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Determination Of Mechanical Properties Of Al_2O_3, Mg $(OH)_2$ And Sic Filled E-Glass/ Epoxy Composites

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ABSTRACT

In this research work, mechanical behavior of E-glass fiber reinforced epoxy composites filled with varying concentration of aluminum oxide (Al_2O_3), magnesium hydroxide ($Mg(OH)_2$) and silicon carbide(SiC) were studied. Composites were fabricated by standard method. The objective of this work was to study the mechanical properties like ultimate tensile strength, impact strength, flexural strength and hardness of the fabricated composites. The experimental results show that composites filled by (10% Vol.) $Mg(OH)_2$ exhibited maximum ultimate tensile strength and SiC filled composites exhibited maximum impact strength, flexural strength and hardness.

Key words: Composites, Fillers, Mechanical, Properties, Strength

1. INTRODUCTION

There is an increasing demand for advanced materials with better properties to meet new requirements or to replace existing materials. The high performance of continuous fiber (e.g. carbon fiber, glass fiber) reinforced polymer matrix composites is well known and documented [1]. However, these composites have some disadvantages related to the matrix dominated properties which often limit their wide application and create the need to develop new types of composite materials. In the industry, the addition of filler materials to a polymer is a common practice. This improves not only stiffness, toughness, hardness, heat distortion temperature, and mold shrinkage, but also reduces the processing cost significantly. In fact, more than 50% of all produced polymers are in one way or another filled with inorganic fillers to achieve the desired properties [2]. Among the thermosetting polymers, epoxy resins are the most widely used for high-performance applications such as, matrices for fibre reinforced composites, coatings, structural adhesives and other engineering applications. Epoxy resins are characterized by excellent mechanical and thermal properties, high chemical and corrosion resistance, low shrinkage on curing and the ability to be processed under a variety of conditions [3]. Mechanical properties of fibre-reinforced composites are depending on the properties of the constituent materials (type, quantity, fibre distribution and orientation, void content). Beside those properties, the nature of the interfacial bonds and the mechanisms of load transfer at the interphase also play an important role [4]. Now-a-days specific fillers/additives are added to enhance and modify the quality of composites as these are found to play a major role in determining the physical properties and mechanical behavior of the composites. For many industrial applications of glass fiber reinforced epoxy composite, information about their mechanical behavior is of great importance. Therefore, this work presents an experimental study of the mechanical properties of E-glass fiber reinforced epoxy composites filled by varying concentration of Al_2O_3, Mg $(OH)_2$ and SiC.

2. EXPERIMENTATION

2.1. MATERIALS

The composites were made from E-glass fiber and commercially available ARALDITE (L-12) along with hardener K-6. Al_2O_3, Mg $(OH)_2$ and SiC was used as filler materials. Aluminum oxide particles is a ceramic powder commonly used filler, it is also used as an abrasive due to its hardness. Magnesium hydroxide is an inorganic compound and it is a white powder with specific gravity of 2.36, very slightly soluble in water; decomposing at 350^o C. Magnesium hydroxide is attracting attention because of its performance, price, low corrosiveness and low toxicity. Silicon carbide exhibits favorable mechanical and chemical properties at high temperatures for many applications. The benefits of using SiC as reinforcement are improved stiffness, strength, thermal conductivity, wear resistance, fatigue resistance, reduced thermal expansion and dimensional stability.

2.2 FABRICATION OF COMPOSITES

The E-glass /Epoxy based composites filled with varying concentrations (0, 10 and 15 Vol %) of aluminum oxide (Al_2O_3), magnesium hydroxide (Mg $(OH)_2$), and silicon carbide (SiC) were prepared. The volume fraction of fiber, epoxy and filler materials were determined by considering the density, specific gravity and mass. Fabrication of the composites is done at room temperature by hand lay-up techniques. The required ingredients of resin, hardener, and fillers are mixed thoroughly in a basin

and the mixture is subsequently stirred constantly. The glass fiber positioned manually in the open mold. Mixture so made is brushed uniformly, over the glass plies. Entrapped air is removed manually with squeezes or rollers to complete the laminates structure and the composite is cured at room temperature.

