Fabrication & Mechanical Characterization Of Marble Powder Filled Epoxy Composites

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Abstract- *In present Research article the fabrication of the Epoxy based composites with and without the addition of filler materials (marble powder) by manual hand layup technique was done. After the fabrication of composites specimens were prepared from fabricated sheet as per ASTM Standards and mechanical properties like Tensile Strength(T.S), Tensile Modulus(T.M), Compression Strength(C.S), Flexural Strength(F.S), ILSS and Impact Strength(I.S) of the Composites were determined and the Effect of and filler content on mechanical properties were studied and the TOPSIS (Technique for Order Performance by Similarity to Ideal Solution) is implemented to measure the proximity to the ideal solution.*

Keywords- Marble Powder, Mechanical Properties, TOPSIS

I. INTRODUCTION

When two or more different materials are combined together to create a superior and unique material; this material comprehends to be a composite. In broader sense and terminology, this definition holds true for all composites. The most common example of a “composite" in day to day life is concrete. The basic fundamentals holds true for structural steel bar which provides the strength and stiffness to the concrete, while the cured cement holds the bar stationary [1]. A composite tends to be a combination of two materials in which one of the materials, called the reinforcement, is in the form of fibers, sheets, or particles, and is embedded in the other materials called the matrix [2]. Usually matrix is a ductile or tough material and reinforcing materials are stronger with low densities which can be metal, ceramic, or polymer. Generally, there must be a substantial volume fraction (~10% or more) of the reinforcement to exhibit better mechanical properties.

Borsellino et.al. [3] Studied the behavior of composite structures reinforced with marble powder. They researched on the variation in mechanical and physical properties of the composite with different matrix materials (epoxy and polyester resins) and different weight fractions of reinforced particles. Their work shows that a composite with 60% marble powder with epoxy resin gave much superior properties compared to monolithic marble.

Bilgin et.al. [4-7], investigated the usability of marble powder as an additive for industrial bricks. They concluded that, the presence of marble powder had a positive effect on the mechanical, physical and chemical properties of the bricks. They have suggested that the use of marble dust can contribute to the economy and also minimize environmental pollution.

Arunit et.al. [8-9] examined the effect of post curing temperature on the properties of a polymer matrix particle reinforced composite. Their aim was to draw a relationship between the post curing mode and the composite application. Their work suggests that the composite material should be cured at 60-800C. They also concluded that with increasing curing temperature, the glass transition temperature increases but the material becomes more brittle.

Imran Oral [10] studied the effects of marble powder, type of coagulant and their dosages on the ultrasonic properties of the epoxy resin/marble powder composites. His work also showed that the morphological and ultrasonic properties of the epoxy resin improved by addition of marble powder. He concluded that the ultrasonic non-destructive method is very useful for evaluating the elastic properties of epoxy/marble powder composites.

Bahar Demirel [11] has investigated the effect of using waste marble powder as a fine additive on the mechanical properties of concrete. He prepared different concrete-marble powder-sand mixture for mechanical testing. His work suggests that the addition of waste marble powder resulted in the enhancement of the compressive strength of the concrete and also a decrease in the porosity of the concrete.

Marras et.al. [12-14] studied the effective recovery and reuse of by-products of marble processing industries. Their focus was to integrate these by-products with industrial applications. They concluded that the addition of marble dust and other traditional constituents improved the quality of industrial bricks. Their work shows that marble powder can partially replace the clay in the bricks, leading to less waste generation.

TOPSIS is a multiple criteria method to identify solutions from a finite set of alternatives based upon simultaneous minimization of distance from an ideal point and maximization of distance from a nadir point. TOPSIS has been applied to a number of applications many researchers. Singh et al. [15] studied the selection of material for bicycle chain in Indian scenario using MADM Approach. They concluded that both MADM and TOPSIS methods User friendly for the ranking of the parameters. Huang et al. [16] studied the multi-criteria decision making and uncertainty analysis for materials selection in environmentally conscious design. It was reported that TOPSIS method demonstrates a reasonable performance in obtaining a solution; and entropy method presents designers' or decision makers' preference on cost or environmental impact and effectively demonstrates the uncertainties of their weights. Khorshid et al. [17] studied the selection of an optimal refinement condition to achieve maximum tensile properties of Al-15%Mg2Si composite based on TOPSIS method and observed that the TOPSIS method is considered to be a suitable approach in solving material selection problem when precise performance ratings are available. Ghaseminejad et al. [18] used data envelopment analysis and TOPSIS method for solving flexible bay structure layout, and found that this method is useful for creating, initial layout, generating initial layout alternatives and evaluating them. Chakladar and Chakraborty [19] studied the combined TOPSIS-AHP-method-based approach for non-traditional machining processes selection and also include the design and development of a TOPSIS/AHP- method-based expert system that can automate the decision-making process with the help of a graphical user interface and visual aids. Shahroudi and Rouydel [20] studied a multi-criteria decision making approach (ANP TOPSIS) to evaluate suppliers in Iran's auto industry. Lin et al. [21] studied on customer-driven product design process using AHP and TOPSIS approaches and results shows that the proposed approach is capable of helping designers to systematically consider relevant design information and effectively determine the key design objectives and optimal conceptual alternatives. Isiklar and Buyukozkan [22-23] studied a multi-criteria decision making (MCDM) approach to assess the mobile phone options in respect to the users preferences order by using TOPSIS method.

