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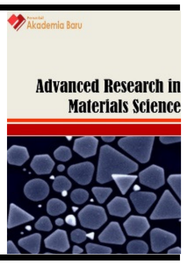

Experimental investigation on mechanical properties of coal ash and fly ash reinforced glass fiber polymer matrix composites

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ABSTRACT

In the present paper, a method is proposed to study the effect of filler material on mechanical properties of GFRP by mixing coal ash and fly ash powders into the resin. Five different types of specimens (FRP without filler material, FRP with 10% and 5% weight percentages of coal ash and the fly ash as filler material) are fabricated by using hand lay-up technique. The mechanical properties such as tensile and flexural properties of the specimens are analyzed using computerized Universal Testing Machine as per the standards ASTM D 638 and ASTM D790 respectively. The behaviour of mechanical properties of the FRP with coal and fly ash materials are listed and compared with GFRP composites. The addition of coal ash and fly ash to polymer matrix increases the overall mechanical strength of the composite materials as compared to the other polymer composite. The availability of waste products such as fly ash and coal can be incorporated into the GFRP to obtain better mechanical properties and can be used in the applications involving high strength and ductility.

1. Introduction

Worldwide research is underway to develop newer composites with varied combinations of fibers and fillers so as to make them usable under different operational conditions. The properties of polymers are modified using fillers and fibers to suit the high strength/high modulus requirements. It is well documented in the literature that majority fillers have a positive influence on mechanical properties. The process of coal combustion results in coal ash. The problem with coal ash lies in the fact that not only does its disposal require large quantities of land, water, and energy, its fine particles, but also if not managed well, by virtue of their weightlessness, can become airborne. Currently, 90 Million tons of fly ash is being generated annually in India, with 65000 acres of land

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being occupied by ash ponds. Such a huge quantity poses challenging problems, in the form of land usage, health hazards, and environmental dangers. Both in disposal, as well as in utilization, utmost care has to be taken, to safeguard the interest of human life, wild life, and environment.

The last few decades have witnessed vast research on new types of combination of filler materials in different types of fibers, namely waste material added like ash reinforced fiber composites [1-2]. The various failure modes of columns, hybrid structures and fiber reinforced polymer poles depends on the material properties, geometric dimensions and type of loading while testing is discussed in [3-5]. The cracking of matrix and more brittleness of the fiber composite was found after failure according to laminate directions and thickness. Several researchers [8-9] discussed that the use of steel wires in glass and carbon fiber composites also increases the flexural strength. The use of Aramid fiber composites and the increase of flexural strength is discussed by Park and Jang [12] and stated that it depends on the type of fibers at compressive face and dispersion extent of the fibers. Berrabah *et al*. [19] reported that the transverse shear deformation and rotary inertia have remarkable influences on the thermal buckling behaviours. The study by Ismail *et al*. [20] presented an experimental investigation on the use of natural fibres i.e. coconut and paddy straw fibres as a substitution for the synthetic materials.

From the thorough literature review it is observed that the reinforcement of by products such as fly ash and coal ash in Glass Fibre Reinforced Polymer (GFRP) can increase the overall strength of the composites. The present work investigates the mechanical properties of fly and coal ash reinforced GFRP composites and to obtain the mechanical properties such as tensile and flexural properties of the composites as per ASTM standards by using hand lay-up technique in different weight percentages.

2. Fabrication Process

2.1 Materials

In the present experimental investigation, Glass fibers were used as reinforcements which are manufactured by the Pultrusion process. After melting glass with minerals in the large furnaces, the glass fibers were extruded through bushings which are bundles of very small orifices (typically 5–25 micrometers in diameter for E-Glass, 9 micrometres for S-Glass), then those filament bundles are woven in different manners. The Bi-axial manner woven Glass fiber mat is shown in Fig 1.

