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Study of Physio-Mechanical Properties of Epoxy Resin Reinforced Maize Cob and Glass Fibre Hybrid Composites

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ABSTRACT
Natural and synthetic fibre hybrid composites are becoming more popular in engineering due to their eco-friendliness, lightweight nature, and low cost. This study focused on creating Maize Cob (MC)/Glass Fibre (GF) hybrid Epoxy Resin (ER) composites using hand-lay-up techniques with a 10% filler content. Various filler combinations (1%GF/9%MC, 7%GF/3%MC, 5%GF/5%MC, 3%GF/7%MC) in 90% ER were tested for physical and mechanical properties. The findings revealed that density decreased with higher filler content, ranging from 1.52 to 1.20 g/cm³, and water absorption increased due to voids and agglomeration. The 5%GF/5%MC/ER composite demonstrated good tensile strength (67.65 MPa) and flexural strength (60.79 MPa) owing to effective filler-matrix integration, while impact strength improved significantly from 1.73 J/m for 100% ER to 2.48 J/m for 5%GF/5%MC/ER. The study concluded that MC/GF hybrid epoxy resin composites offer a sustainable and eco-friendly approach to waste disposal and management.

Keywords: *Maize cob, Glass Fibre, Epoxy Resin, Hybrid composites.*

INTRODUCTION
Now-a-days hybrid composites are receiving considerable attention for their capability of providing designers new freedom of tailoring composites and thus achieving properties that cannot be attained in systems containing one type of fibre dispersed in a matrix (Anuar *et al.,* 2006). Natural fillers, appreciated for biodegradability, low cost, lightweight, non-toxicity, and machinery abrasion reduction, are gaining attention for cost-effective, eco-friendly, lightweight composites (Abilash & Sivapragash, 2013). Environmental concerns and sustainability needs have fueled interest in using natural fibres instead of synthetics like glass, graphite, and carbon fibres (Danladi and Shuaib, 2014). It has also provided a more cost-effective utilization of expensive fibres by replacing them partially with less expensive fibres (Agrawal *et al.,* 2000).

Polymer composites incorporating natural or bio-fillers from renewable, biodegradable sources, known as green composites, are gaining industrial relevance (La Mantia & Morreale, 2011). Hybrid composites combining multiple fillers in a single matrix, offer flexibility in tailoring specific properties such as balanced stiffness, strength and ductility (Nishino, 2006).

Recent developments include blending natural fibres like hemp, bamboo, and jute with glass fibres to fabricate cost-effective hybrid composites (Ishidi *et al.,* 2011). Notable advantages of hybrid composites over conventional ones include balanced properties, reduced weight, improved fatigue resistance, and enhanced fracture toughness (Siddika *et al.,* 2013).

Natural fibres can be mixed either with thermosetting or thermoplastic polymer matrix to fabricate composites. Epoxy resin a thermosetting matrix, known for its balanced chemical and mechanical attributes, holds commercial importance across various fields (Sreekala *et al.,* 2002).

Bhoopathia *et al.,* (2014) have studied the fabrication and property evaluation of Banana-Hemp-Glass fibre-reinforced composites. The results showed banana-glass fibre hybrid composites had a tensile strength of 39.5MPa and hemp-glass fibre reinforced composites of 37.5MPa. Flexural strength of 0.51kN for banana-hemp-glass fibre reinforced composites and banana-glass fibre reinforced composites having the value of 0.50kN. The impact strength of the hybrid composites varied from 5.33 to 8.66 Joules.

Ramesh *et al.,* (2013) studied the comparative evaluation of properties of hybrid glass fibre-sisal/jute reinforced epoxy composites, results showed sisal/GFRP composite samples possess good tensile strength and can withstand strength up to 68.55 MPa and jute/GFRP composite flexural load of 1.03KN.

