Experimental Investigation on Mechanical Behavior of Epoxy based Jute/Glass Fiber Reinforced Hybrid Composite

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Abstract

The natural fibers from renewable natural resources offer the potential to act as a reinforcing material for polymer composites alternative to the use of glass, carbon and other man-made fibers. Among various fibers, jute is most widely used natural fiber due to its advantages like easy availability, low density, low production cost, environmental aspect and satisfactory mechanical properties. In this work, the mechanical properties like tensile strength, flexural strength and impact energy of epoxy based jute and glass fiber reinforced composite specimens fabricated with different fiber orientations, were compared. Also Epoxy based Jute/glass fiber reinforced hybrid composites were prepared for various volume fractions, different fiber orientations and testing was carried out as per ASTM standards. The mechanical properties and moisture absorption were obtained experimentally and compared. The results revealed that tensile strength, flexural strength, impact energy and moisture absorption were significantly influenced as the glass fiber volume fraction varied.

Keywords: Jute & Glass Fibre, Volume fraction, Tensile, Flexural & Impact Test, Moisture absorption.

1. Introduction

The Monolithic metals and their alloys have high density and cost of fabrication. Hence they cannot meet the requirements of the latest technology. The metals and their alloys have been replaced with the advent of composites since they have relatively low cost, low density, high specific strength, high specific modulus, low specific gravity, high stiffness, resistance to fracture, fatigue, impact, and creep. In recent years, Fiber Reinforced Polymer Matrix Composites are being used for various primary and secondary components of aerospace, transport, automotive and domestic applications. The mechanical behavior of composites is greatly influenced by fiber reinforcements and matrices. The mechanical properties of composite like elastic moduli and strengths have directly influenced the material of fiber. In unidirectional composite fibers are oriented in one direction and exhibits high stiffness and strength in the fiber direction. In multidirectional composite such as mat, the fibers are oriented in more than one direction, and there will be high stiffness and strength in fiber orientations. However, for the same for the same volume of fibers per unit volume of the composite, it cannot match the stiffness and strength of the unidirectional composite. The fibers can be short or long. Long continuous fibers are easy to orient and process, while short fibers cannot be controlled fully for proper orientation. Benefits of long fibers over short fibers impact resistance, low shrinkage, improved surface finish, and dimensional stability. However short fibers provide low cost, are easy to work with, and have fast cycle time fabrication procedures. Short fibers have few flaws and therefore have higher strength [1]. Under different environmental conditions, the moisture absorption capacity of fiber reinforced polymer matrix composites, over a period of time, might increase with salt concentration, lower fiber content and in the fiber direction. This results in degradation of fiber-matrix bonding and affects the elastic properties which influence the mechanical behavior [5].