Against this background, the following objectives were chosen for the present research project work.

- Fabrication of epoxy resin composite with/without marble powder filler.
- Evaluation of mechanical properties (tensile strength, flexural strength etc.)
- The study of effect of filler content on Mechanical Properties.

II. MATERIALS AND METHODS

Raw materials used in this experimental work are:

1. Epoxy resin.
2. Hardener.
3. Filler material->Fine Marble Powder.

1. EPOXY RESIN:

Epoxy resin (Araldite LY 556) made by CIBA GUGYE Limited, having the following outstanding properties has been used.

I. Excellent adhesion to different materials
ii. Great strength, toughness resistance
iii. Excellent resistance to chemical attack and to moisture
iv. Excellent mechanical and electrical properties.
v. Odorless, tasteless and completely nontoxic.
vi. Negligible shrinkage.

2. HARDNER:

In the present work Hardener (araldite) HY 951 is used. This has a viscosity of 10-20 poise at 25^0C.

3. FILLER MATERIAL

FINE MARBLE POWDER:

Marble is a metamorphic rock produced from limestone by pressure and heat in the earth's crust due to geological processes. It is widely used cement, construction and sculpture industries. Marbles are, chemically, crystalline rocks constituting mainly calcite and dolomite. In the last 2 decades, the marble industry has gained industrial importance. Countries like USA, France, Belgium and other European countries have considerable marble reserves. During marble processing, 30% of the stone goes to scrap because of being smaller in size and/or being irregularly shaped. Millions of tons of marble powder are processed every year during extraction around the world. As a result, significant environmental damage occurs from the large quantities of marble dust produced in these industries. Marble dust may also lead to skin allergies. However, apart from these disadvantages, marble powder is also among the most useful substances in the planet and has found uses in several applications, in a number of different forms. It is mainly used as a filler or additive in several industrial applications.

Fig 2.1 Raw materials for specimen preparation

SAMPLE PREPARATION PROCESS:

Epoxy based Composites are prepared with four compositions filled with marble powder (0wt%, 5wt%, 10wt%, and 15wt %) by manual hand layup process. The calculated weights of marble powder are added to the epoxy resin as per the composition. Epoxy resin and marble powder were stirred mechanically to get homogeneous mixture and then hardener HY951 is added. Mansion white wax polish was applied on the inner walls of the mould made of rubber mat for easy removal of the casting after solidification. After application of the white wax to the mould prepared epoxy and marble powder mixture is poured into the mould and is left to solidify for 72 hours. Prepared composites are removed from the moulds and mechanical characterization (Tensile strength, tensile modulus, Compression Strength, Flexural Strength, ILSS and Impact strength) will be done.

Table2.1: Designation & Composition

Desgn..	Composition
C1	100wt% of epoxy without filler
C2	95wt% of epoxy + 5wt% of marble powder
C3	90wt% of epoxy + 10wt% of marble powder
C4	85wt% of epoxy + 15wt% of marble powder

Fig.2.2 Tensile test specimens before Test

Fig.2.3 Flexural test specimens before Test

Fig.2.4 Impact test specimens before Test

TESNSILE TEST:

The tensile strength of a material is the maximum amount of tensile stress that it can take before failure. The commonly used specimen for tensile test is the dog- bone type. During the test a uni-axial load is applied through both the ends of the specimen. The dimension of specimen is per ASTM D638 (TENSILE). Typical points of interest when testing a material include, ultimate tensile strength (UTS) or peak stress; offset yield strength (OYS) which represents a point just beyond the onset of permanent deformation ; and the rupture (R) or fracture point where the specimen separates into pieces. The tensile test is performed in the universal testing machine (UTM) Instron 1195(capacity 40 ton) and results are analyzed to calculate the tensile strength of composite samples .Tensile strength is calculated by dividing the load at break by the original minimum cross sectional area. The result is expressed in mega Pascal’s (MPa).

$$\text{tensile strength} = \frac{\text{(load at break)}}{\text{(original width) (original thickness}}$$

Fig. 2.5 UTM machine sample loading condition for tensile test

FLEXURAL TEST:

Flexural strength is defined as a materials ability to resist deformation under load. The short beam shear (SBS) tests are performed on the composites samples. It is a 3-point bend test, which generally promotes failure by inter-laminar shear. This test is conducted as per ASTM D790 (FLEXURAL) using UTM (capacity 60T). The loading arrangement is shown in figure. The flexural strength is expressed as modulus of rupture (MR) in psi (MPa). Flexural MR is about 10 to 20 present of compressive strength depending on the type, size and volume of coarse aggregate used. However the best correlation for specific materials is obtained by laboratory tests for given materials and mix design

$$\text{Flexural Strength} = 3PL / 2bd^2$$

Where P= applied central load (N)

L= test span of the sample (m)

b= width of the specimen (m)

d= thickness of specimen under test (m)

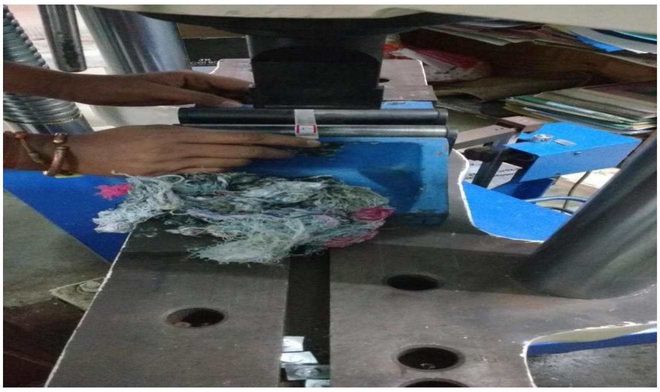

Fig 2.6 Sample loading condition for 3 point bending test

IMPACT TEST:

Impact strength, is the capability of the material to withstand a suddenly applied load and is expressed in terms of energy. Often measured with the Izod impact strength test or Charpy impact test. Low velocity instrumented impact tests are carried out on composite specimens. The tests are done as per ASTM D 256 using an impact tester (Figure 3.9). The Charpy/Izod impact testing machine ascertains the notch impact strength of the material by shattering the V-notched specimen with a pendulum hammer, measuring the spent energy, and relating it to the cross section of the specimen. The standard specimen for ASTM D256 is 64 x 12.7 x 3.2 mm and the depth under the notch is 10.2 mm.

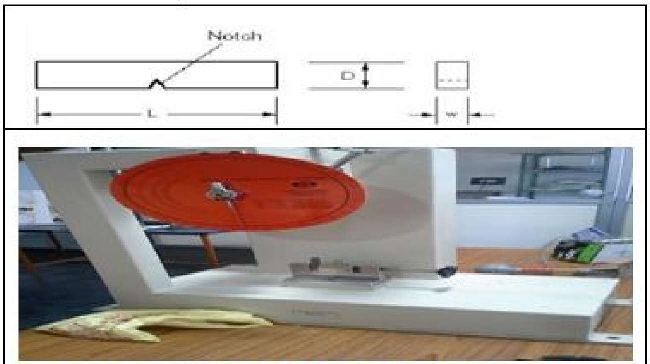

Fig 2.7 Sample loading condition for Impact Test

Specimens after testing:

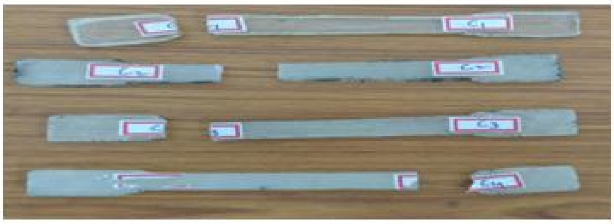

Fig 2.8. Specimens after Tensile Test

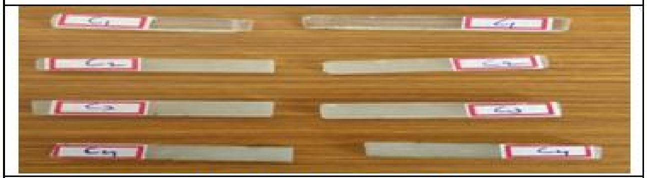

Fig 2.9. Specimens after Flexural Test

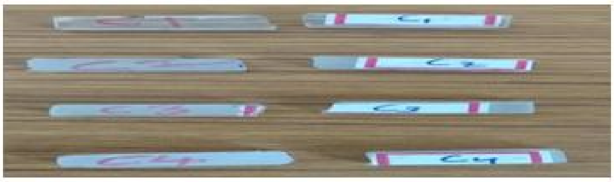

Fig 2.10. Specimens after Impact Test

III. RESULTS AND DISCUSSIONS

Mechanical Properties of composites will be enhanced by addition of filler material, the prepared composites are tested for mechanical properties like tensile strength, flexural strength, impact strength, hardness etc., by mechanical characterization equipments and their results are as follows.