Ajith *et al.,* (2014) have investigated the mechanical properties of Jute-Polyester and Jute-Epoxy composites. The results showed that the tensile strength for Jute-Epoxy and Jute-Polyester composites was 12.46 N/mm² and 9.23 N/mm². the flexural strength of jute-epoxy and jute polyester composites was found to be 38.68 and 44.71 N/mm² respectively. The jute-polyester composite seemed to have better impact energy than jute-epoxy composites. Recognizing the potential of natural fibres, readily available, the present study is designed to incorporate Maize cob in particulate form and Glass fibre in short-staple length into Epoxy Resin.

METHODOLOGY

MATERIALS

Materials: The materials and types of equipment used are Maize cob (250µ), Epoxy resin supplied by Refintech Nig. Ltd Lagos, Glass fibre supplied by Refintech Nig. Ltd Lagos, Hardener (Di-Phenyl Amine) was supplied by Refintech, Nig Ltd Lagos. Analytical balance (Sartorius. Model: ED2245), Stopwatch, Tensometre type 'W' (Made in UK by Monsanto), 200 × 120 × 6(mm) glass mould, Indentec Universal Hardness testing machine (Model:8187.5) LKV 'B', Measuring cylinder, Universal material testing machine (Cat Nr. Model:261), Retsch sieve shaker machine (Endocatt.Model:7416), Charpy impact testing machine "15 Joules Capacity (Cat Nr. Model:412), Scanning Electronic Micoscope (SEM) Phenon Pro-X by Phenon-world Eindhoven Neitherlands.

Maize Cob: Maize cob was sourced from farmers in Bajabure, Girei Local Government Area of Adamawa State. The maize cob was reduced to smaller chunks by pounding and subsequent grinding into powder. The maize cob powder was further sieved on a Retsch sieve shaker to obtain particles of 250µ because smaller particles increase the modulus and decrease the ductility of the matrix.

Glass Fibre: Glass fibre was purchased from Refintech Nig. Ltd Lagos and cut into short fibre staple lengths for proper interaction with the matrix.

Epoxy Resin: Epoxy is a thermoset, capable of being cured from liquid to solid state through reactive epoxy sites. Epoxy resin and its hardener (Di-Phenyl Amine) were purchased from Refintech Nig. Ltd Lagos.

Composite Preparation

Preparation of Hybrid Composites (Glass fibre/Maize cob/Epoxy resin): The composite board was fabricated by hand lay-up techniques. Varying percentages of maize cob and glass fibres at 1%GF/9%MC, 3%GF/7%MC, 5%GF/5%MC, 7%GF/3%MC, 9%GF/1%MC were weighted out. 90%ER and hardener (di-phynyl amine) were weighed out and poured in a container and mixed thoroughly to ensure even distribution of the fibres. The mixture is poured into a glass mold and kept for 24hrs and after curing composite was taken out from the mold. The composites were subsequently cured under laboratory conditions before subjecting them to physical and mechanical tests.

Tensile Strength Test: The tensile strength was examined using ASTM D638 standards to prepare dumbbell-shaped test samples.

$S = P/a$ ------------------- (1)

where: S = Tensile strength
P = Breaking load
a = Cross-sectional Area of sample.

Impact Strength Test: The Charpy Impact Testing Machine, Cat Nr.412, with a 15 Joules capacity, was employed to perform impact tests following ASTM D-256 standards.

Hardness Test: Hardness measurements were conducted utilizing the "Indentec Universal Hardness Testing Machine Model 8187.5 LKV" with a "B" Rockwell HRF indenter employing a 1/16" steel ball. The testing adhered to ASTM D2240 standards.

Flexural Strength Test: Flexural strength also referred to as modulus of rupture, bend strength, or fracture strength, represents a material's capacity to withstand stress before yielding in a flexure test (Hodgkinson, 2000). The three-point bending test, following ASTM D790 standards, was executed using a Cat Nr.261 Universal Material Testing Machine-100KN.

