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Degradation of Mechanical Properties of Hybrid Reinforcement with Epoxy-Polyester Matrix Under Water Absorption

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Abstract*— Natural fibers represent a good renewable and biodegradable alternative the most common man-made reinforcement. Among various fibers, natural fibers are used due to their advantages, easy availability, low density, low production cost and better mechanical properties. The aim of this work is to study the degradation of hybrid composites when exposed to moisture condition at room temperature. Hand lay-up method is used to prepare the laminates with the J-G FRP and epoxy matrix. Water absorption test is carried out by immersing the specimen in water tub at room temperature for different time periods. Mechanical properties like Tensile strength, Flexural strength, Impact strength and Hardness are evaluated by performing different tests on laminates. The mechanical properties of water immersed specimen were tested and compared with dry samples as per the ASTM standard. The composites specimens with J-G FRE matrix absorbs less amount of water when compared to polyester specimens. Equilibrium moisture content and water absorption curves were determined. J-G FRE matrix composite was found to have less water absorption and decreased impact strength is 0.19J / mm2, decreased tensile strength is 61.11MPa, decreased flexural strength is 31.29MPa and decreased stiffness is 13HN compared to J-G FRP matrix composite.

Keywords*— Hybrid composite, epoxy resin, polyester resin, water absorption.

I. INTRODUCTION

Previously, a lot of work has been done on natural fibre composites and they tried to develop different types of composites by combining various resins with natural fibers. The advantages of natural fibre composites are, lightweight, reasonable strength, biodegradable, free from health hazards, and therefore, their potential to be used as building materials [1]. Hybrid composites are usually used when a combination of different types of fibers wants to be achieved, or when longitudinal as well as lateral mechanical performances are required [2].

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They are widely used in the sports goods, marine industry for making ship hulls, aviation, aircraft, building and construction, etc. [3]. Comparable in stiffness to mass ratio of jute/epoxy laminar composites with glass fabric/epoxy laminar composites. Hybrid composite has mechanical properties way ahead than mono fibre jute composite under various loading conditions [4].
Hybrid composite has better performance it can be used accordingly in many ways as well as easy cultivability of fibers and its biodegradable nature. The bamboo fibre is modified into the 'cotton shape' High weight content of bamboo fibre enables the bamboo composites to increase their strength in the most effective way [5]. The mechanical properties increases due to hybridization. For final Composite, the composite manufacture can be much more in damage to the interfacial strength and exposure to high humidity during material storage [6]. The natural fiber is hydrophilic in the humid environment with mechanical degradation and remarkable swelling deformation, by damage variable it can be used modified Mori-Tanaka method. The influence of ageing temperature and the elastic response of natural FRC is analyse by applying the theoretical model [7]. Fick's law obeys the diffusion of pure, salt and boiling water in epoxy. The composite specimens was immersed in water at room temperature is found to follow Fickian behaviour, whereas the absorption behaviour is non-Fickian at the elevated temperature [8]. Mechanical properties increases marginal due to poor interfacial bonding between matrix and the fibre, which is evident from SEM analysis [9].

II. METHODS AND MATERIAL

The laminate composites, the sequence of layers are used in this work. Each laminate consist of eight layers of fabric with two different resin from below table:

Table 1 Sequence Of Layers

Resin	Sequence
Epoxy/Polyester	J+J+G+J+J+G+J+J

A. Jute fibre

Jute is one of the most affordable natural fibers and other names are brown fibre, golden fibre depending on its usage and it is environment friendly. It is import from Jute world Industries, India.

Fig. 1. Jute fiber

B. Glass fiber

E- Glass fibre is made of alumino borosilicate glass with alkali oxides less than 1% used for glass reinforced plastics. In this work woven glass fiber is used because of light weight, high strength, corrosive resistance and robust material.

Fig. 2. E - Glass fiber

C. Epoxy resin

Lapox L-12 is a liquid, unmodified epoxy resin of medium viscosity which can be used with various hardeners for making composites. It is import from Atul Industries, India. Hardener used is K-6 in the proportion of 10:1. The epoxy resin is used aerospace, marine applications because of its high strength, chemical resistance, low viscosity compared to other thermoset resins.

D. Polyester resin

The polyester resin used is isothalic polyester resin. Hardener used is the MEKP (Methyl Ethyl Ketone Peroxide) with the catalyst of cobalt. Resin, hardener, and catalyst is used in the proportion of 1:0.015:0.015. The polyester resin is a good performance and reasonable cost.