K Sabeel Ahmed & S Vijayarangan [2] evaluated the elastic properties of jute-glass fiber hybrid polyester composites. The composite specimens were prepared by hand layup technique with a different relative weight fraction of jute and glass fiber. The laminate elastic properties were predicted theoretically by classical lamination theory and rule of the hybrid mixture model. Also, they evaluated the elastic properties experimentally by tension and in-plane shear tests as per ASTM standards. Vivek Mishra & Sandhyarani Biswas [3] developed and characterized a new set of natural fiber based polymer composites consisting of bidirectional jute fiber mat as reinforcement and epoxy resin as matrix material. The composites were fabricated using hand lay-up technique and were characterized with respect to their physical and mechanical properties. Experiments were carried out as per ASTM standards, to study the effect of fiber loading on the physical and mechanical behavior of these composites. The result indicated the significant effect of fiber loading on the mechanical properties of the composites. Also, the formation of voids in the composites was an influencing factor on the mechanical properties. K G Satish et al [4] conducted experiments to study the effect of a hybrid composite specimen subjected to in-plane tensile and compressive loading. The laminated specimens were fabricated using steel and nylon bi-directional mesh as reinforcements and polyester as the binder, as per ASTM standards. The various volume fractions and fiber orientations were used in which the percentage of polyester (40%) was maintained constant. From the investigations, it is revealed that the specimens with a higher percentage of steel sustain greater loads & also the strengths are superior in case of $0/90^0$ oriented specimens. A relationship between the tensile/compressive strength, fiber content and orientation has been established. K V Arun et al [5] carried out experimental analysis of the glass/textile fabric reinforced hybrid composites under normal condition and sea water environments. The critical stress intensity factor, interlaminar shear strength, and impact toughness were evaluated, both in interlaminar and translaminar directions. The specimen preparation and the experimentations were carried out according to the ASTM standards. Results revealed that the damage in hybrid composite under sea water environment is entirely different. The characterizing parameters showed changes in their magnitudes with the variation in immersion time. The nature of fracture as a function of the reinforcement volume, loading, and environmental conditions has been analyzed with the aid of scanning electron microscopy. The SEM analysis showed that the fibers pull out, matrix cracking and also the nature of crack growth is different in a seawater environment. The fracture in individual fiber has also been identified. Sanjay M R et al [6] prepared Composites using Jute – glass fibers of 50/50, 40/60 and 30/70 Weight fraction ratios and mechanical properties like tensile, impact and flexural strength of Jute - glass fiber reinforced polyester were evaluated. The results show that tensile strength and impact Strength of 50% Jute-50% glass fiber composition is found to be better than the other two compositions and the flexural strength of 40% Jute-60% glass fiber composition is found to be better than the remaining two compositions. B Vijaya Ramnath et all [7] fabricated and characterized mechanical properties of a hybrid (Jute+Flax+GFRP) composite and also compared it with the (Jute+GFRP) based composite. These composites were fabricated using hand lay-up technique. The arrangement of the hybrid composite was such that a layer of vertically laid flax fiber is flanked between layers of horizontally laid jute fiber. Epoxy resin alongside with HY951 hardener was used as the binding agent throughout the layer. Glass fiber laminates were used on both sides for improving the surface finish and surface hardness. The volumetric fraction was such that one-third of the total volume is occupied by Jute and Flax fibers. Test results showed that the hybrid natural composite had excellent properties under tensile, flexural loading. At last failure, morphology analysis was done using a Scanning Electron Microscope (SEM) and the internal structure of the broken specimen was discussed. C Velmurugan et all [8] revealed in their study that the properties of jute fiber are improved by combining it with glass fiber with the help of epoxy resin, found and compared its mechanical properties like tensile, compression, impact strength and flexural strength. M Ramesh et all [9] evaluated mechanical properties such as tensile and flexural properties of hybrid glass fiber-sisal/jute reinforced epoxy composites. Microscopic examinations were carried out to analyze the interfacial characteristics of materials, the internal structure of the fractured surfaces and material failure morphology by using Scanning Electron Microscope (SEM). The results indicated that the incorporation of sisal fiber with GFRP exhibited superior properties than the jute fiber reinforced GFRP composites in tensile properties and jute fiber reinforced GFRP composites performed better in flexural properties. The objectives of this paper are to fabricate epoxy based hybrid composite reinforced with bi-directional jute and glass fibers and study the influence of hybridization of fibers, volume fraction and fiber orientation on mechanical properties such as tensile strength, flexural strength, impact energy and moisture absorption of composites.

2. Experimental Methods

The Hand Lay-up method is used for the fabrication of Jute/Glass reinforced with Epoxy Natural Hybrid composite specimens. The Matrix material used is a medium viscosity Epoxy resin, Lapox L-12 and a room temperature curing polyamine Hardener, K-6. The Material properties are listed in Table 2.1. Composite specimens are fabricated with different compositions based on volume fraction. The composition and codes are mentioned in Table 2.2

Table 2.1 Properties of Reinforcements and Matrix

Properties	E-Glass Fabric	Jute Fabric	Epoxy (Lapox L-12)
Density in g/cc	2.54	1.46	1.25
Tensile strength in MPa	3400	500	50 - 60
Compressive strength in MPa	30000	10000	110 - 120
Modulus of elasticity in GPa	72	55	4.4 - 4.6
The coefficient of linear thermal expansion in μ/°C	5	2	64 – 68