$F = 3PL/2bt^2$ ----------------------------- (2)

where: P = maximum load
L = gauge span of the sample
b = sample width
d = sample thickness

TEST FOR PHYSICAL PROPERTIES

Water Absorption: The water absorption test was conducted following ASTM 2842 guidelines.

Density: Composite densities were assessed following ASTM D792-13 guidelines.

$\rho = m/v$ -------------------------------------- (3)

where: m = mass

v = volume

RESULTS AND DISCUSSION

MECHANICAL TESTS:

Tensile Strength

From Fig 1, it was observed that hybrid composites of GF/MC/ER showed the highest tensile strength value of 67.65 MPa at 5%GF/5% MC/90% ER. This is close to that of 100% ER with 73.65 MPa. This behaviour could be attributed to the extent of excellent intermingling between the two fillers (MC and GF) and may be a possibility that the combination of maize cob in particulate form and glass fibre in the fibrous form in the matrix could have provided a kind of synergism responsible for the high tensile strength at 5%GF/5%MC/90% ER. Ramesh et al (2014) reported a similar result in the study of the comparative evaluation of properties of hybrid glass fibre-sisal/jute reinforced epoxy composites and reported that the sisal/GFRP composite samples possess good tensile strength and can withstand the strength of up to 68.55 MPa.

Flexural Strength:

Fig 2: shows an initial decrease in flexural strength. Formation of agglomerates results in the creation of stress centres in the composites contributing to an adverse effect on the mechanical properties and failure in mechanical properties of the composites (Shenoy and Melo, 2007). However, an increase in flexural strength of 60.79 MPa at 5%GF/5%MC/ER hybridization was observed, this is close to the 100% Epoxy Resin which is at 67.1MPa. This improvement in flexural strength at 5%MC/5%GF may be due to the interfacial bonding and additional load-bearing capacity of the matrix, which can be due to good filler-matrix adhesion and good interaction and dispersion with the matrix.

Impact Strength Test:

Fig. 3 shows an increase in impact strength indicating a maximum value of 2.48J/m at 5%GF/5%MC/90%ER then afterwards impact strength decreases to 0.94J/m for 3%GF/7%MC. The increase in impact strength may be attributed to the fibres which are present in sufficient amounts that can provide the effective stress transfer between the fibres and the matrix. The presence of longitudinal fibres at the loading points contributes to an increase in resistance and invariably, better mechanical properties. This can only take place if the interfacial adhesion between the matrix and the filler does not result in a crack, lowering the impact strength of the composites. (Karmakar *et al.,* 2007).

Similar results were observed for oil palm fibres and glass fibre reinforced hybrid composite, impact strength was found to have increased with an increase in fibre content for composites up to 35wt%, but composites having fibre loading of over 35wt% exhibited a reduction in impact strength as reported by (Jacob *et al.,* 2003).

PHYSICAL TEST:

Density

The results in Fig. 4 show a decrease in density for composites as the percentage of maize cob fillers increases from (1.41/cm^3 to 1.2g/cm^3), which is about 30% decrease from the pure epoxy resin which is 1.36(g/cm^3), this can be attributed to the fact that natural fibres have the advantage of having lighter weight but occupy substantial amount of space which explains why as the filler content of maize cob increased, the density of the composites decreased, this is in line with the result obtained by (Danladi and Shuaib, 2014). Since the weight of the filler is less than that of the resin and volume is inversely proportional to density, then density will therefore decrease with increasing filler content.

Water Absorption

The hybrid composite of GF/MC/ER at different filler content showed moderate water absorption. This could be attributed to the fact that hybridization with glass fibre which is also hydrophobic has reduced the water absorption ability of the maize cob. The maize cob fillers which are in particulate form are fully embedded in the matrix giving a good interfacial adhesion between the fillers and the matrix, therefore the moderate water absorption values. A similar result was obtained by (Mishra *et al.,* 2003) in studies on the mechanical performance of fibre/glass-reinforced polyester hybrid composites. It is a well-known fact that most natural fibres are generally hydrophilic in nature, whereas, polymer molecules are hydrophobic in character (Kabir *et al.,*2011). Because of the moderate water uptake exhibited by the composites, this limits their application to indoor usage

