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Mechanical Properties of Fly Ash filled GFRP Composite Material

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ABSTRACT: In the present investigation, synthesis and characterization of a polymer composite material comprising of glass fiber reinforcement, epoxy resin and fly ash has been carried out. Epoxy glass composites with different measure of fly ash were manufactured by hand lay-up method. The newly developed composites are subjected to various tests to study their mechanical behavior. Tensile test, three point bending and Vickers hardness were conducted as per the ASTM standards to find the influence of filler material on mechanical characteristics of GFRP composites. The distribution and interaction of constituent materials plays major role in their properties. The analysis confirmed the change in properties of the GFRP with respect to the percentage of fly ash present in the composite material. The glass fiber reinforced composite with 2% of fly ash had better strength compared to composite of 5% fly ash.

Keywords: Composite material, Filler material, Fly ash, GFRP, Glass fiber, Strength.

I. INTRODUCTION

In current scenario the composite materials are exceptionally helpful in different applications like air ship parts, space equipment's, family units and auxiliary applications. The glass fiber reinforced polymer (GFRP) composites could be considered to substitute framework segments or for headway and/or supplanting customary structural designing materials. The composite materials quality can be expanded altogether by adding the fibers to the polymer framework [1]. Rahman *et al*., (2013) observed the improvements in the tensile strength and increase in the flexural strength with respect to addition of nano clay particles and higher fiber contents in glass/epoxy composites [2]. Nano composites show higher strength and stiffness properties; hence it can be used in applications like automotive, aircraft, marine industries and structural applications [3]. Thermosets usually have high melting point and high tensile strength. Thermoset resins are largely accepted in composites. In our study we have used epoxy matrix which has superior properties such as good adhesive performance, large corrosive force, because of the presence of polar groups [4]. It also has excellent stability, flexibility and diversity in designing. Liu *et al*., (2019) observed the enhancement of thermal conductivity when graphite was used as filler material in Cu based composite [5]. Polyester/alumina composites with various amount of alumina substance demonstrated that tensile strength of the composites improved with the expansion of alumina content. The integration of filler could enable an “interlocking mechanism” of the polymeric chains, which brought change in hardness of the composites [6]. Bamboo epoxy composite having certain minimum fibre length had more fracture toughness [7]. The walnut particles are used as filler materials to increase the flexural and tensile strength [8]. Prasanna and Kumar (2019) discussed about the experimental analysis of cylindrical laminate of composites when it is subjected to free vibration and also carried out the numerical analysis of the composites by applying shear deformation. The damping characteristics effects discussed with longitudinal stiffeners with several end conditions, along with varying the percentage of Caoutchouc to strengthen the polymer resin. The results of damping effect compared with numerical analysis and experimental results. The laminates with Caoutchouc were have shown better results [9]. Fly ash is a one of the product acquired from coal based thermal power plants and it consists of fine particles. In thermal power plant, ash that falls in the bottom of the boiler is known as bottom ash. Every year about 140 million tons of fly ash are generated and its disposal is a challenge and it’s also health hazardous. The composition of fly ash will vary based on the nature of coal consumed in power plant and it contains substantial amount of amorphous and crystalline silicon dioxide, aluminium oxide (Al_2O_3) and calcium oxide (CaO) and bearing rock strata [10, 11]. In the present investigation fly ash which has less usage will be utilized as filler material to increase the strength of polymer composite material.

II. MATERIALS AND METHODS

We fabricated fiber reinforced polymer composite laminates which consists of the following materials. Epoxy: Araldite LY552 was used as epoxy along with hardener HY917. We have used epoxy as the matrix because of its better adhesion properties when compared to the polyester. Araldite was found to be the best of the epoxies, easily available and cost effective.

Glass fiber as reinforcement: E-glass provides excellent insulation and water resistant properties. It is also easily available and is used in many applications. Hence E-glass fiber of 300 gsm is used.