Table 2.2 Composite Composition and Codes

Sl. No.	Volume fraction	Specimen Code
1	Epoxy 40% + Jute Fiber 60%	**EJ**
2	Epoxy 40% + Jute Fiber 45% + Glass Fiber 15%	**EJG1**
3	Epoxy 40% + Jute Fiber 30% + Glass Fiber 30%	**EJG2**
4	Epoxy 40% + Jute Fiber 15% + Glass Fiber 45%	**EJG3**
5	Epoxy 40% + Glass Fiber 60%	**EG**

The Tensile test specimens are fabricated as per the ASTM D3039 standard [10], and tests were conducted in UTM. The Bending test specimens are prepared according to the ASTM D790 [11] standard and the 3- point bending test has been carried out in the UTM. Impact test specimens are prepared as per the ASTM D256 [12] standard, and tests were conducted in the Impact testing machine. Water absorption test specimens are prepared according to ASTM D570 standard, and tests were conducted by immersing them in distilled, pond and seawater.

Fig. 2.1 Tensile and Flexural test specimens

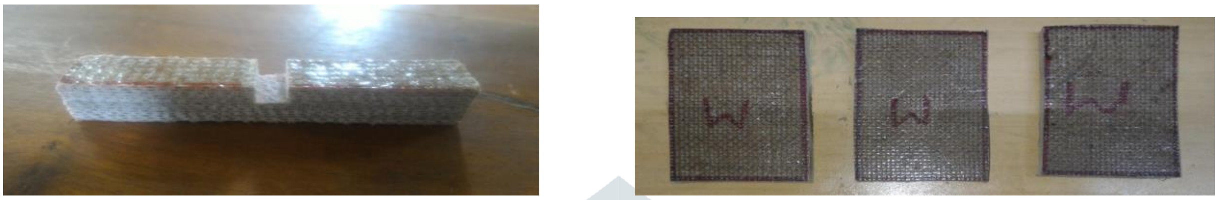

Fig. 2.2 Impact and Moisture Absorption Test Specimen

Fig. 2.3 Failed specimens after tensile test

Fig. 2.4 Failed specimens after bending test

Fig.2.5 Specimen after Impact Test and Moisture absorption setup

3. Results and Discussions

3.1 Tensile properties: The Tension tests were conducted on the fabricated Epoxy based, Jute, Glass, Jute/Glass fiber composites in a Universal Testing Machine as per ASTM standards. The Tensile strength of the Epoxy-Glass composite is more when compared to that of Epoxy-Jute composite, as shown in Fig. 3.1. Also, the Tensile load capacity was found to be more in fiber direction (0/90) than the other direction (-/+ 45).

