Influence of Ca_2SiO_4 as fillers on Mechanical Properties of Epoxy Polymer Matrix Composites

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***Abstract*— In the present work, the investigation is carried out on Epoxy composites filled with Ca_2SiO_4 as filler material. Epoxy matrix Composites were fabricated by using hand layup technique, by varying the concentration of filler material Ca_2SiO_4 with respect to vol% of 0%, 2% 4% and 6%. The experiments are conducted for the evaluation of the mechanical properties such as ultimate tensile strength, flexural strength and impact strength of the Epoxy composites. The test results showed that there was an increase in mechanical properties of the composites with the increase in vol% of Ca_2SiO_4. Experimental results of mechanical properties for different filler material concentration were evaluated and compared. SEM analysis is done to conclude.**

Keywords*— Epoxy, Calcium Silicate, Mechanical Properties, Fillers, Composites

I. INTRODUCTION

Polymer composites due to their ease of processing, productivity, cost reduction and high strength to weight ratio are becoming popular and used in many applications. Conventional metals and materials have been replaced by polymer composites in various applications. Polymers along with fibers exhibit high strength and high modulus which are the essential parameters. The continuous carbon and glass fiber reinforced polymer matrix composites are in great demand [1]. Epoxy matrix resin is the thermoset polymer which has been widely used in many applications because of their high performance, excellent characteristics of low shrinkage on curing, corrosion resistance and chemical resistance. Thermoset epoxy resin exhibits good mechanical and thermal properties under various operating conditions [2].

The moisture absorption is a common problem with composite materials. To design a polymer matrix composite structures and components it is very important to know the kinetics of moisture uptake and the effect of moisture adsorption on the mechanical properties [3]. In extreme environment condition the performance of the composite must be reliable. The damage tolerance behaviour must be determined in hot and wet condition which plays an important role in influencing the damage behaviour. It has been reported in many researches that the kinetics of moisture uptake can be altered by adding the filler material or by particulates reinforcement [4, 5]. The addition of filler materials to polymer resins is a common practice in the industrial applications to overcome the disadvantages related to the matrix dominated properties and to improve the mold shrinkage, hardness, stiffness, heat distortion temperature and toughness of the material along with significant reduction in the processing cost [6]. To enhance and to modify the properties of composites the specific fillers or additives are added. This will improve the mechanical and physical properties of the composite [7].

The enhancement of mechanical properties has been found with fly-ash as the filler material and reinforcement material [8]. The flow of water molecules in to the polymer matrix composite takes place in three ways. First is the flow of molecules through the interface of fiber and matrix. Second is due to the direct diffusion of molecules in resin matrix. Third is the flow of molecules through micro damages [9]. The moisture absorption follows the Fick's Second Law of diffusion, according to law the concentration gradient and the weight gain is proportional to square root of time [10]. Once the moisture uptake reaches maximum there will be decrease in gain of mass and leads to double step absorption kinetics [11]. Moisture absorption leads to the delamination mechanism influencing the interlaminar failure in polymer matrix composites. The mechanical properties of the polymer matrix composite are influenced by the moisture intake rate [12].

The matrix dominated properties of the polymer matrix particulate reinforcement composites leads the limitation for their applications. The polymer matrix reinforced composite with some filler materials enhances the mechanical properties such as tensile strength, stiffness, flexural strength, hardness, and impact strength and heat distortion temperature. In the present day applications over 50% of polymer composites are filled with organic or inorganic fillers to enhance the mechanical properties [6].

II. EXPERIMENTAL PROCEDURES

A. Materials

Raw materials selected for the present study are as follows.

- *Matrix Material*

Epoxy Lapox L-12 is a liquid, unmodified epoxy resin of medium viscosity which can be used with various hardeners for making fiberglass reinforced composites and Laminates. Epoxy resins are the thermosetting polymers that are most widely used for their high-performance applications. Epoxy resins have find the wide application due to their ability to be processed and cured under varieties of conditions, excellent corrosion resistance, high chemical resistance, low shrinkage and their mechanical and thermal properties [2]. Epoxy resins generally react with themselves through reaction known as catalytic homo-polymerization.

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Density of Epoxy resin (Lapox -12) = 1.120 gm/cm^3

- *Curing Agent*

Hardner K-6 is a low viscosity room temperature curing aliphatic amine curing agent. It is commonly employed for civil engineering systems where low viscosity and fast setting at ambient temperature is desired. The choice of hardener depends upon the processing method to be used and on the properties required of the cured composite.