Fly ash: Industrial grade fly ash was used as an additive to raise the overall strength of the composite laminate. Fly ash is easily available and cost effective. We have used glass fiber, epoxy and fly ash as the raw materials for the fabrication of composite laminate by Hand lay-up method which is simple and cost effective tool, and does not have any restriction to the shape and size. The surface plate cleaned by applying acetone and then the releasing agent (wax) applied on the high quality surface. The mix jar has been used to mix the resin and fly ash with different proportion. This mixture is applied on the surface plate above which a layer of glass fiber is placed over one more layer of the resin applied. Similar steps are followed until the formation of 11 layers. Once the sandwich is prepared then a roller was used to remove air entrapment and get the even distribution of the resin throughout the laminate.

The composition of the composite laminates that were used for the testing purposes are as follows,

Specimen 1: The epoxy comprises of a mix of araldite LY-552 with hardener HY-917. The amount of epoxy used was 440g which has 400g of araldite and 40g of hardener. 11 layers of E-glass fiber of 300gsm were used as reinforcement. 9g of industrial grade fly ash was used as an additive. The total weight of the composite laminate was found to be 750g. The size of the composite laminate was 350 mm x 350 mm.

Specimen 2: The epoxy comprised of a mix of araldite LY-552 with hardener HY-917. The amount of epoxy used was 385g which had 350g of araldite and 35g of hardener. 11 layers of E-glass fiber of 300gsm were used as reinforcement. 20g of industrial grade fly ash was used as an additive. The total weight of the composite laminate was found to be 660g. The size of the composite laminate was measured to be 310 mm x 310 mm.

III. RESULTS AND DISCUSSION

A. Tensile Test

Specimen preparation for tensile testing involves moulding and cutting of the composite specimen into the dog-bone shape. Specimens were prepared as per American society for testing of materials (ASTM) norms. The ultimate tensile strength of all the specimens were studied and the sample 2 of both the 2% and 5% additive specimen was found to exhibit higher ultimate tensile strength.

The 2% additive specimen exhibits higher ultimate strength than the 5% specimen. This may be attributed to the presence of fly ash which increases the interfacial bonding between the fibre and matrix. The comparison is shown in Fig. 1. The overall load comparison of the specimen reveals that the specimen containing 2% fly ash withstands higher loads than the specimen that contains 5% fly ash. The comparison is shown in Fig. 2.

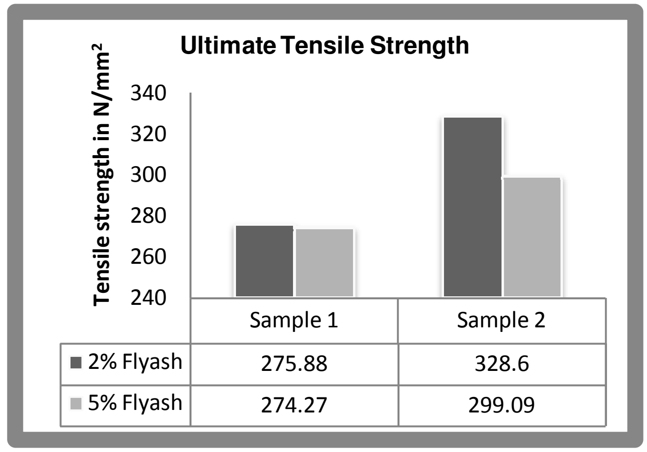

Fig. 1. Ultimate tensile strength of specimens having 2% and 5% fly ash additives.