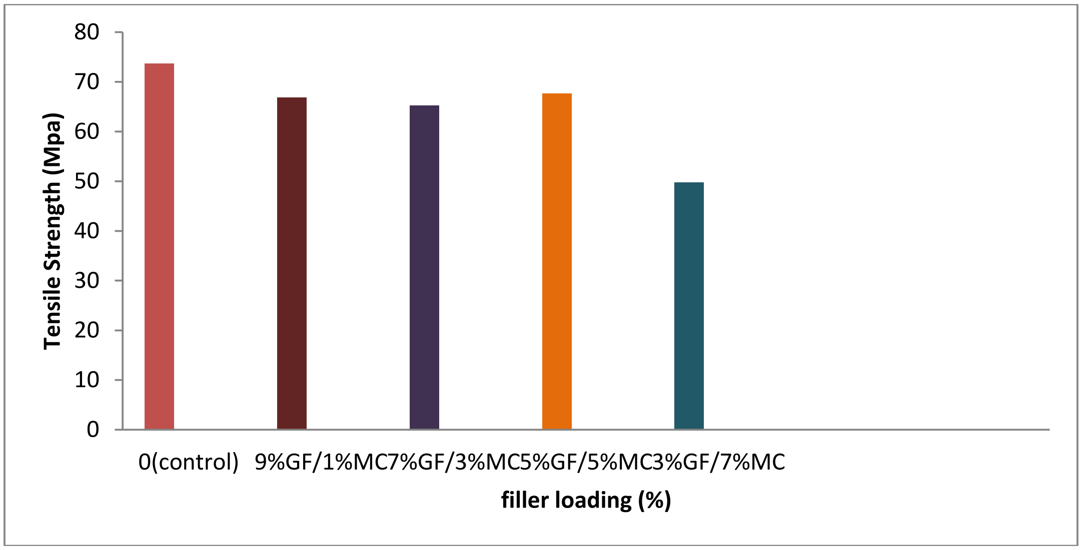

Figure 1: Tensile Strength against Filler loading of GF/MC/ER Hybrid Composites.