Density of K6 hardener = 0.954 gm/cm^3

- *Filler Material*

Calcium silicate (Ca_2SiO_4) is used as the filler material in the present work attempt has been made to evaluate the influence of Ca_2SiO_4 as the filler material on the mechanical properties of the Epoxy polymer resin based composites. Due to the good resistance to moisture absorption and good hardness property of the Ca_2SiO_4, the selection of Ca_2SiO_4 as the filler material is done in the work.

B.Fabrication of Composites

The epoxy polymer composites laminates are fabricated by hand layup technique, by varying the filler material Ca_2SiO_4 with respect to vol% of 0%, 2%, 4% and 6%. The Epoxy (Lapox L-12) is mixed with Hardener (K-6) at the ration of 100:10. The pot life of this mixture is 30 min at 25 ºC, hence the mixture is poured in to the mould within the pot life. The composite laminates measuring 250 mm x 250 mm x 3 mm were fabricated by the hand layup technique. The test coupons were cut as per the ASTM standards for the testing purpose. Average density of the Epoxy (Lapox L12) and hardener (K6) is 1.037 gm/cm^3 with the resin and hardner ratio of 100:10.

TABLE I. SPECIMEN DETAILS

Composite	Specimen Designation	Vol. Fraction of Epoxy (%)	Vol. Fraction of Ca2SiO4 (%)
Epoxy+0%	EPC0	100	0
Epoxy+2%	EPC2	98	2
Epoxy+4%	EPC4	96	4
Epoxy+6%	EPC6	94	6

Fig. 1. Epoxy/Ca_2SiO_4 Composite Test Coupons

C. Tensile test

The capability of a material to overcome the forces nurturing to pull it separately is known as 'tensile strength'. In this test, material will be subjected to a uniaxial tensile force with continuous increasing in load. Meanwhile, an observation will be made on the elongation of the specimen. The test will be conducted on the specimen till it breaks. ASTM D-3039 is the Standard Test Method for evaluating the Tensile Properties of the Polymer matrix composite.

D. Flexural test

The flexural test is conducted to measure the force that is required to bend the material and flexural test will be done under three point loading condition. This test helps in selecting the material that will support loads without flexing. The specimen is support between the span and at the center of the specimen the load is applied. At the specified rate the loading nose produces the three point bending. The 5% deflection is considered as maximum or the specimen must fail before 5% and the testing is stopped. ASTM E-190-14 is the Standard Test Method for evaluating the flexural Properties of the Polymer matrix composite.

E. Impact test

The impact tests were conducted on Charpy Impact Testing Machine. The different specimens were tested for the energy absorption by dropping the weight of the impactor. In the charpy test the specimen is clamped to the fixture, so that one end of the specimen face is the striking end and the impact energy absorbed for breaking is directly obtained. ASTM D-6110 is the Standard Test Method for evaluating the Impact Strength of the Polymer matrix composite.

III. RESULTS AND DISCUSSIONS

A. Tensile Strength

The tensile strengths of epoxy based composites filled with Calcium Silicate as filler material are shown in Fig. 2. It is found that, there is a gradual increase in tensile strength with increase in filler content. The unfilled epoxy laminate has strength of 64.32 MPa in tension, and this value increases to 67.87 MPa, 80.74MPa and 97.57 MPa with Ca_2SiO_4 filler material addition of 2 vol.%, 4 vol.% and 6 vol.% respectively. The increase in tensile strength with filler addition is due to the excellent surface bonding between the filler particles and the resin indicating the desired purpose of using the filler material as a load bearing material and hence the increase in tensile strength.