2.3 SPECIMEN PREPARATION

The prepared slabs of the composite materials were taken from the mold and then specimens were prepared from composite slabs for different mechanical tests according to ASTM standards. The test specimens were cut by laminate by using different tools in work shop. Three identical test specimens were prepared for different tests

2.4 MECHANICAL PROPERTY TESTING

Tensile, bending, impact and hardness tests were carried out using Universal testing machine, impact machine and hardness testing machine respectively. Three identical samples were tested for tensile strength, bending, impact strength and hardness.

2.4.1TENSILE STRENGTH

The tensile behavior of prepared samples was determined at room temperature using Universal testing machine in accordance with ASTM D3039. Test specimens having dimension of length 250 mm, width of 25 mm and thickness of 2.5 mm. The specimen was loaded between two manually adjustable grips of a 60 KN computerized universal testing machine (UTM) with an electronic extensometer. Each test was repeated thrice and the average value was taken to calculate the tensile strength of the composites.

Details of Universal Testing Machine
Make- Micro Control Systems
Model- MCS-UTE60
Software-MCSUTE STDW2KXP

System uses add-on cards for data acquisition with high precision and fast analog to digital converter for pressure/Load cell processing and rotary encoder with 0.1 or 0.01 mm for measuring cross head displacement (RAM stroke). These cards are fitted on to slots provided on PC's motherboard WINDOW9X based software is designed to fulfill nearly all the testing requirements. MCS make electronic extensometer is used with a extremely accurate strain sensor for measuring the strain of the tensile samples.

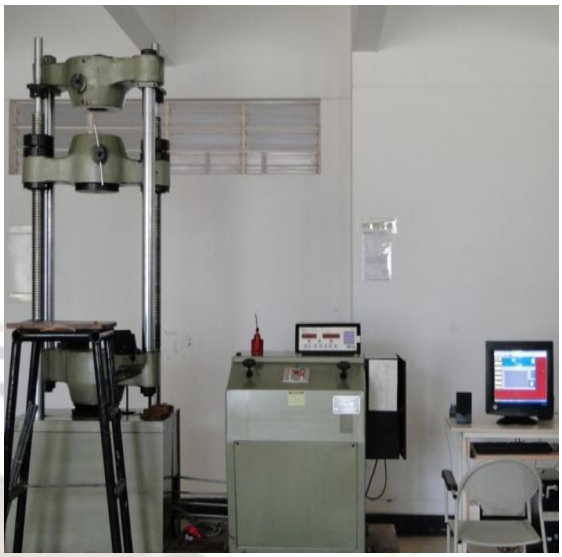

Fig.1 Universal Testing Machine

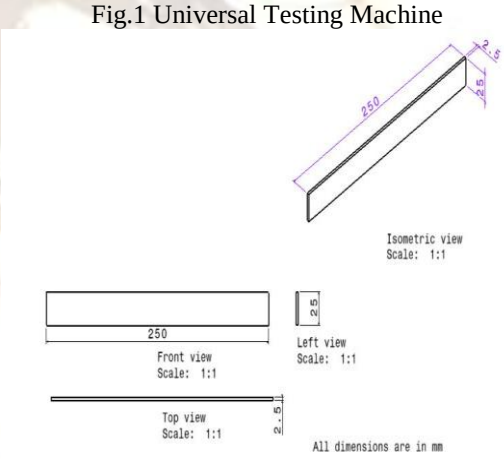

Fig. 2 Tensile strength test specimen

2.4.2 IMPACT STRENGTH

The charpy impact strength of composites was tested using a standard impact machine as per ASTM E23 standard. The standard test specimen 55mm long 10 x 10mm^2 cross section, having 45^0 V-notch and 2mm deep were used for the test. Each test was repeated thrice and the average values were taken for calculating the impact strength.

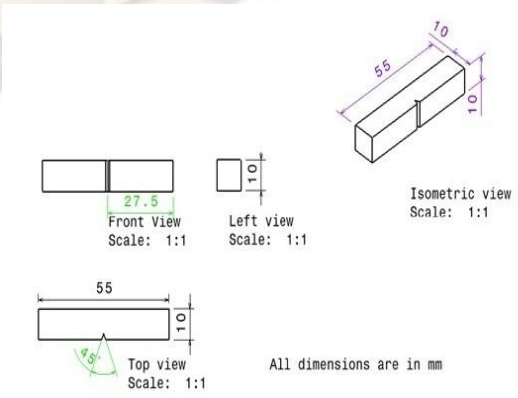

Fig. 3 Charpy Impact Test Specimen

2.4.3 FLEXURAL STRENGTH

Flexural strength is determined by 3-point bend test. The test specimen of dimension 130 mm × 25mm×3.2 mm were used for test. This test method determines the flexural properties of fiber reinforced polymer composites.

