Effect of Fly Ash Addition and Moisture Absorption on Fracture Toughness of Jute-Glass Epoxy Hybrid Composite

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***Abstract*— In this paper, the effect of fly ash addition on fracture toughness in Jute-Glass Epoxy hybrid composites were studied experimentally on specimens under dry and moisture absorbed conditions. The Jute/Glass epoxy laminates along with fly ash filler material were fabricated using hand lay-up technique. The fracture toughness was evaluated for CT specimens machined according to ASTM E399 standards from the fabricated laminates. The moisture absorption process for CT specimens was done in compliance with ASTM D 570 standards and absorptivity was found out by hygrometric principle. The fracture toughness, for dry and moisture conditions, with and without fly ash was estimated from load *vs.* displacement curve upon tensile loading of the CT specimens. The results ascertain that the addition of fly ash particles to Jute-Glass Epoxy hybrid composite will increase the fracture toughness under both dry and moisture conditions.**

Keywords— Fly ash; Fracture Toughness; CT specimen; Jute-Glass Epoxy composite.

I. INTRODUCTION

Over the last three decades, most of the engineering structures were replaced by composite materials as compared to conventional materials due to their better strength to stiffness ratio [1]. Moreover, composite materials own better properties such as: corrosion resistance, high strength to weight ratio, low thermal conductivity [2]. Nonetheless, majority of composites possess brittle nature, which undergoes less deformation there by leading sudden failure. The failure of these composite materials under monotonic loading will be characterize by fracture toughness. Generally, if the fracture toughness of composite material is more means that material bears better strength and stiffness. Several investigators [3-5] have shown that the fracture toughness of composite material can be improved by hybridization.

Recently, many researchers [6-8] have illustrated that the synthetic fiber reinforced polymer composites were replaced by natural fibers due its potential use and environmental concern. Dittenber and GangaRao [6] demonstrate that natural fibers are easier handling and processing, recyclability, good thermal and acoustic insulation as compare to glass fibers. However, the main disadvantages of natural fibers are of low strength, variability in quality, high moisture absorption, limited processing temperature, and a lesser durability and incompatibility between fibres and polymer matrices [6-8]. Although, the continuous development of natural fibers composites nowadays leads to application in field of Aerospace, Marine and Automobile structures [6-8]. To overcome the disadvantages of natural fiber composites, several researchers [9-11] recommended the addition of synthetic fiber to natural fiber in a single matrix system to form hybridization. Thus, modification of natural fiber composites to hybrid composites will reduce the moisture absorption and enhancement of strength and stiffness properties [10].

Furthermore, Mihaela Cosnita. *et.al.*, [12] analyzed that the addition of fly ash as filler material to polymer matrix composite will improve the properties of composites and reveals that the fly ash filler material forms fine fine dispersion, homogeneity, inertness and chemical stability with polymer matrix composites. Dalbehera and Acharya [13] study the effects of fly ash filler material to Jute-Glass Epoxy hybrid composites and analysed that addition of fly ash will increase the wear resistant property. In our earlier work [14, 15] the fly ash with 3wt%, 6wt%, 9wt% and 12 wt% proportions were added to Jute-Glass hybrid laminate composites to estimate the tensile property under dry and wet conditions. The results [14, 15] clearly demonstrate that the 6wt% of fly ash filler material with Jute-Glass hybrid laminate composites gives better values both with dry and wet (moisture) conditions as compare to remaining wt% of fly ash. Hence, here we present an experimental work to estimate the fracture toughness of Jute-Glass hybrid laminate composites with 6wt% of fly ash filler material under dry and wet conditions using CT specimens.