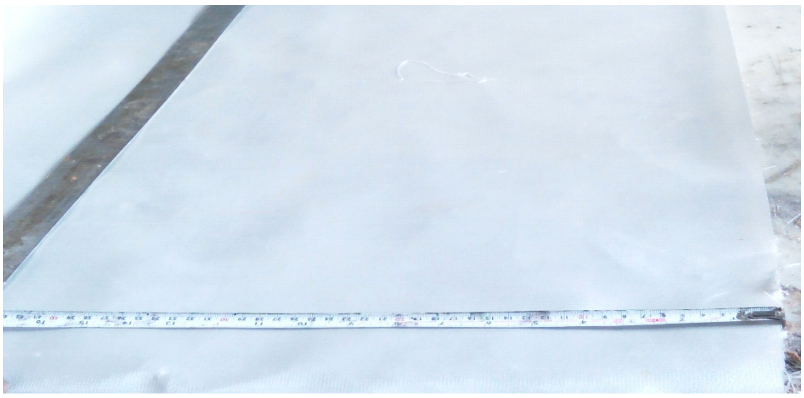

Fig. 1. Glass fiber mat

Epoxy resin has been chosen for matrix for its good cross-linking tendency and processability. For 100 ml of resin, 0.75 mg of hardener was taken at ambient temperature as per the manufacturer's recommendations. Coal ash with fine particle size is collected from the industrial boilers wastage. Fly ash usually refers to ash produced during combustion of coal. The Fly ash used here was collected from the thermal power plant after combustion process by using electric precipitators. The composition of fly ash is listed in the Table 1.

Table 1
General chemical composition of fly ash

Chemical Composition	**Percentage**
SiO2	30-60%
Al2O3	11-19%
Fe2O3	4-11%
MgO	5-6%
CaO	2-45%

2.2 Preparation of Composite specimens:

The open mould technique is adopted for the fabrication of composites, where an open mould is used. A known weight of woven Glass fiber mat was spread in the mould of size 165mm x 19mm x 3.5mm shown in Fig 2 with a weight percentage of 40%.

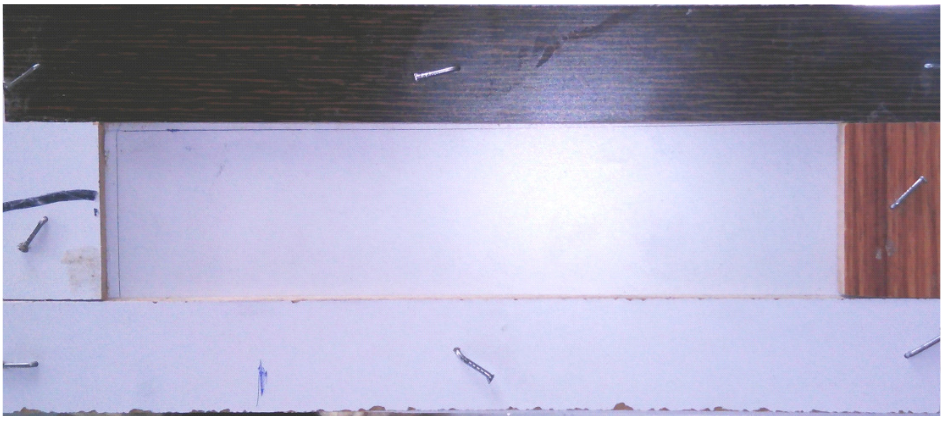

Fig. 2. Open mould

Extreme care has been taken for the orientation of the warp and weft of the mat. Measured quantity of epoxy resin is applied in the die which forms the matrix. The resin solution is degassed prior to pouring, to remove the air bubbles. A roller is used to remove the air bubbles between the mat and resin. The mould is kept free in room temperature up to 12hrs for curing. This results in the fabrication of glass fiber polymer composite specimen. This open moulding is called as wet layup method which is done in an open mould as shown in Fig 3.

Similar to the above process, samples having weight percentage of 5% and 10% of fly ash and coal ash are fabricated upon varying the matrix weigh percentage and keeping the woven glass fiber mat weight percentage as a fixed one. The resin and fillers were metered and mixed thoroughly using stirrers to enclose the coal ash and fly ash inside the epoxy resin. Thus, after curing it results in the fabrication of 5 composite specimens of prescribed size and they are machined to get desired designations as per the ASTM standards.