Flexural strength is calculated by the following equation from the standard ASTM D 790

$$\sigma f = \frac{3PL}{2bh^2} \quad \text{---------- (1)}$$

Where

σf = Stress in the outer fibers at midpoint (MPa)

P = Load at a given point on the load-deflection curve (N)

L = Support span, (mm)

b = Width of beam tested, (mm)

h = Depth of beam tested, (mm

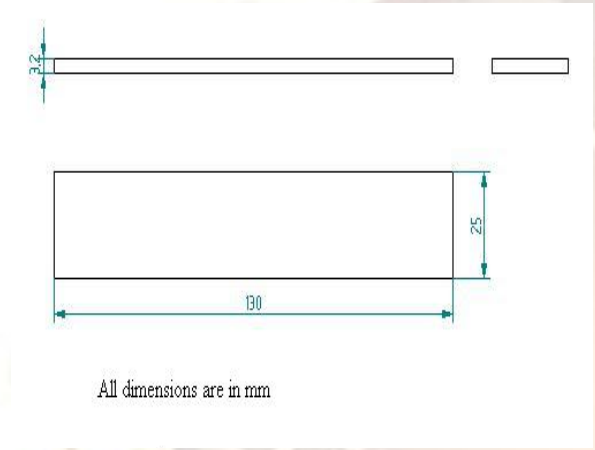

Fig. 4 Bending test specimen

2.4.4 BRINELL HARDNESS TEST

Brinell hardness test was conducted on the specimen using a standard Brinell hardness tester. A load of 250 kg was applied on the specimen for 30 sec using 5mm diameter hard metal ball indenter and the indentation diameter was measured using a microscope. The hardness was measured at three different locations of the specimen and the average value was calculated. The indentation was measured and hardness was calculated using equation (2).

$$BHN = \frac{2P}{\pi D\left(D - \sqrt{(D^2 - d^2)}\right)} \quad \text{---------- (2)}$$

Where:

P= Applied force (kgf)

D = Diameter of indenter (mm)

d = Diameter of indentation (mm)

Table 1: Designation of Composites

Material Designation	Glass Fiber (%Volume)	Epoxy (%Volume)	Filler Materials (% Volume)
GE	50	50	Nil
GEA_1	50	40	10% Al_2O_3
GEA_2	50	35	15% Al_2O_3
GEM_1	50	40	10% $Mg(OH)_2$
GEM_2	50	35	15% $Mg(OH)_2$
$GESI_1$	50	40	10% SiC
$GESI_2$	50	35	15% SiC

3 RESULTS AND DISCUSSION

The ultimate tensile strength, impact strength, flexural strength and Brinell hardness number for different composition of composite materials are presented in tables 2- 5 and their variations shown in figures 5 to 8 respectively.

3.1 ULTIMATE TENSILE STRENGTH

The tensile strength of the composite materials depends upon the strength and modulus of the fibers, the strength and chemical stability of the matrix, the fiber matrix interaction and the fiber length.

Table 2: Comparison of Ultimate Tensile Strength

Composite materials	Ultimate Tensile Strength, (M Pa)
GE	450.24
GEA_1	292.8
GEA_2	257.21
GEM_1	375.36
GEM_2	347.2
$GESI_1$	285
$GESI_2$	224.53

From the obtained results it is observed that composite filled by (10% Vol.) Mg $(OH)_2$ exhibited maximum ultimate strength(375.36MPa) when compared with other filled composites but lower than the un filled composite this may be due to good particle dispersion and strong polymer/filler interface adhesion for effective stress transfer but further increase in filler content (up to 15 % Vol.) the tensile strength is found to be less this is due to more filler material distribution in the material. Composites filled by Al_2O_3 exhibited better ultimate strength when compared with SiC filled composites. From the "fig.5" it is observed that increase in addition of filler materials to composites leads to decrease in ultimate strength this may be due to more filler distribution and filler materials dominated in the composite materials.