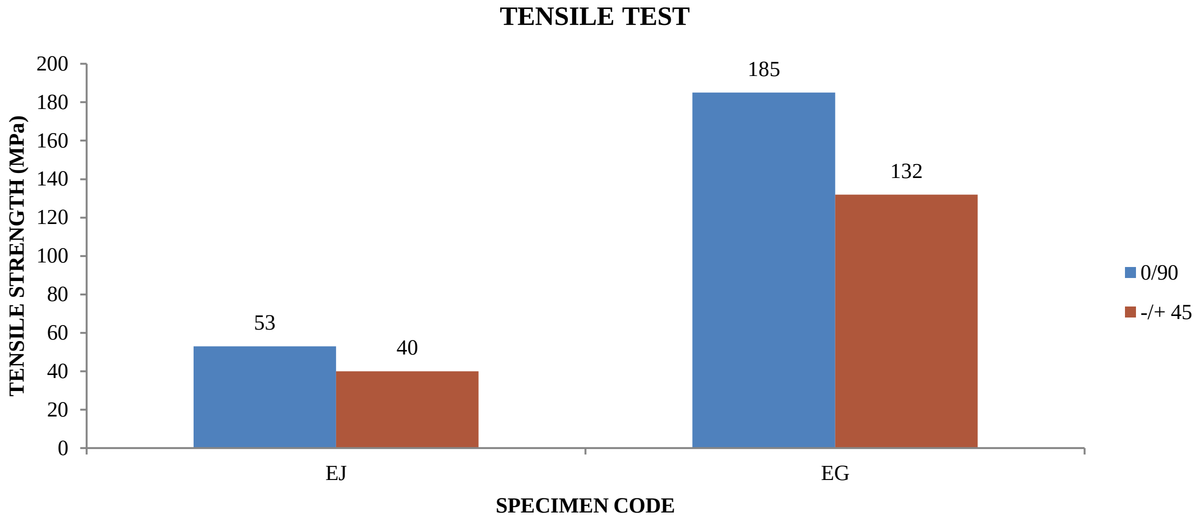

Figure 3.1 Tensile strengths of Epoxy-Jute and Epoxy-Glass composites

Figure 3.2 shows the Tensile strengths of Epoxy based Jute/Glass fiber hybrid composites. From the results, as the volume fraction of glass fibres increases (15%, 30%, 45%), the Tensile Strength increases (79.2 MPa, 92.5 MPa, 158.4 MPa in 0°/90° fiber direction and 59 MPa, 66 MPa, 105.6 MPa in -/+ 45° fiber direction), as shown in Fig.3.2. Thus the hybridization Jute and Glass fiber improve the Tensile strength of composites.

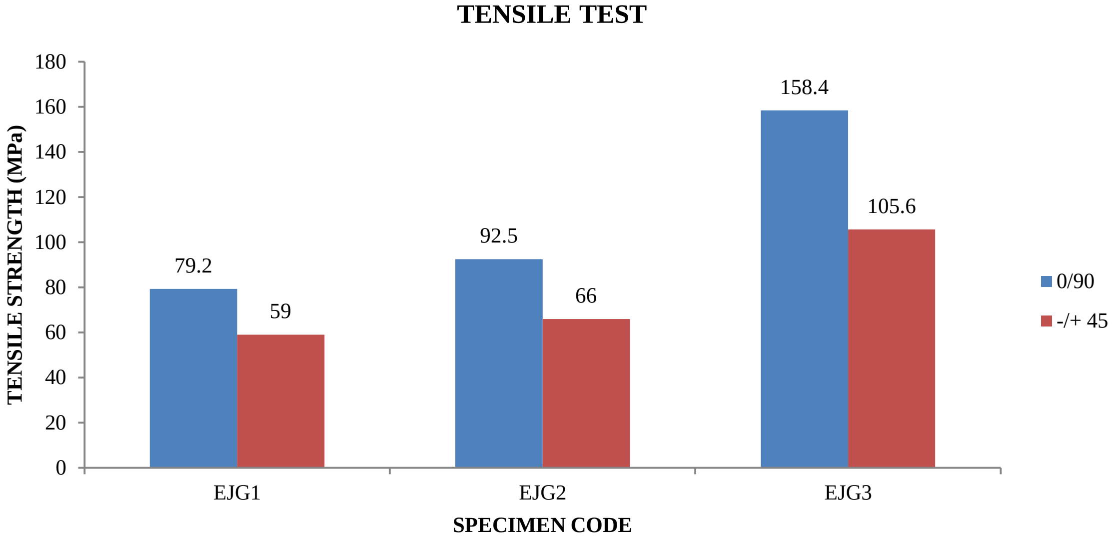

Figure 3.2 Tensile Strengths of Epoxy based Jute/Glass fiber hybrid composites.

3.2 Flexural properties: The Flexural tests were conducted on the fabricated Epoxy based, Jute, Glass, Jute/Glass fiber composites in a Universal Testing Machine as per ASTM standards. The Flexural strength of the Epoxy-Glass composite is more when compared to that of Epoxy-Jute composite, as shown in Fig. 3.3.