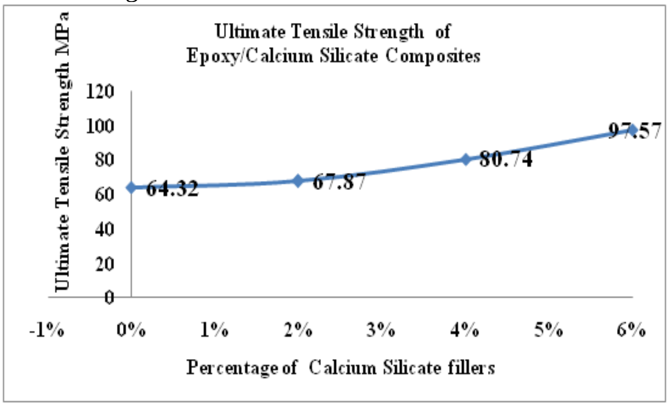

Fig. 2. Tensile Strength of Epoxy/ Ca_2SiO_4 composites

TABLE II. TENSILE AND FLEXURAL PROPERTIES OF EPOXY/CA2SIO4 REINFORCED PMC

Composite	Specimen Designation	Ultimate Tensile Strength (MPa)	Flexural Strength (MPa)
Epoxy+0%	EPC0	64.32	27.78
Epoxy+2%	EPC2	67.87	32.07
Epoxy+4%	EPC4	80.74	36.37
Epoxy+6%	EPC6	97.57	38.42

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B. Flexural Strength

In the present work, the variation of flexural strength of Epoxy matrix composites with Ca_2SiO_4 fillers has been shown in Figure 3. The unfilled epoxy laminate has strength of 27.78 MPa, and this value increases to 30.32 MPa, 36.37 MPa and 38.42 MPa with Ca_2SiO_4 filler material addition of 2 vol.%, 4 vol.% and 6 vol.% respectively. The increase in flexural strength of the composites with filler content is probably caused by an compatibility of the particulates and the Epoxy matrix, leading to excellent bonding fillers and base resin.

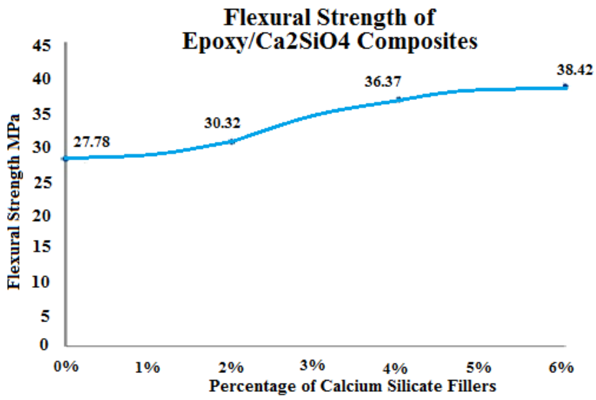

Fig. 3. Flexural Strength of Epoxy/ Ca_2SiO_4 composites

C. Impact Strenfth

The impact energy absorption by the Epoxy matrix composites with Ca_2SiO_4 fillers has been shown in Figure 4. The unfilled epoxy laminate absorption the Impact energy of 17.5 J, and this value increases to 18 J, 19 J and 20 J with Ca_2SiO_4 filler material addition of 2 vol.%, 4 vol.% and 6 vol.% respectively.

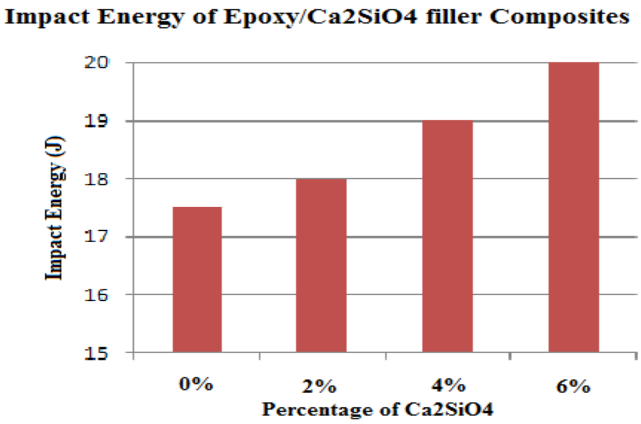

Fig. 4. Impact Energy absorption of Epoxy / Ca_2SiO_4 composites

TABLE III. IMAPCT STRENGTH OF EPOXY/CA2SIO4 REINFORCED PMC

Specimen Designation	Percentage of Ca2SiO4	Impact Energy (J)	Impact Strength (J/mm2)
EPC0	0%	17.5	0.4575
EPC2	2%	18	0.4686
EPC4	4%	19	0.4929
EPC6	6%	20	0.5199