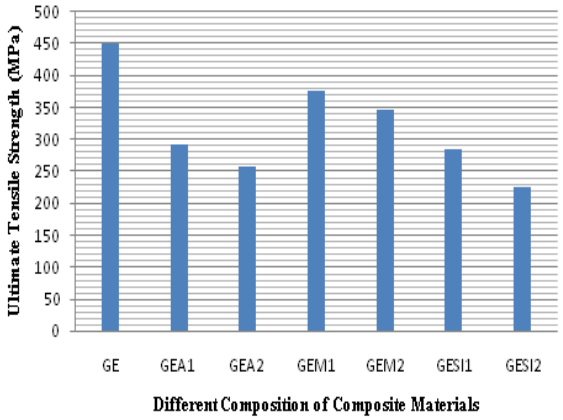

Fig.5 Ultimate tensile strength for different composition of composite materials

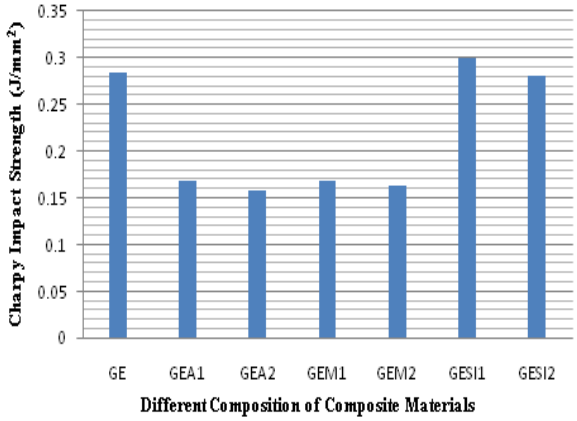

Fig. 6 Charpy Impact strength for different composition of composite materials

3.2 IMPACT STRENGTH

Impact strength is defined as the ability of a material to resist the fracture under stress applied at high speed. The impact properties of composite materials are directly related to overall toughness and composite fracture toughness is affected by inter laminar and interfacial strength parameters.

Table 3: Comparison of Charpy Impact Strength

Composite materials	Charpy Impact Strength (J/mm^2)
GE	0.2846
GEA_1	0.16812
GEA_2	0.1575
GEM_1	0.16875
GEM_2	0.1625
$GESI_1$	0.3
$GESI_2$	0.28

Experimental results is indicated that SiC filled composites having high impact strength when compared with other filled composites this due to that good bonding strength between filler, matrix and fiber and flexibility of the interface molecular chain resulting in absorbs and disperses the more energy, and prevents the cracks initiator effectively. The energy absorbing capability of composites depends on the properties of the constituents, based on literature review it is found that the benefits of using SiC as reinforcement are improved stiffness, strength and chemical stability. Composites filled by (10% Vol) Al_2O_3 and Mg $(OH)_2$ exhibited good impact strength but increase in addition of Al_2O_3 and $Mg(OH)_2$ leads to decrease in impact strength . Typically, a polymer matrix with high loading of fillers has less ability to absorb impact energy this is because the fillers disturb matrix continuity and each filler is a site of stress concentration, which can act as a micro crack initiator and reduces the adhesion and energy absorption capacity of composite materials this is observed in composites filled by (15% Vol.) Al_2O_3 , $Mg(OH_2)$ and SiC.

3.3 FLEXURAL STRENGTH

Comparison of the flexural strengths of composite materials are shown in “fig. 7” they indicated that composites filled by (10%Vol) SiC exhibited maximum flexural strength (291.55MPa) when compared with other filled composites but lower than the un filled composites this due to that good compatibility between filler and matrix. The reduction of flexural strengths is observed with increase in addition of SIC this may the fillers disturb matrix continuity and reduction in bonding strength between filler, matrix and fiber. However, test results show that increase in addition of Al_2O_3 and Mg (OH_2), enhances the flexural strength this is due to uniform distribution of filler materials and increased in effective bonding between filler materials and matrix and strong polymer/filler interface adhesion.