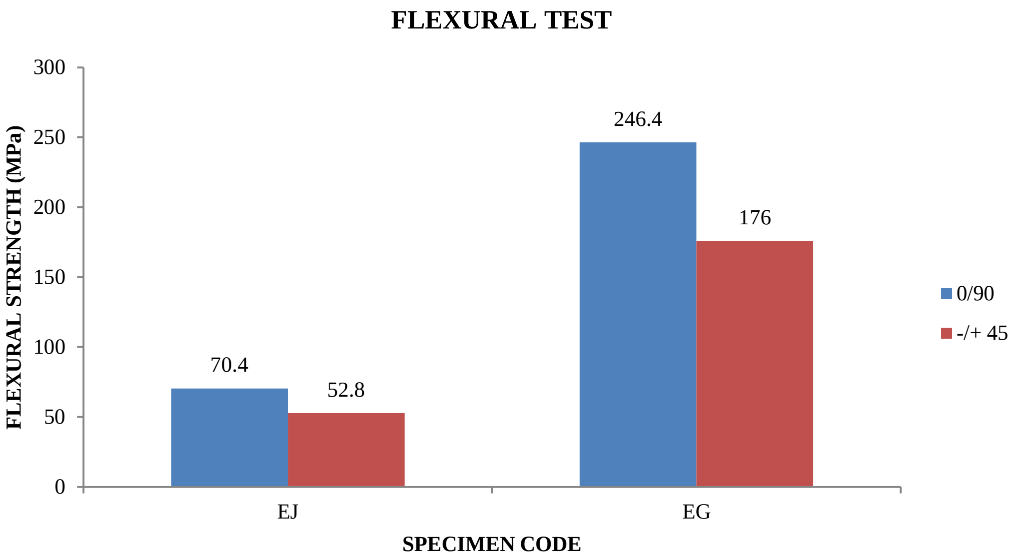

Figure 3.3 Flexural strengths of Epoxy-Jute and Epoxy-Glass composites

Figure 3.4 shows the Flexural strengths of Epoxy based Jute/Glass fiber hybrid composites. From the results, as the volume fraction of glass fibres increases (15%, 30%, 45%), the Flexural Strength increases (105.6 MPa, 123.2 MPa, 211.2 MPa in 0°/90° fiber direction and 79 MPa, 88 MPa, 140.8 MPa in -/+ 45° fiber direction), as shown in Fig.3.4. Thus the hybridization Jute and Glass fiber improve the Flexural strength of composites.

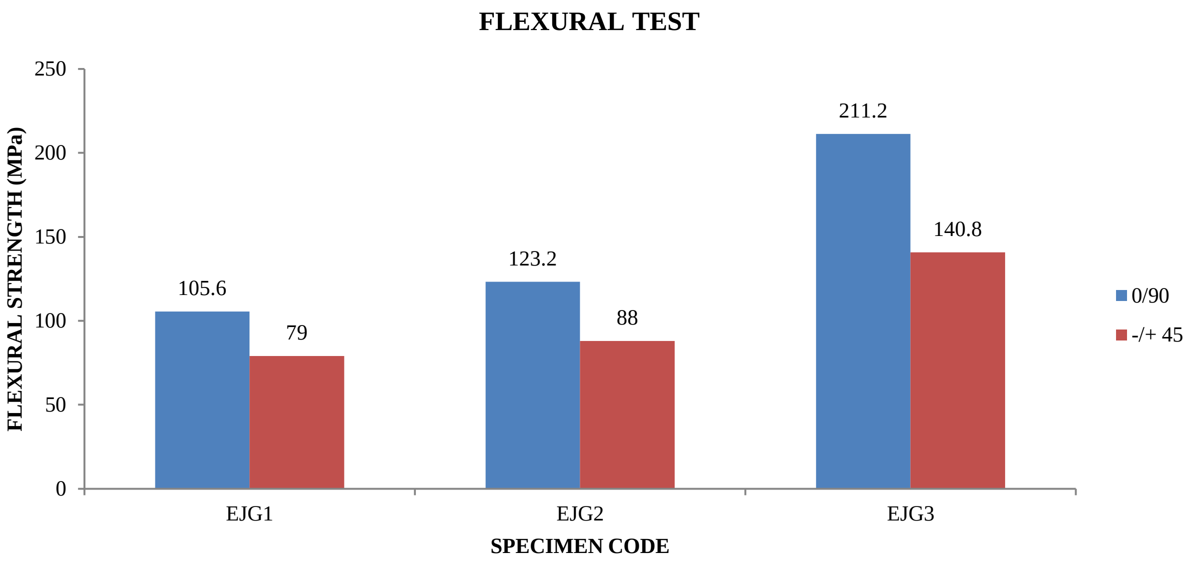

Figure 3.4 Flexural Strengths of Epoxy based Jute/Glass fiber hybrid composites.