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II. MATERIALS AND FABRICATION OF THE COMPOSITE

Bidirectional Jute of 0.8 mm thick with 200 gsm, 0.2 mm thickness with 250 gsm of Glass laminate and fly ash filler material with size 70 microns (µ) which are available in the market were supplied by Marktech Composites, Bangalore, India. The Epoxy matrix consists of mixture of lapox L-12 resin and H-6 hardner with ratio 10:1. Atul Polymer Division Limited (Gujarat, India) supplied these polymers products.
Composite laminate is fabricated using the hand layup process as this process is simple, easy and economical, as described in our earlier publications [14, 15]. The cured composite laminate of size 200x300x15 mm^3 is cut into smaller blocks of size 37.5x36x15 mm^3.

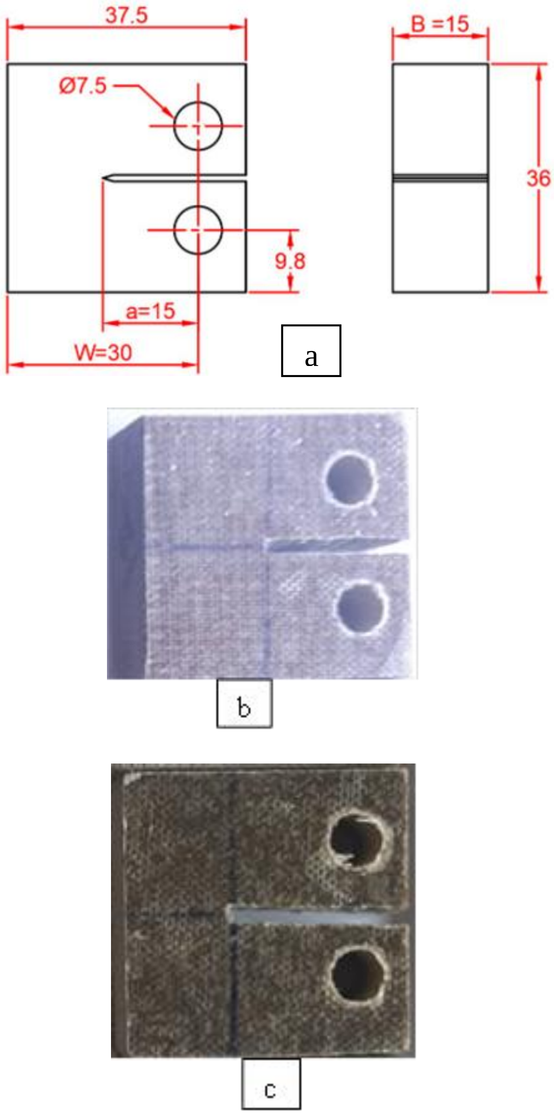

Figure 1: a) 2D specifications of CT specimen b) Composite CT specimen without fly ash c) Composite CT specimen with fly ash.

As per the specifications of CT specimen mentioned in ASTM 399 standard, a crack of length 22.5 mm is cut manually using a saw band and two holes of diameter 7.5 mm were drilled. The specifications and the photo of the CT specimen are shown in figure 1.

III. MOISTURE ABSORPTION CAPACITY TEST

The moisture absorption capacity test (ASTM D 570 standards) was conducted for jute-glass CT specimens with and without fly ash filler material. Initially the dry weight of the CT specimens was measured by electronic balance as shown in figure 2. After that, the weighted specimens were soaked in water for 24 hours. Then, the specimens were taken out and the extra water contents on the surface of the CT specimens were removed using clotting papers. Finally, the 24 hours wet CT specimens were weighted. The moisture absorption capacity for all the specimens was calculated using Eq. 1 and tabulated in the Table 1(without fly ash) and Table 2(with fly ash).
Water absorption percentage was calculated according to the formula:

$$W(\%) = \frac{Wt - Wo}{Wo} * 100 \quad (1)$$

where,
W is the weight of water absorbed by the specimen
W_o is the initial dry weight of the specimen
Wt is the final wet weight of the specimen after 24hours of soaking.