Table 4: Comparison of Flexural Strength

Composite materials	Flexural Strength (MPa)
GE	326.83
GEA_1	185.12
GEA_2	240.96
GEM_1	241.06
GEM_2	264.87
$GESI_1$	291.55
$GESI_2$	280.84

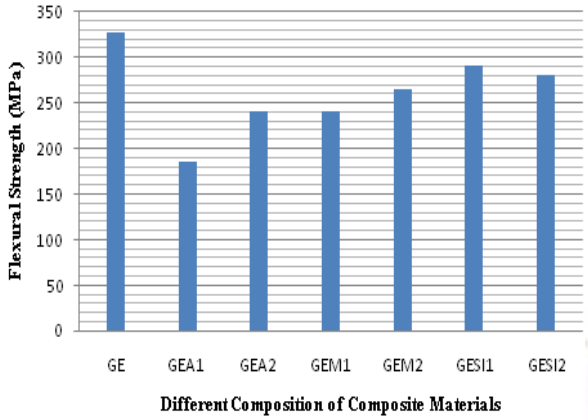

Fig. 7 Flexural strength for different composition of composite materials

3.4 HARDNESS

Hardness numbers of all the composites are presented in the table-5

Table 5: Comparison of Brinell hardness number

Composite materials	Brinall Hardness Number (BHN)
GE	57.64
GEA_1	73,90
GEA_2	82.13
GEM_1	88.69
GEM_2	88.10
$GESI_1$	72.46
$GESI_2$	91.73

The experimental results indicated that composite filled by (15 % Vol.) SiC exhibited maximum hardness number (91.73BHN) this due to uniform dispersion of SiC particles and decrease in inter particle distance with increasing particle loading in the matrix results in increase of resistance to indentation. From the obtained results it is observed that increase in addition of Al_2O_3 increases the hardness of the composites. Composites filled by Mg $(OH)_2$ exhibited better hardness number when compared with Al_2O_3 filled composites this may be due to the improved bond between the matrix and reinforcement and reduced porosity.

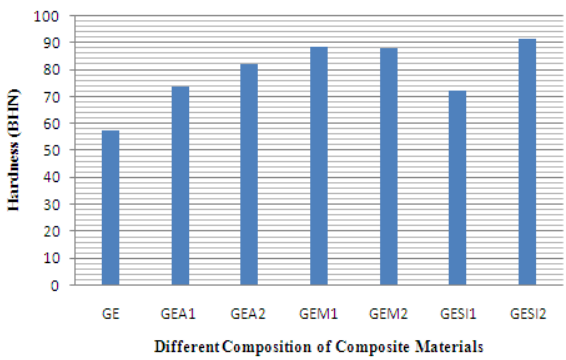

Fig. 8 Brinell hardness number for different composition of composite materials

4 CONCLUSIONS

In the present research work E-glass/Epoxy based composites filled with varying concentrations of Al2O3, $Mg(OH)_2$ and (SiC) were prepared. Fabrication was conducted at room temperature by hand lay-up techniques. Based upon the test results obtained from the different tests, several important conclusions can be drawn.

From the obtained results composite filled by (10% Vol.) Mg $(OH)_2$ exhibited maximum ultimate strength (375.36MPa) when compared with other filled composites but lower than the un filled composite this may be due to good particle dispersion and strong polymer/filler interface adhesion for effective stress transfer. Increase in addition of filler materials to composites leads to decrease in ultimate strength this may be due to more filler distribution and filler materials dominated in the materials. Experimental results indicated that SiC filled composites having high impact strength when compared with other filled composites this due to that good bonding strength between filler, matrix and fiber and flexibility of the interface molecular chain resulting in absorbs and disperses the more energy, and prevents the cracks initiator effectively. The flexural strength results indicated that composites filled by (10%Vol.) SiC exhibited maximum flexural strength (291.55MPa) when compared with other filled composites but lower than the un filled composites this due to that good compatibility between filler and matrix. However, test results show that increase in addition of Al_2O_3 and Mg (OH_2), enhances the flexural strength this is due to uniform distribution of filler materials and increased in effective bonding between filler materials and matrix and strong polymer/filler interface adhesion. Composite filled by (15 % Vol.) SiC exhibited maximum Brinell hardness number (91.73 BHN) this due to uniform dispersion of SiC particles and decrease in inter particle distance with increasing particle loading in the matrix results in increase of resistance to indentation.

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