3.3 Impact properties: The Impact tests were conducted on the fabricated Epoxy based, Jute, Glass, Jute/Glass fiber composites in an Impact Testing Machine as per ASTM standards. The Impact energy of Epoxy-Glass composite is more when compared to that of Epoxy-Jute composite, as shown in Fig. 3.5. Also, the impact energy was found to be more in fiber direction (0°/90°) than the other direction (-/+ 45°).

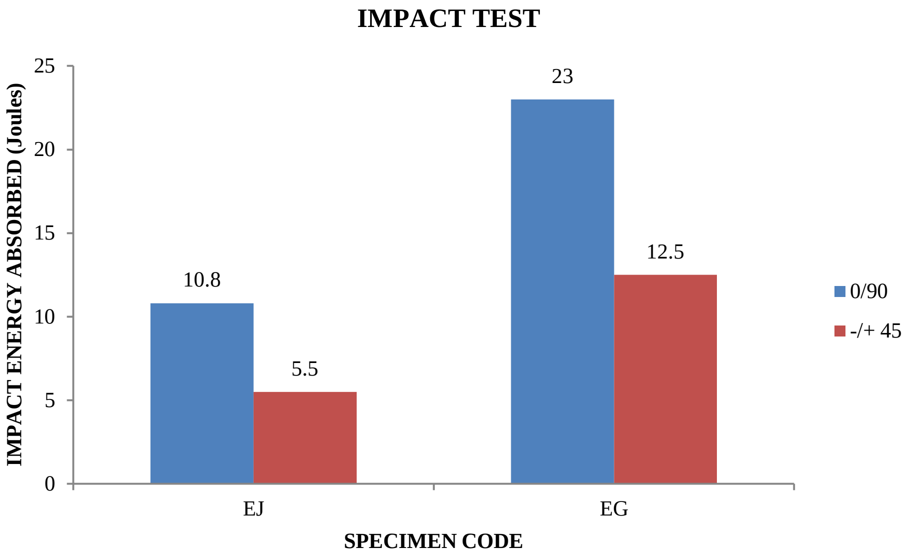

Figure 3.5 Impact energies of Epoxy-Jute and Epoxy-Glass composites

Figure 3.6 shows the Impact energies of Epoxy based Jute/Glass fiber hybrid composites. From the results, as the volume fraction of glass fibres increases (15%, 30%, 45%), the Impact energy increases (13.7 J, 16.6 J, 20.5 J in 0/90 fiber direction and 7.2 J, 9.3 J, 10.7 J in -/+ 45 fiber direction), as shown in Fig.3.4. Thus the hybridization Jute and Glass fiber improve the Impact energy of composites. Also, the Impact energy was found to be more in fiber direction (0°/90°) than the other direction (-/+ 45°).