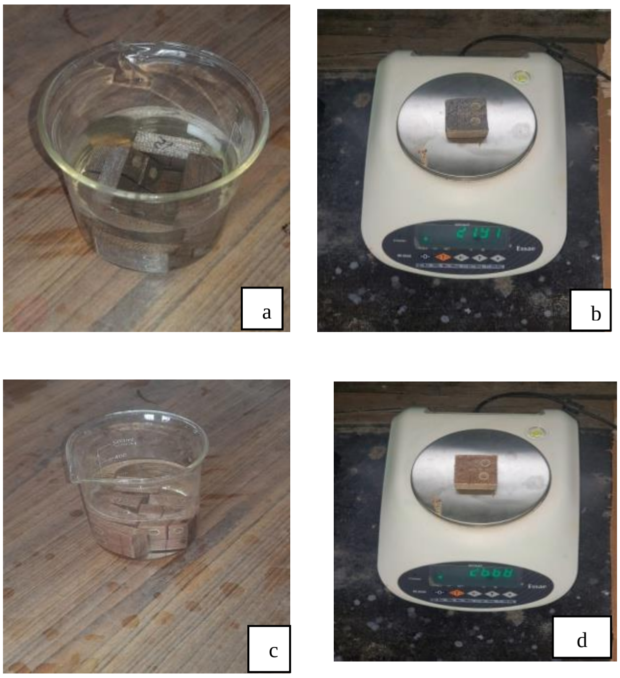

Figure 2: a) Soaking of fly ash composite CT specimen. b) Weight measurement of fly ash composite CT specimen. c) Soaking of non-fly ash composite CT specimen. d) Weight measurement of non-fly ash composite CT specimen.

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IV. FRACTURE TOUGHNESS TEST

The fracture toughness tests for bidirectional jute-glass epoxy CT specimens with and without fly ash under dry and wet conditions were done as according to ASTM E399 standards. The experimental set up consisting of UTM and specimen fixture is shown in figure 3. All the fracture tests are conducted at room temperature in a computerized universal testing machine with maximum load cell of 10 kN and 2 mm/min displacement-controlled rate. For each dry and wet condition, with and without fly ash filler material of Jute-Glass Epoxy hybrid composites, five identical CT specimens were tested to estimate the fracture toughness.

Table 1: Water absorption capacity of non-fly ash composite specimens

Specimen	Weight (W_O) in grams	Weight (W_t) in grams	Water absorption(W) in grams	Percentage W %
1	24.55	24.86	0.31	1.26
2	26.33	26.68	0.35	**1.33**
3	27.53	27.88	0.35	1.27

Table 2: Water absorption capacity of fly ash composite specimens

Specimen	Weight (W_O) in grams	Weight (W_t) in grams	Water absorption(W) in grams	Percentage W %
1	26.85	27.12	0.27	1.01
2	27.54	27.85	0.31	1.13
3	27.54	27.86	0.32	**1.16**

Hence, total 20 CT specimens were tested for dry and wet conditions, with and without fly ash as filler material for Jute-Glass Epoxy hybrid composites. For wet conditions, both with and without fly ash as filler material for Jute-Glass Epoxy hybrid composites the CT specimens were kept in normal water bowl for 24 hours as explained in section 3. After that, the specimens were dry cleaned with clotting paper once it taken out. Then, at room temperature the tests were conducted similar to the dry conditions.

The average peak load for wet conditions, both with and without fly ash as filler material for Jute-Glass Epoxy hybrid composites were substituted in stress intensity factor equation. The equation to estimate the stress intensity factor is explained below:

$$K_{1C} = \frac{P}{B\sqrt{W}} \times f\left(\frac{a}{W}\right) \qquad (2)$$

The plot of Load *vs* Displacement for the different CT specimens with $a/W = 0.5$ and $B/W = 0.5$ is shown in figure 4. Table 3 shows the data of fracture tests conducted on all the specimens where P is the peak load as obtained from the load displacement test conducted in UTM. Using the equation 2 the fracture toughness values are calculated for the different CT specimens with $a/W = 0.5$ and $B/W = 0.5$.

