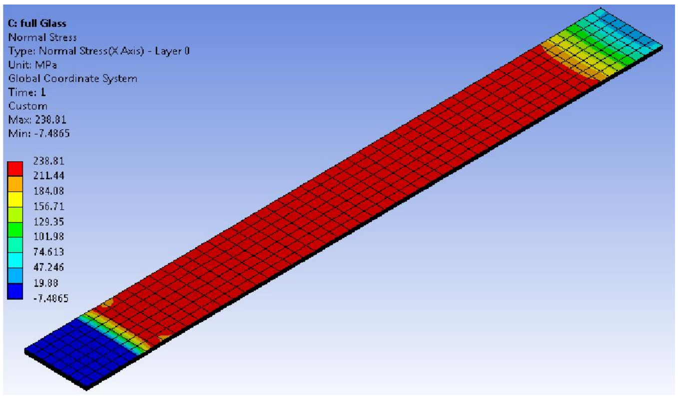

Fig7. Normal stresses of Pure Composite Material

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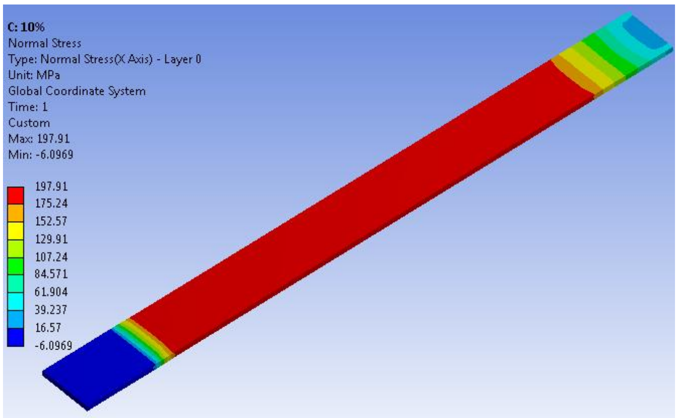

Fig 8. Normal stresses with the filler content of 10 % Fly ash on Composite Material

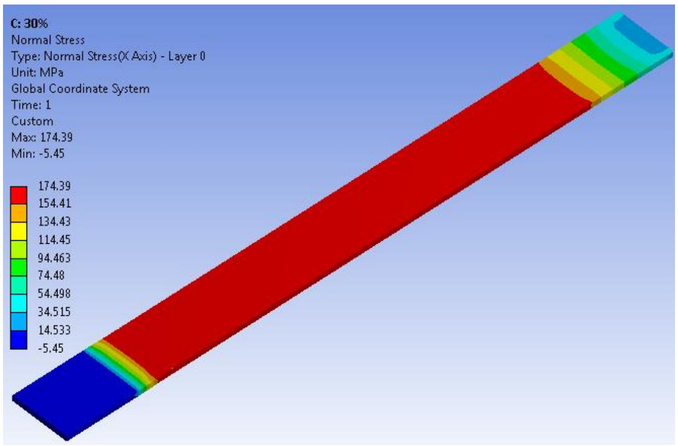

Fig 9. Normal stresses with the filler content of 30 % Fly ash on Composite Material

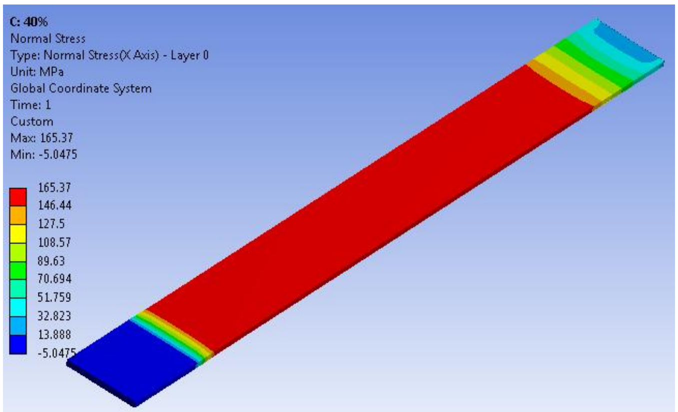

Fig10. Normal stresses with the filler content of 40 % Fly ash on Composite Material

V. EXPERIMENTAL WORK

Fabrication Process

Hand Lay-up Technique

The fabrication of composite material is done by Hand lay-up technique. Glass mat is positioned manually in the open mould and resin is into glass plies. Entrapped air is removed manually with the roller to complete the laminate structure.