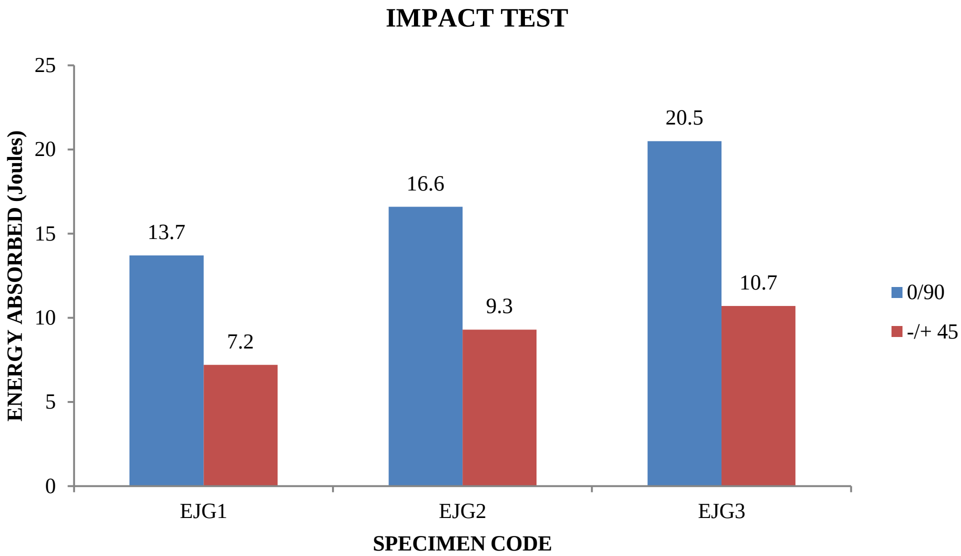

Figure 3.6 Impact energies of Epoxy based Jute/Glass fiber hybrid composites.

3.4 Moisture absorption: The Moisture absorption tests were conducted by immersing the fabricated Epoxy based Jute/Glass hybrid composites in Distilled, Pond and Seawater. Due to Distilled, Pond and Sea water, the moisture absorption was more in EJG1 specimens when compared to EJG2 and EJG3 specimens because Jute fiber volume fraction was more in EJG1 specimens, as shown in Figures 3.7, 3.8 and 3.9 respectively.

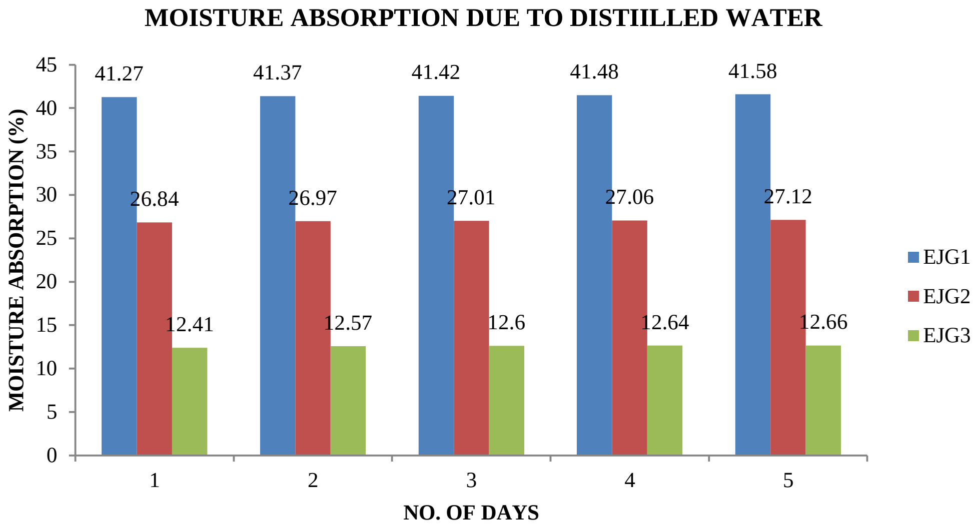

Figure 3.7 Moisture absorption of Epoxy based Jute/Glass hybrid composites in Distilled water