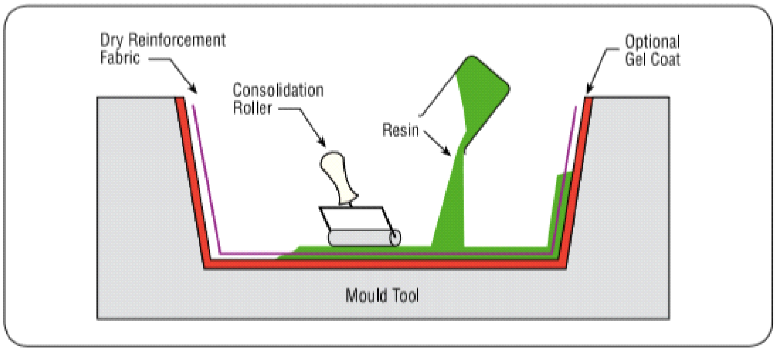

Fig. 3. Wet layup method

3. Experimentation

3.1 Tensile Behaviour of GFRP Composites

In this test, the tensile behaviour of coal ash and fly ash reinforced polymer composites with different weight percentages of ash (5%, 10%) is tested along with GFRP and compared each other. The tensile test is carried out on universal testing machine, as per the ASTM standards. The five specimens are subjected to tensile test and their values are reported in the Table 2.

3.1.1 Method of tensile testing

Standard test method ASTM D638, for tensile properties of the composite has been used to test the composite specimens. As per this, the servo mechanism controlled universal testing machine as shown in Fig 4 is used. This type of machine has two crossheads; one is adjusted for the length of the specimen and the other is driven to apply tension to the test specimen.

Fig. 4. Testing specimen on (UTM)

Various ASTM standard specimens are used for tensile testing. The prepared ASTM D638 standard specimens are tested for tensile test and the specimens before and after testing are shown in the below Fig. 5 and 6.

Fig. 5. Specimens before Testing

Fig. 6. Specimens after Testing

3.2. Flexural Behaviour of GFRP Composites

In this test, the flexural behaviour of coal ash and fly ash reinforced polymer composites in different weight percentages of ash (5% and 10%) is presented. The flexural test is carried out on computerized universal testing machine, as per the ASTM standards. The test specimens are prepared as per ASTM D790 (125 x 3.2 x 12.7) mm. The five specimens are subjected to flexural test and their values are reported in the Table 3.

3.2.1 Method of flexural testing

The method of testing flexural property of the specimens went on as the testing process explained above in the testing section. The loading of the specimens is as shown in the Fig 7.

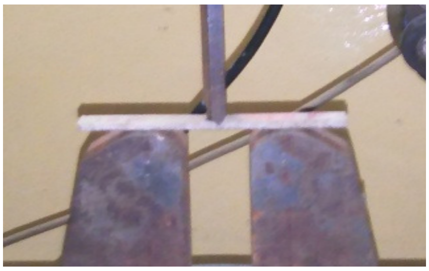

Fig. 7. Loading of specimen for flexural test

The different composite specimens are tested one after the other and the values are noted. The specimens after testing are shown in the below Fig. 8.

Fig. 8. Specimens after flexural test

4. Results and Discussion

4.1 Analysis of Tensile Test Results

The tensile test is carried out in the universal testing machine as per the ASTM D638 Standards and the stress strain curves are observed. The graphs of stress-strain for 10 % fly ash, 10 % coal ash and GFRP are superimposed as shown in the Fig. 9.