The fibers are manually placed into one sided gel coated male or female mould. A matrix of thermosetting resin is rolled onto the fibers using hand . Additional layers can be added to the composite part, and once dried, it can be removed from the mold.roller

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Fig.11 Test Specimens of various (10%, 30%,40%) of fly ash content and pure composite material

A. Tensile Test of Composite Material:-

The test specimens are fabricates in accordance with the ASTM D3039.The test is conducted on UTM/E-40 with resolution of piston movement 0.1 mm.

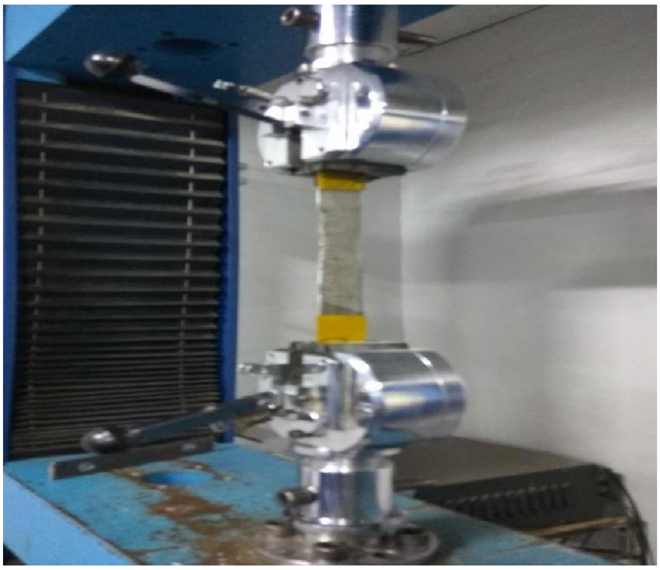

Fig.12 Specimen on UTM during tensile test

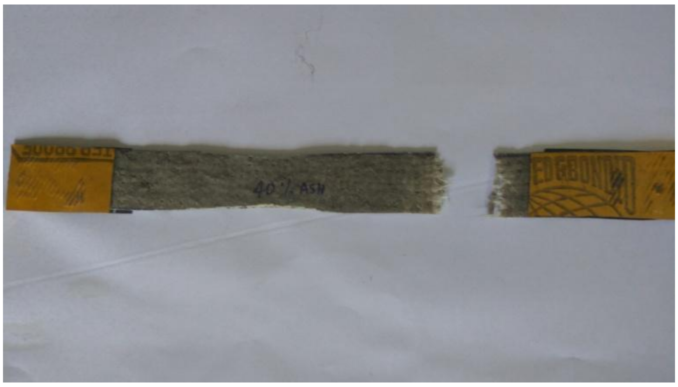

Fig.13 Specimen of fly ash content of 40% after testing

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VI. RESULT AND DISCUSSION

Table 3: Finite Element Analysis Results

Sr.No.	Filler content in % (fly ash)	Force (N)	Normal Stresses in (MPa)
1	-	10000	238.81
2	10	9500	197.91
3	30	9000	174.39
4	40	8500	165.37

Table 4: Experimental Results

Sr.No.	Filler content in % (fly ash)	Force (N)	Normal Stresses in (MPa)
1	-	10789	213.33
2	10	10270	181.26
3	30	9751	159.95
4	40	8105	147.31

Above table shows the finite element analysis and experimental results of different composite specimens with the varying percentage of fly ash and pure composite material.

VII. CONCLUSION

In this present work the residues from the thermal power plant is utilized as filler material in the glass fiber reinforced epoxy composites. The CAD model and analysis is carried out on ANSYS 16.0.The composites specimens are prepared on the basis of variation in filler content (10%, 30%, 40%) of fly ash and one pure composite material. Numerical analysis was performed on above three specimens and on one pure composite material. It is found that the pure composite material requires maximum forces (10000 N by FEM and 10789 N by Experimental) and composite material with 40% filler content of fly ash requires minimum forces (8500 N by FEM and 8105 N by Experimental).Thus by increasing the percentage of filler content the tensile strength is decreases. It is concluded that pure composite material showed significant strength when compare to filler content of 10%, 30% and 40%.

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