III. FABRICATION PROCEDURE

Composite laminate is made by hand lay-up technique with 6 layers of jute and 2 layers of glass fibers. The mold is cleaned with the acetone and applied with grease. The polythene sheets are placed top and bottom of the mold to get better surface finish. Layers of jute and glass fibers are marked and cut according to the mold dimensions (350 x 350 x 10 mm). The layers are arranged accordingly (J/J/G/J/J/G/J/J) and mixture of resin is applied middle of the jute fibers. The mold is allowed for curing about 7-8 hours and further post curing is done for 24hours at room temperature. After that the composite laminates are cut according to ASTM standards and performed different test.

Fig. 3. Hand lay-up technique

Fig. 4. Laminate of j-g fiber with epoxy resin

Fig.5. Laminate of j-g with polyester resin

IV. TESTING AND COMPOSITES

The following tests were conducted, such as tensile test, flexural test, Impact test and Hardness test. The tests specimens were conducted as per ASTM standards as shown in table 2.

Table 2 Test Specimen Details

Test specimens	ASTM Standards	Size	Thickness
Impact test	D256	55mm x 10 mm	3-5mm
Tensile test	D3039	250mm x 25mm	3-5mm
Flexural test	D790	125mm x 13mm	3-5mm
Hardness test	D785	25mm x 20mm	3-5mm
Water absorption	D570	30mm x30mm	3-5mm

A. Water absorption test

Water absorption test specimens are taken as per ASTM standards. The size of specimens according to ASTM standards are 30mm * 30mm. for each laminate 3samples were taken, those are kept in oven at 70 ° C about 6 hours to dry the specimens. After this the specimens are removed from oven, then these are submerged in water tub with the time interval of 30days. The specimens are weighted at 7, 15, 30 to know the weight gain percentage, the equation is given by [10]

$$m_t = \frac{m - m_0}{m_0} \times 100\ \%$$

B. Water absorption behavior of hybrid composites

During and after water absorption process the percentage of weight gain by both hybrid composites are shown in table 3, which shows composites polyester matrix composite has 3.16 times more water absorption than epoxy matrix composite.

The increase in water percentage is due to the hydrophilic nature of jute fibre and larger interfacial area between continuous and discontinuous phase. The less percentage of water absorbed in case of epoxy matrix due to the strong bond between fibers and matrix, which results in minimum number of micro-cracks.

Table 3: Water Absorption Behavior Of J-G Frc Epoxy And Polyester Resins For 30 Days

SPECIMENS	WATER ABSORPTION (%)		
	07 Days	15 Days	30 Days
Epoxy	0.32	1.78	2.18
Polyester	4.00	4.79	5.34

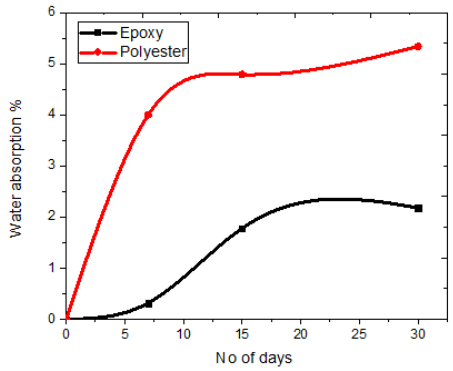

Fig. 6. Water absorption vs no of days of j-g FRC epoxy and polyester matrix

V. RESULTS AND DISCUSSION

Mechanical Test

For the both the hybrid composites the mechanical properties (impact strength, flexural, hardness and tensile strength) are evaluated at before and after submerged in water.

A. Tensile test

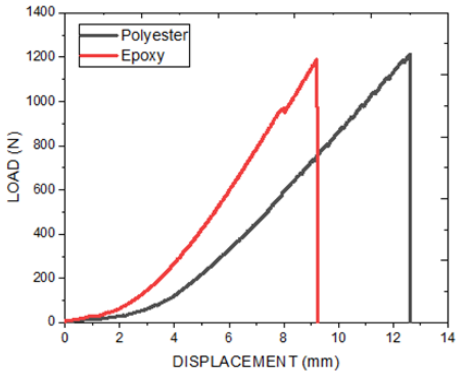

Fig. 7. Tensile load Vs displacement of J-G FRC with epoxy and polyester

The maximum tensile strength is observed that the Jute-glass fiber reinforced epoxy (J-G FRE) and polyester resins composites before water immersion specimens is 92.00MPa and 100.64MPa and tensile modulus is 1200.82MPa and 988.68MPa. The Tensile load Vs displacement of Jute-glass fiber reinforced polyester (J-G FRP) resin composite is increases compare to J-G FRE resin composite before water absorption as shown in fig 7.