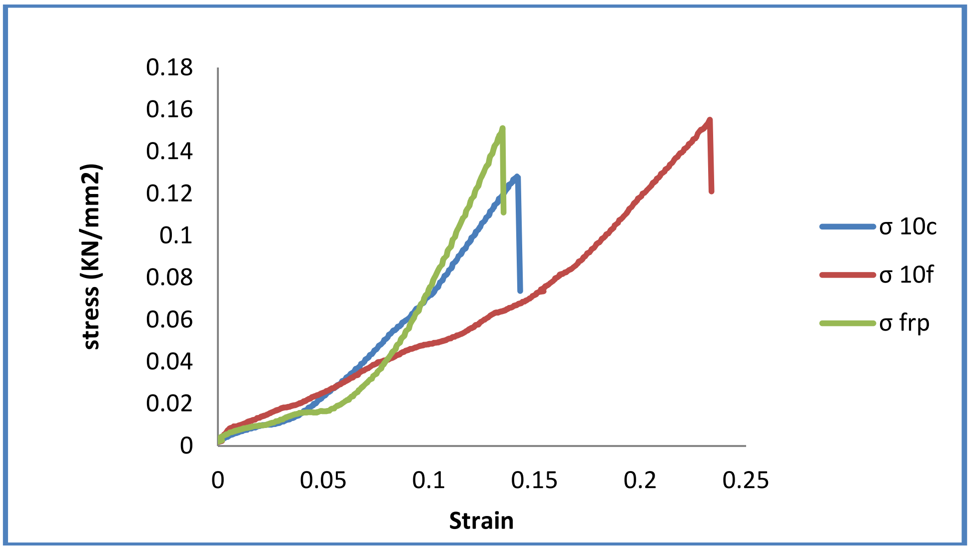

Fig. 9. Stress-Strain curve for 10% weight of coal ash and fly ash with GFRP

From the Fig. 9, it is observed that the percentage of elongation for 10 % Fly ash is increased by 38.18% and 42.01% when compared to 10 % coal ash and GFRP respectively. The increased percentage of elongation of Fly ash shows that it is more ductile as compared to other composites. Also it is found that the ultimate tensile strength for 10 % Fly ash is increased by 17.4% and 2.51% more when compared to 10% coal ash and GFRP respectively.