D. SEM Analysis

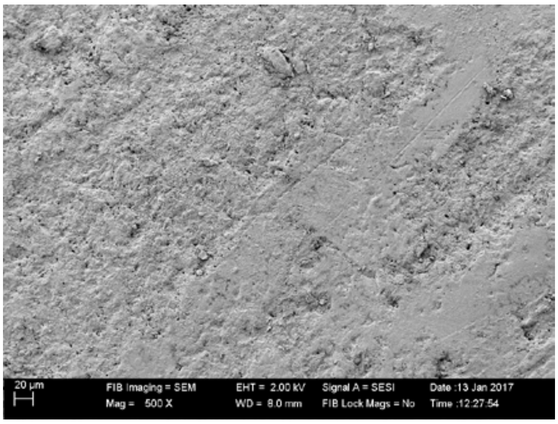

Fig. 5. Pure Epoxy with no fillers

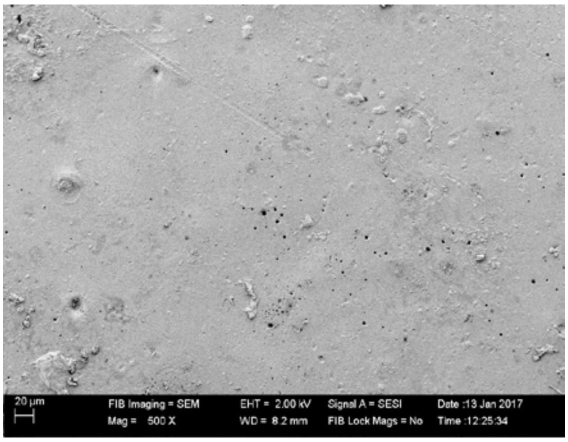

Fig. 6. Epoxy with 2% Ca_2SiO_4 fillers

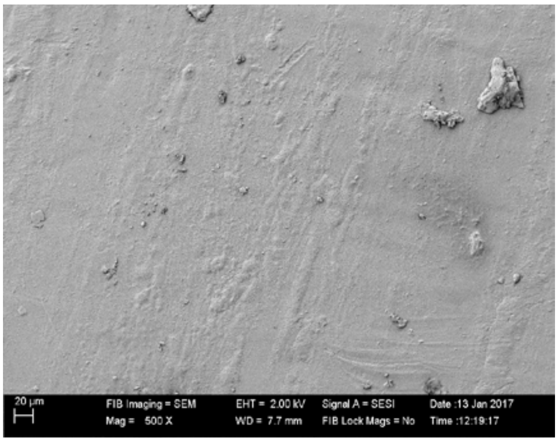

Fig. 7. Epoxy with 4% Ca_2SiO_4 fillers

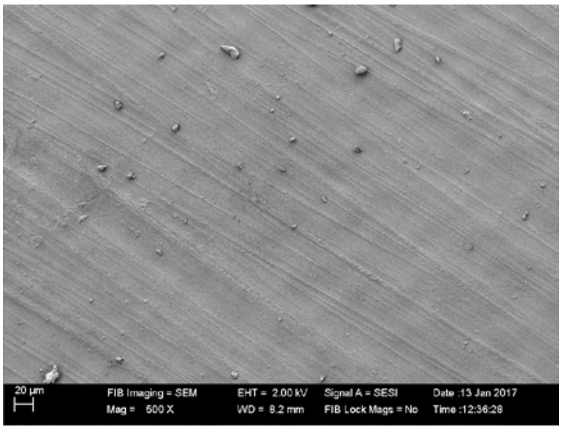

Fig. 8. Epoxy with 6% Ca_2SiO_4 fillers

From the SEM analysis it was observed that there is a excellent surface bonding between the Ca_2SiO_4 filler particles and the epoxy resin. The compatibility of the particulates and the epoxy resin has resulted in improved mechanical properties. Fig. 5, Fig. 6, Fig. 7 and Fig. 8 represents the epoxy composites with Ca_2SiO_4 filler material with vol.% of 0%, 2%, 4% and 6% respectively. From the SEM analysis it is observed that with the increase in vol.% of Ca_2SiO_4 fillers the bonding of the epoxy matrix composite increases.

IV. CONCLUSION

This experimental investigation on particulate filled composites has led to the following specific conclusions:

1. Successful fabrication of Epoxy/Calcium Silicate composites with reinforcement of conventional Chemical compounds is possible.
2. Incorporation of this filler as the primary reinforcement modifies tensile, flexural and impact strengths of the composites.
3. Usage of chemically synthesized filler materials has the potential in modifying properties of fibre reinforced composites.
4. With the increase in chemically synthesized filler materials the excellent surface bonding between the filler particles and the resin are obtained. The load bearing capacity of the material increases with the increase in vol.% of the filler materials.

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