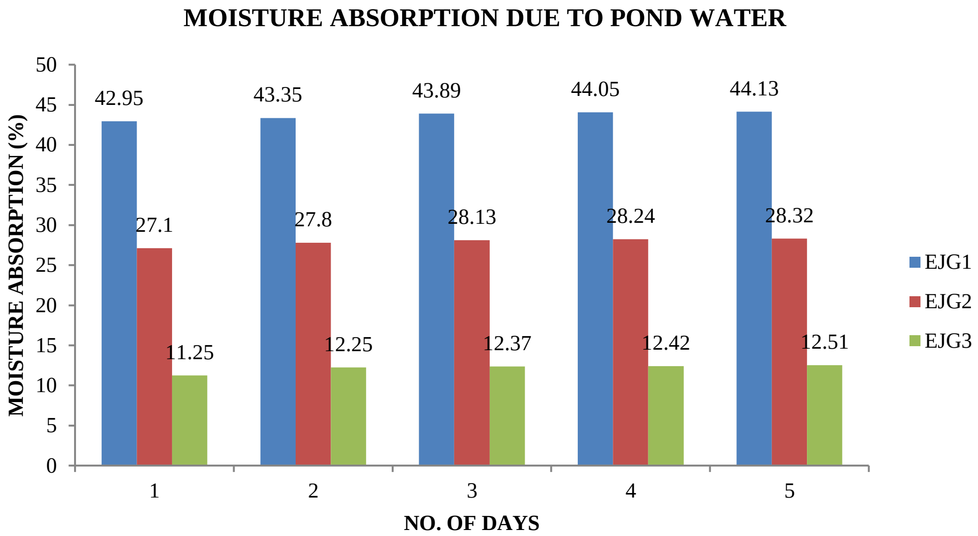

Figure 3.8 Moisture absorption of Epoxy based Jute/Glass hybrid composites in Pond water

But the moisture absorption due to Sea water was more in all Epoxy based Jute/Glass fiber hybrid specimens when compared with those of specimens immersed in Distilled and Pond water.

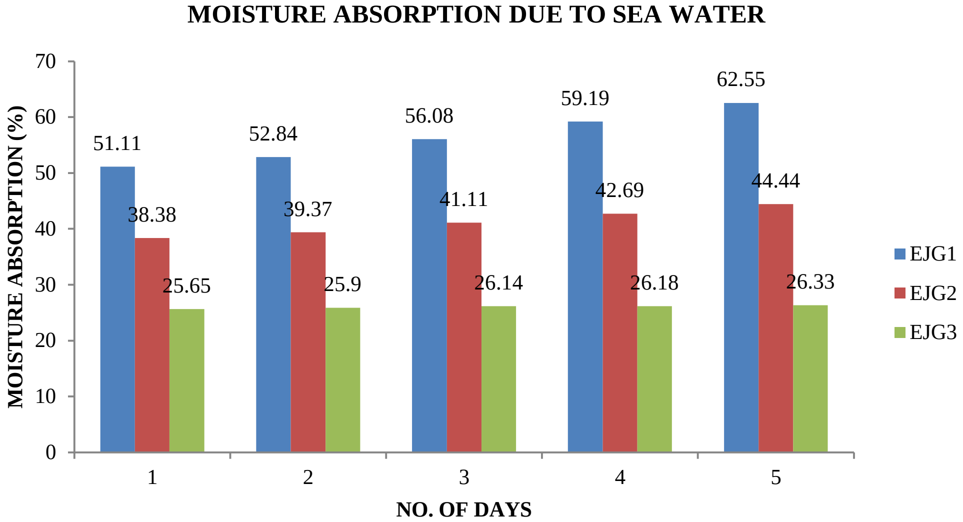

Figure 3.9 Moisture absorption of Epoxy based Jute/Glass hybrid composites in Sea water

4. Conclusion

The Experiments were conducted on Epoxy based jute, glass and jute/glass fiber hybrid composite specimens fabricated by Hand lay-up method for various volume fractions and fiber orientations as per ASTM standards. The epoxy glass composite specimens exhibited higher tensile strength, flexural strength, and impact energy. These values were found to be more in fiber direction than the other direction. The hybridization of Jute fiber with Glass fiber influenced Tensile strength, Bending strength, Impact energies, and moisture absorption. The specimens with the increasing volume fraction of Glass fiber showed an increasing trend in Tensile strength, Flexural strength and Impact energies. All types of tensile specimens failed with fiber breakage. In failed flexural tested specimens, both fiber breakage and delamination of fiber layers were observed. The composite specimens immersed in distilled and pond water showed a decreased trend of moisture absorption, as the volume fraction of glass fiber increased. On the other hand, the sea water affected all the specimens and moisture absorption due to sea water was more compared to other types of water.

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