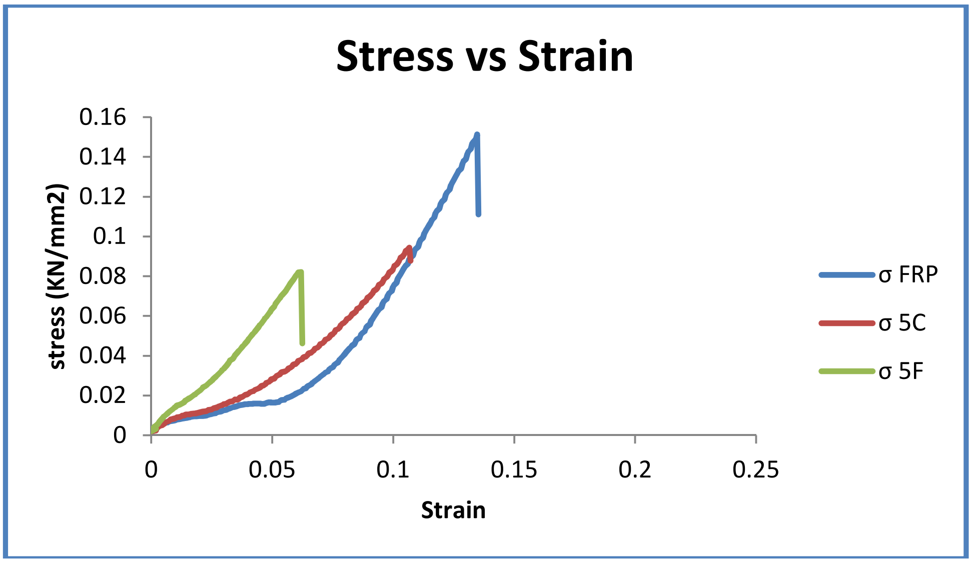

Fig. 10. Stress-strain Graph of GFRP, 5% C & 5% F

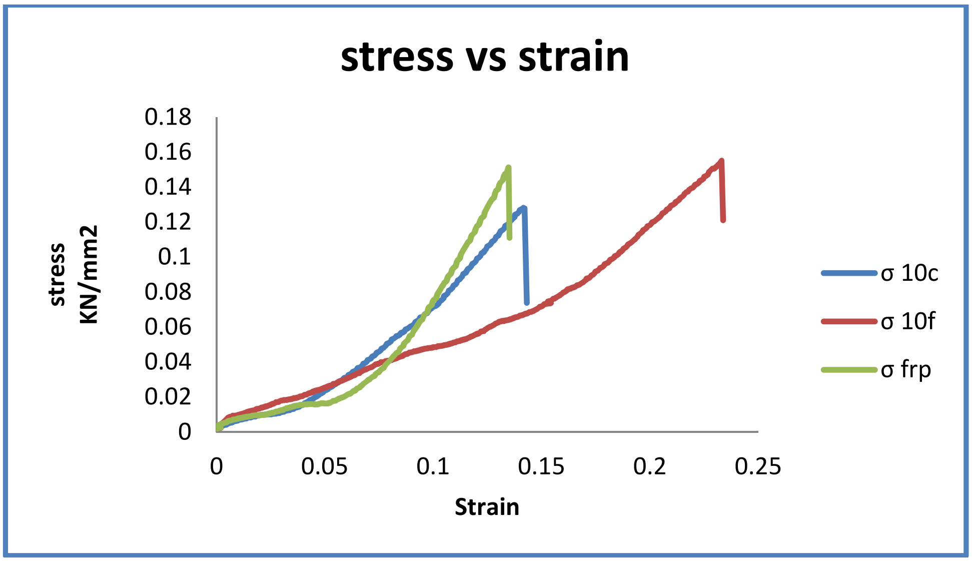

Fig. 11. Stress-strain Graph of GFRP, 10% C & 10% F

Figures 10 and 11 show stress-strain plots for 5% F, 5%C and 10%F 10%C respectively. From the Figures it is observed that as the percentage of fly ash and coal ash increases in the GFRP the percentage of elongation and ultimate tensile strength increases which shows that there is a linear relationship existing and further found that the increase in percentage of fly ash and coal ash increases the ductility in the composites. This could be attributed to the contribution provided by the high strength fly ash particles, thus strength increased with increasing concentration of fly ash.

The results of the tensile test observed while testing are tabulated as shown in the Table 2.

Table 2
Tensile strength of composites

S.No	Specimen	Ultimate Tensile Strength (N/mm^2)
1.	GFRP	151.26
2.	10% coal ash	128.16
3.	5% coal ash	94.26
4.	10% fly ash	155.17
5.	5% fly ash	82.15

4.2 Analysis of Flexural Test Results

The results of flexural testing and their analysis for the coal ash and fly ash reinforced polymer composites are presented in this section. The test data for each specimen is recorded separately and further calculations are carried out and the results are tabulated for each specimen in the Table 3.

Table 3
Flexural Strength of Composites

S. No	Specimen	Flexural Strength (KN/mm^2)
1	GFRP	0.4358
2	10% COAL ASH	0.4691
3	5%COAL ASH	0.6242
4	10%FLY ASH	0.4912
5	5%FLY ASH	0.5188

From the Table 3, it is found that the ultimate flexural strength for 5% coal ash is increased by 30.18% more when compared to GFRP.

5. Conclusions

The present study investigates the mechanical properties of various proportions of fly ash and coal ash based GFRP composites. The availability of waste by products such as fly ash and coal can be incorporated into the GFRP to obtain better properties and thereby they can be used in the applications involving high strength and high ductility. Based on the present work the following conclusions are derived.

1. The ultimate tensile strength and percentage of elongation for 10 % Fly ash is more when compared to other composites of different weight percentages.
2. The ultimate flexural strength for 5% coal ash is more when compared to other composites.
3. By observing the above results it is noticed that the addition of filler materials will increase the properties of the fibre composite.

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