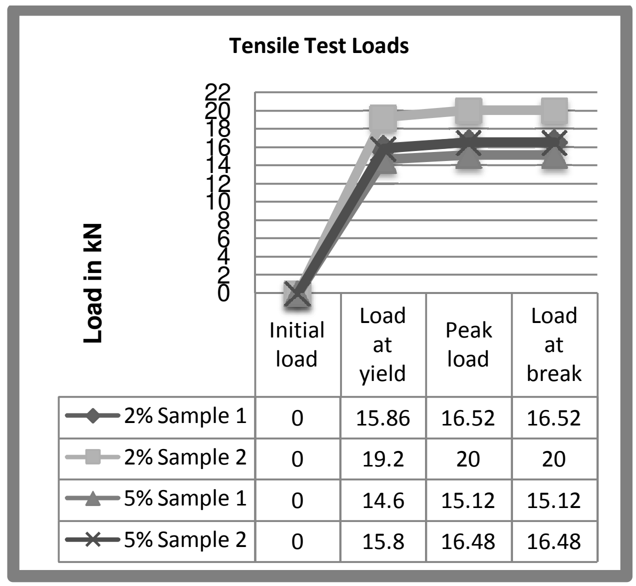

Fig. 2. Overall load comparison of the composite specimens.

B. Bending Test

The flexural tests conducted to obtain the interlinear shear strength of the composite laminates. The three point bending test is conducted as per the ASTM standards. The outcome obtained from bending test of the composite specimen made out of epoxy and glass fiber with fly ash as an additive, showed that the sample 2 containing additive of 2% is able to withstand the highest peak load.

The sample 2 of both the specimen containing 2% and 5% as an additive are able to withstand higher loads. It can be concluded that the specimen containing an additive of 2% can withstand higher peak loads when compared to the specimen containing an additive of 5% shown in Fig. 3.

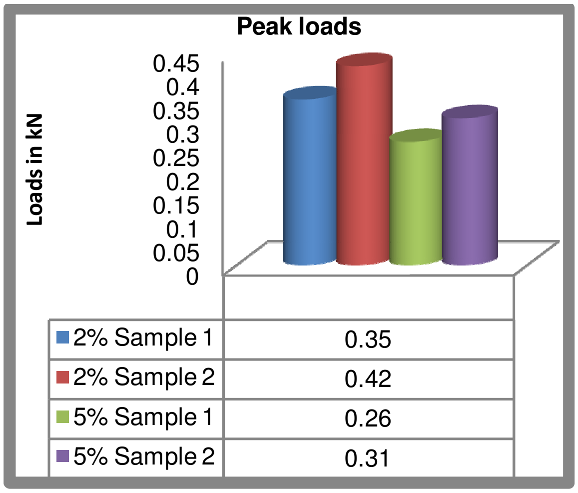

Fig. 3. Peak loads of the composite specimens.

Fig. 4 shows bending test results indicate that the sample 2 of both the specimen containing an additive of 2% and 5% exhibit higher compression strength. The sample 2 of the 2% additive specimen exhibits slightly higher compression strength among all the samples. The specimen containing 2% additive exhibits higher compression strength, on overall comparison, with the specimen containing 5% additive.

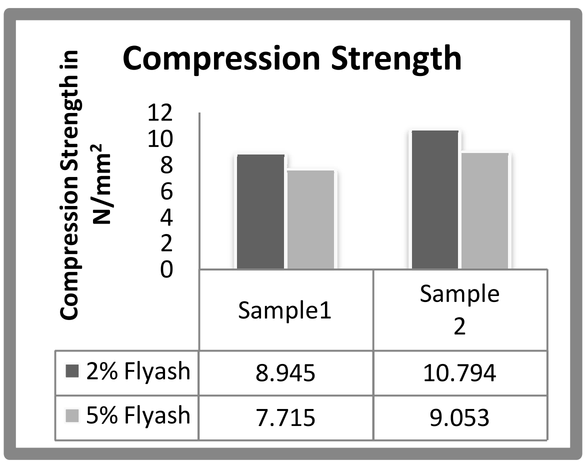

Fig. 4. Bending test results of the composite specimens.

C. Micro Vickers Hardness

The Fig. 5 shows the test results and it indicates that the sample 2 of the specimen containing 2% additive has the highest hardness number, of 16.7, among all the samples. The samples of the specimen having 5% additive have equal hardness number of 15.3. The specimen having 2% additive has a higher hardness number, on comparison, with the specimen having 5% additive.

Polypropylene polymer matrix incorporated with fly ash particles which were coated with furfuryl palmitate shown increase in of glass transition temperature and a change in flexural strength [12]. Our present study established that the addition of fly ash in composite has significant improvement in mechanical properties of composites.