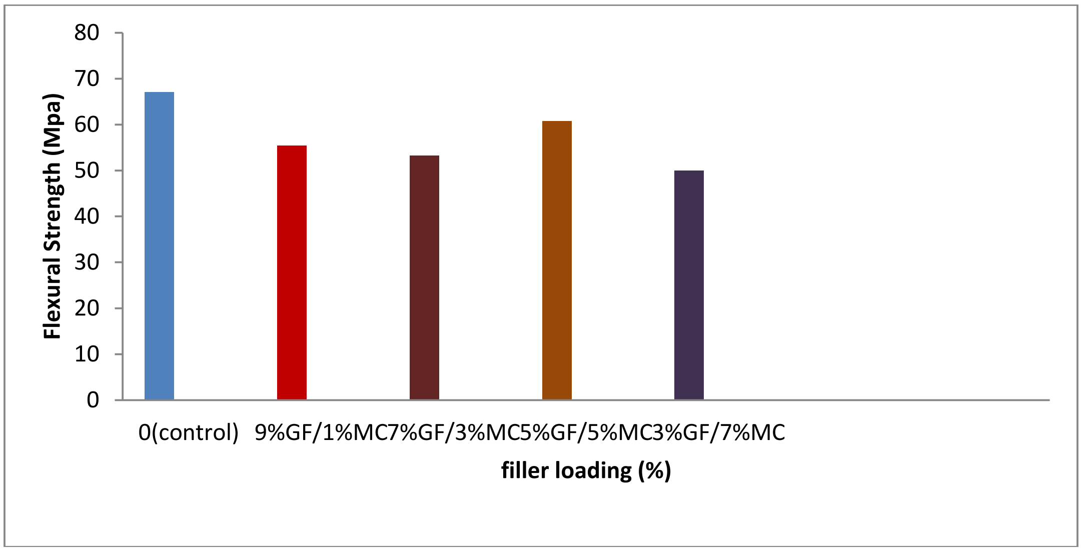

Figure 2: Flexural strength against Filler loading of GF/MC/ER Hybrid Composites

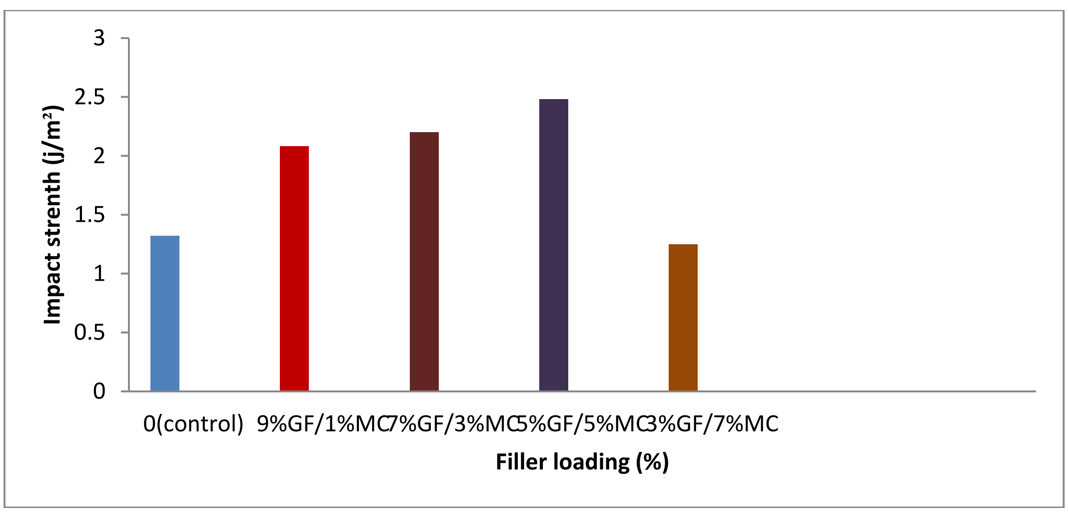

Figure 3: Impact Strength Against Filler Loading of GF/MC/ER Hybrid Composites.