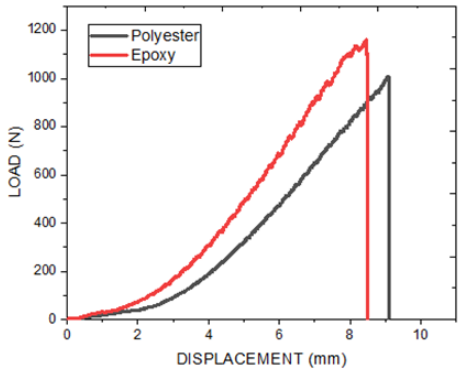

Fig: 8 Tensile load Vs displacement of J-G FRC epoxy and polyester matrix after water immersion

From Fig 8 the tensile load Vs displacement of J-G FRP resin is decrease compared to J-G FRE resin composite after water immersion. After 30days of water absorption is observed that the tensile strength of J-G J-G FRE and polyester resin specimen is 80.28MPa and 82.33MPa and tensile modulus is 1091.29MPa and 724.56MPa.

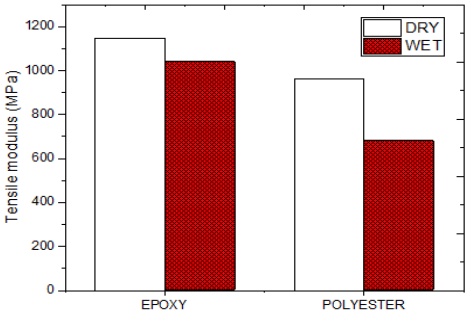

Fig. 9. Dry and wet condition of J-G FRC with epoxy and polyester resins

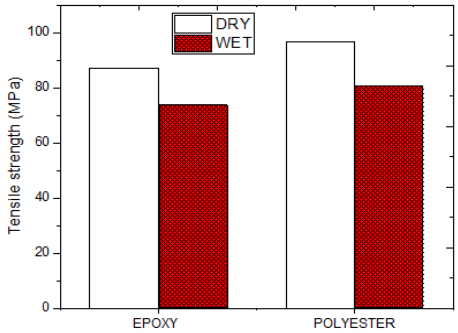

Fig: 10 Dry and wet condition of J-G FRC with epoxy and polyester resins

On comparing the wet and dry specimens of tensile properties, it shows dry specimens have high tensile strength than wet specimens. The decrease in tensile properties is due to the swelling of fibers which results in decrease in stiff of individual fibers which leads to increase in micro-cracks. Results in the improvement of shear stresses at the interface and leads to decrease in the bond strength between reinforcement and matrix.

B. Flexural test

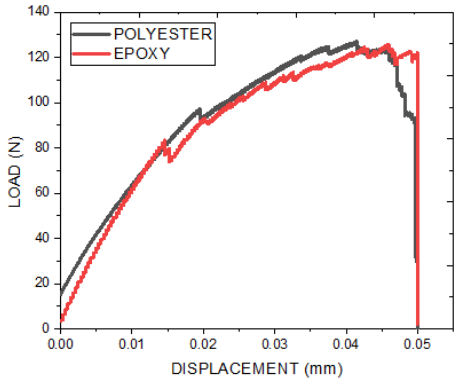

Fig. 11. Flexural load Vs displacement of J-G FRC with epoxy and polyester matrix

From Fig 11 it is observed that flexural load Vs displacement of J-G FRE resin composite is slightly decreased compared to J-G FRP resin composite before water absorption. The flexural strength is observed that maximum strength of J-G FRE and polyester resins composites before water immersion specimens is 129.629MPa and 94.863MPa and flexural modulus is 436.321MPa and 476.702MPa.

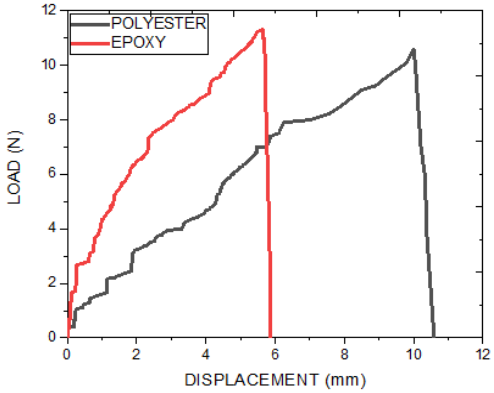

Fig. 12. Flexural load Vs displacement of J-G FRC with epoxy and polyester matrix after water immersion

After water absorption the flexural load Vs displacement of J-G FRE resin composite is increases compared to J-G FRP resin composite as shown in Fig 12. The flexural strength of J-G FRE and polyester resins composites specimens is 88.239MPa and 36.138MPa after 30days of water immersion and flexural modulus is 349.954MPa and 254.378MPa.