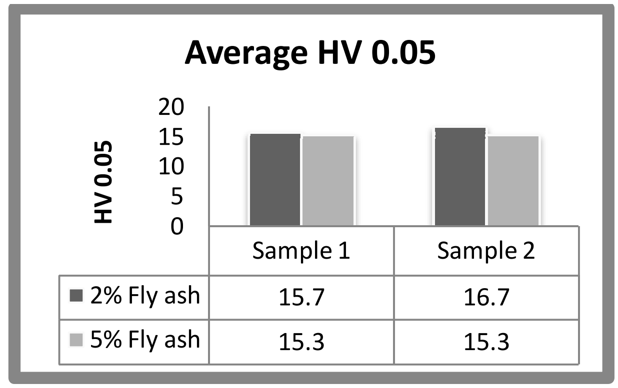

Fig. 5. Microhardness of the composite specimens.

D. Micro structural Analysis

The SEM image shows the dispersal of fly ash particles and the orientation of the glass fiber. Fig. 6 (a) shows the surface imperfection present due to errors in the fabrication process. The surface imperfections may be due to inclusion of foreign particles or due to inequality of the surface. The highlighted parts show the surface imperfections. Due to poor adhesion between the matrix and fly ash similar kind of imperfections reported by Raja and Manisekar (2016) 13]. It can be observed from the marked part of the figure 6b that the glass fibers are arranged with 90° differences in orientation between two consecutive layers. The glass fiber was continuous. The 90°difference in orientation of the glass fibers induces higher strength to the composite. Fig. 6(c) shows the distribution and agglomeration of the fly ash particles. The presence of white particles shows the distribution of fly ash in the polymer matrix. The marked part in the Fig. 6(c) shows the agglomeration of the fly ash particles in the matrix. The agglomeration occurs due to improper stirring. Hence better methods of mixing the fly ash particles with the polymer matrix can be adopted to improve further.

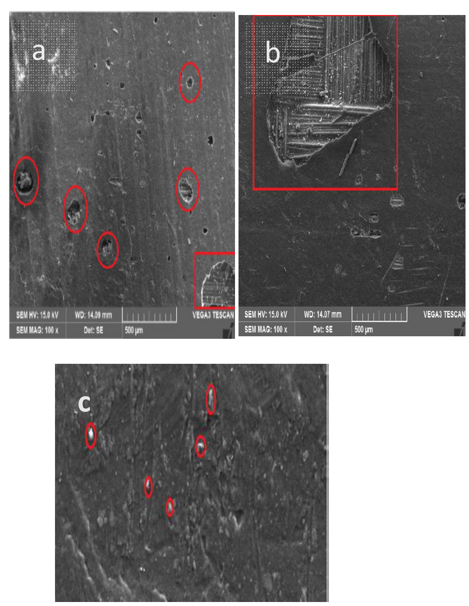

Fig. 6. (a, b, c) Surface morphology of the composite specimens.

IV. CONCLUSION

Laminates of composite are prepared with varying the percentage of the fly ash. The composite material specimens were subjected to testing of mechanical properties which included the following tests: tensile, bending and hardness. The images of the composite were obtained from SEM. The tensile test results indicate that the composite laminate having an additive of 2% can withstand higher peak load than the composite with an additive of 5%. The laminate with 2% additive also has higher ultimate tensile strength when compared to other specimen. The bending test results show that the composite laminate with an additive of 2% can withstand higher peak load and exhibits higher compression strength when compared to the laminate containing 5% as an additive. The hardness test results show that the laminate of composite having an additive of 2% exhibits higher hardness when compared to the composite laminate having an additive of 5%.The scanning electron microscope images showed the orientation of the glass fibers. The glass fibers are arranged such that there is 90^0difference in orientation between two consecutive layers. The SEM images also confirmed the dispersal of fly ash particles in the composite.

V. FUTURE SCOPE

Large size specimen could be prepared and tested for the industrial scale applications.

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Conflict of Interest. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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