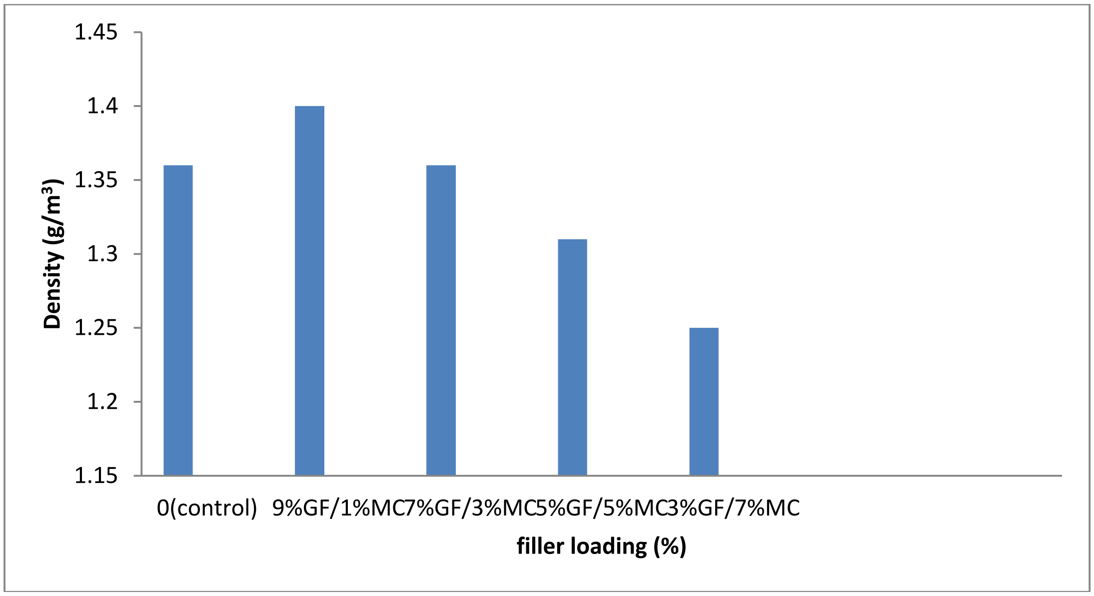

Figure 4: Density against Filler Content of GF/MC/ER Hybrid Composites

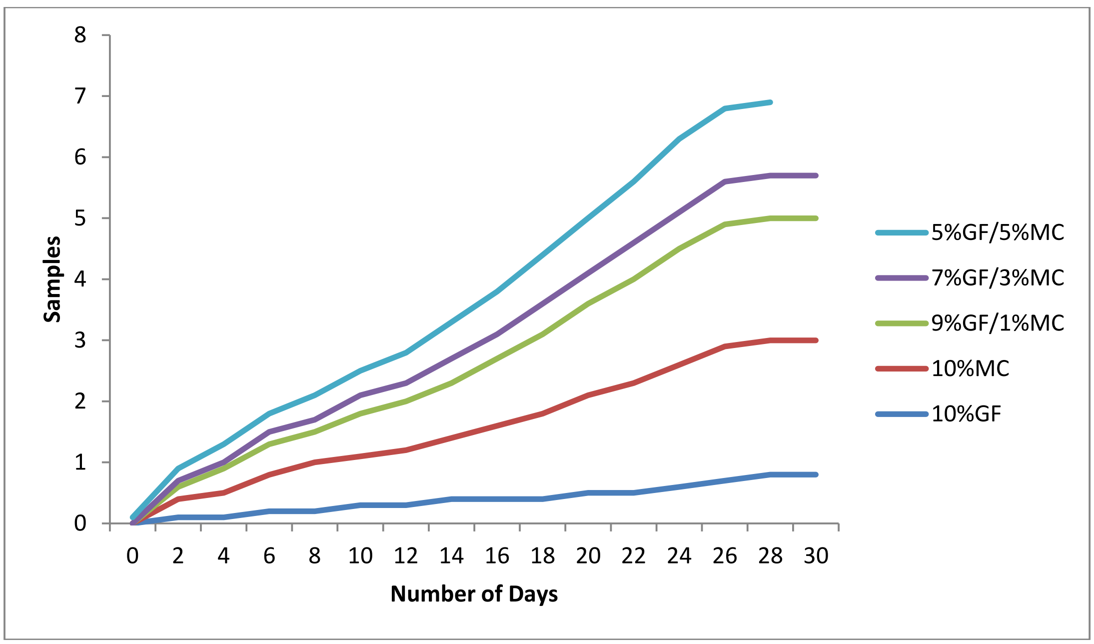

Figure 5: Water Absorption against the number of days for GF/ MC/ER composites

Conclusion

This study successfully fabricated MC/GF/ER hybrid composites using a hand lay-up technique with Maize cob as bio-filler and glass fibre. The physical (Density, water absorption) and mechanical (tensile strength, flexural strength, impact strength) properties were evaluated. Hybrid composites of 5%GF/5%MC/90%ER were observed to have adequate values for tensile strength(65.25Mpa), impact strength (2.48J/m) and Flexural strength (60.79Mpa). The results could be attributed to the extent of intermingling between the two fillers (MC and GF) and may be a possibility that the combination of maize cob in particulate form and glass fibre in fibrous form in the matrix could have provided a kind of synergism which could be responsible for the high mechanical properties. Overall, the GF/MC/ER hybrid composite produced has the potential to be considered as a source of utilizing agricultural waste materials for sustainable resources for manufacturing structural materials such as particle boards, library shelves, and partition panels.

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