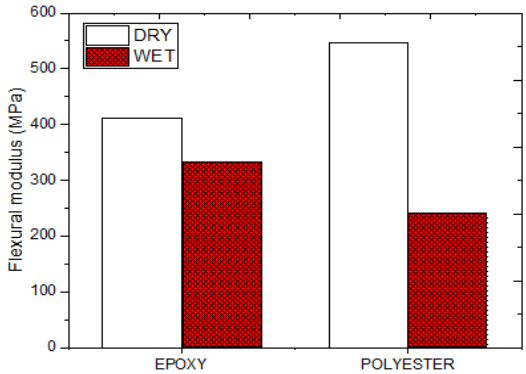

Fig. 13. Dry and wet conditions for J-G FRC with epoxy and polyester resins

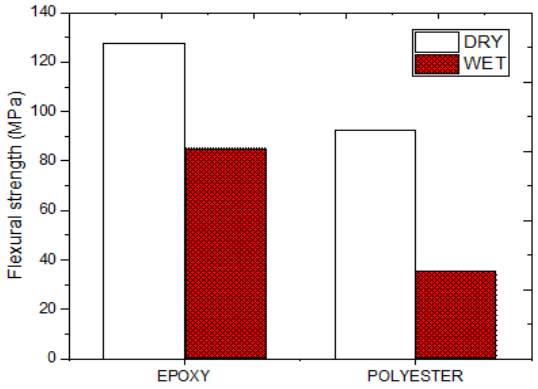

Fig: 14 Dry and wet conditions for J-G FRC with epoxy and polyester resins

From the Fig 13, 14 it is observed that flexural properties of dry specimens has better flexural properties than wet samples. The decreasing in flexural properties is due to high water absorption of fibers.

C. Impact test

From figure 15 the Impact strength of J-G FRP and epoxy resin before water absorption specimens is 0.28J/mm^2 and 0.34J/mm^2 decreases after 30days of water immersion specimens is 0.19J/mm^2 and 0.25J/mm^2.

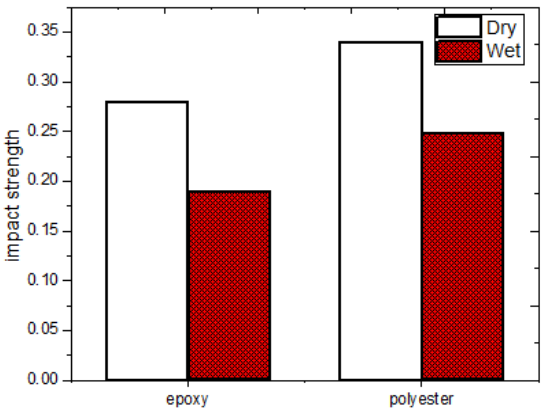

Fig. 15. Dry and wet condition of J-G FRC with epoxy and polyester resins

From the Fig 15 higher impact strength observed in case of before water absorption specimens. This was mainly due to less water absorption of specimens, which provides minimum flaws at interface to diffuse the water molecules and hence increase in capacity to observe the impact energy.

D. Hardness test

The maximum hardness is observed before water absorption of J-G FRE and polyester resins specimens is 28 HN and 18 HN. Hardness of J-G FRE resin is increases compared to J-G FRP resin composite as shown in Fig 16.

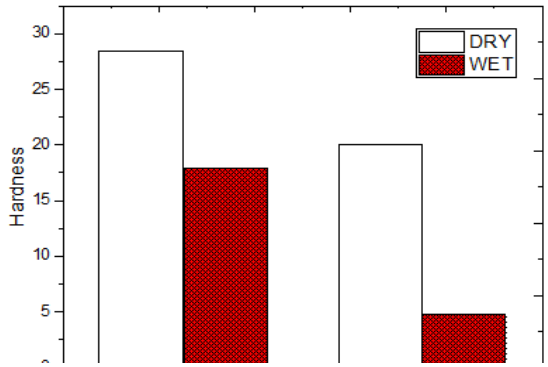

Fig. 16. Dry and wet conditions of J-G FRC with epoxy and polyester

After 30days of water immersion of hardness specimens is decreases compare to before water immersion J-G FRE and polyester resins composites specimens is 18 HN and 5 HN as shown in Fig 16.

VI. CONCLUSION

The mechanical properties of J-G FRE and polyester resins composites in dry and wet condition was investigated. From experimental tests the following conclusions have been drawn from the study:

- The minimum impact strength, tensile strength, flexural strength and hardness of J-G FRE resin composite after 30 days of water absorption is 0.19J/mm^2, 80.28MPa, 88.239MPa and 18HN.
- The mechanical properties is decreases after water absorption of J-G FRP resin composite is 0.25J/mm^2, 82.33MPa, 35.227MPa and 5HN respectively.
- Compared to overall hybrid composites is observed that maximum mechanical properties for J-G FRE matrix composite before water absorption.
- Maximum mechanical properties water intake for J-G FRP matrix composite.

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