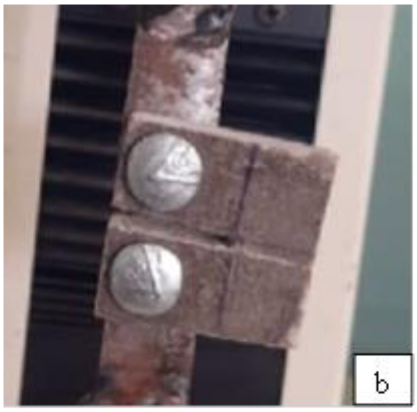

Figure 3 a) UTM setup with CT specimen mounted.
b) Magnified view of CT specimen fixture

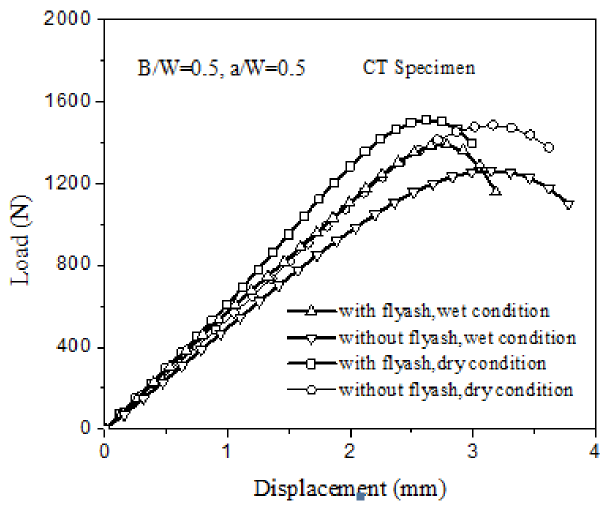

Figure 4: Load *vs* Displacement plot for the different CT specimens with a/W = 0.5 and B/W = 0.5

V. RESULTS AND DISCUSSION

The fracture toughness measures the resistance of material with the presence of crack. A sequence of experiments was conducted for CT specimens of Jute-Glass Epoxy hybrid composites with and without fly ash under dry and wet conditions to estimate fracture toughness. The peak load for each specimen for each condition were extracted from Load *vs*. displacement curve, where the specimen is loaded monotonically using computerized universal testing machine as shown in figure 3. Figure 4 demonstrations the load *vs*. displacement curve for Jute-Glass Epoxy hybrid composites with and without fly ash under dry and wet conditions. The peak load for each five CT specimen and its average peak load along with calculated fracture toughness are shown in table 3. From table 3 it is observed that the fracture toughness value is more for Jute-Glass epoxy containing fly ash under dry and wet conditions as compared to specimens without fly ash. Moreover, it is noticed that from table 1 and 2 the addition of fly ash filler will resist the moisture absorption into the composite. Hence, from the experimental analysis it is clearly seen that addition of fly ash filler material will improve the strength of Jute-Glass Epoxy hybrid composite for dry and wet conditions.

Table 3: Fracture toughness of varying composition composites

Composition of the composite	**Peak load for each sample *P*, (N)**					**Average peak load *P* (N)**	**Fracture toughness K_{IC} (Mpa √m)**
Jute-Glass without fly ash, dry	1482	1498	1480	1490	1475	1485	**5.52**
Jute-Glass without fly ash, wet	1265	1258	1260	1272	1270	1265	4.70
Jute-Glass with fly ash, dry	1505	1520	1517	1510	1508	1512	**5.62**
Jute-Glass with fly ash, wet	1386	1394	1383	1386	1396	1389	5.16

VI. CONCLUSION

From the experimental analyses the major conclusion is that, the addition of fly ash filler material to Jute-Glass Epoxy hybrid composite will increase the bearing load capacity for both dry and moisture conditions. Moreover, the utilization of fly ash will increase resistance towards moisture absorption where it is applicable preferably for marine structures.

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