Tensile strength of composites:

Table:3.1 Tensile strength of Composites

Composite	Tensile strength (M Pa)
C1- 100wt% of epoxy without filler	16.139
C2- 95wt% of epoxy + 5wt% of marble powder	17.336
C3- 90wt% of epoxy + 10wt% of marble powder	9.991
C4- 85wt% of epoxy + 15wt% of marble powder	13.796

From Table 3.1 the tensile strength of pure epoxy is 16.139Mpa and tensile strength of marble powder with 5wt%, 10wt% and 15 wt% filled epoxy composites is 17.336Mpa, 9.991Mpa and 13.796Mpa respectively. Two reasons are responsible for reduction in tensile properties with the addition of marble powder, the possible reasons are

- The weak interface between the filler particles and matrix;
- Sharp edges of the asymmetrical shaped filler particles causes stress concentration.

Tensile Modulus of composites:

Table:3.2 Tensile Modulus of Composites

Composite	Tensile Modulus (G Pa)
C1- 100wt% of epoxy without filler	0.35
C2- 95wt% of epoxy + 5wt% of marble powder	0.45
C3- 90wt% of epoxy + 10wt% of marble powder	0.39
C4- 85wt% of epoxy + 15wt% of marble powder	0.38

From Table 3.2 it is observed that the tensile modulus is maximum for the epoxy composite filled with 10wt% marble powder and decreases with the increase in filler content it may be due to improper filler dispersion in matrix base

Compression Strength of Composites:

Table:3.3 Compression Strength of Composites

Composite	Comp. Strength (MPa)
C1- 100wt% of epoxy without filler	3.752
C2- 95wt% of epoxy + 5wt% of marble powder	2.661
C3- 90wt% of epoxy + 10wt% of marble powder	2.333
C4- 85wt% of epoxy + 15wt% of marble powder	0.589

The test results of compression strengths are shown in Table3.3. It is seen that in all the samples the compression Strength of the composites decreases with the increase in filler content. The unfilled epoxy has strength of 3.752MPa in compression and it may be seen from Tables 3.3 That this value drops to 2.661Mpa, 2.333MPa and 0.589MPa with the addition of 5wt%, 10wt% and 15wt% of marble powder respectively. There can be two reasons for this decline in the compression strength properties of these particulate filled composites compared to the unfilled ones.

- Due to poor interfacial bonding.
- Due to matrix to filler interaction, voids and dispersion problems.

Flexural Strength & ILSS of Composites:

Table:3.4 Flexural Strength of Composites	
Composite	Flexural Strength (MPa)
C1- 100wt% of epoxy without filler	118.27
C2- 95wt% of epoxy + 5wt% of marble powder	77.56
C3- 90wt% of epoxy + 10wt% of marble powder	67.61
C4- 85wt% of epoxy + 15wt% of marble powder	18.10

Table:3.5 Inter Laminar Shear Strength of Composites	
Composite	ILSS (GPa)
C1- 100wt% of epoxy without filler	2.813
C2- 95wt% of epoxy + 5wt% of marble powder	1.995
C3- 90wt% of epoxy + 10wt% of marble powder	1.741
C4- 85wt% of epoxy + 15wt% of marble powder	0.4420

The test results of flexural strengths& ILSS are shown in Tables 3.4&3.5. It is seen that in all the samples the flexural strength & ILSS of the composites decreases with increase in filler content. The unfilled epoxy has strength of 118.27MPa in Bending & ILSS of 2.813MPa and it may be seen from Tables 4.4&4.5. That this value drops to 77.56Mpa, 67.61MPa and 18.10MPa with the addition of 5wt%, 10wt% and 15wt% of marble powder respectively and ILSS of pure epoxy dropped to 1.995MPa, 1.741MPa and 0.4420MPa with the addition of 5wt%, 10wt% and 15wt% of marble powder respectively There can be two reasons for this decline in the Flexural strength and ILSS properties of these particulate filled composites compared to the unfilled ones.

- The incompatibility of the particulates and the epoxy matrix, leading to poor interfacial bonding.
- The lower values of flexural strength may also be attributed to matrix to filler interaction, voids and dispersion problems.

However it also depends on other factors such size, shape, type and loading on filler on material.

Impact Strength of Composites:

The impact energy values of different composites recorded during the impact tests are given in Table 3.6. It shows that the resistance to impact loading of marble powder filled epoxy composites is same as that of unfilled epoxy. All the composites exhibited the impact strength of 2J. This may be

Table:3.6 Impact Strength of Composites	
Composite	Impact Strength (J)
C1- 100wt% of epoxy without filler	2
C2- 95wt% of epoxy + 5wt% of marble powder	2
C3- 90wt% of epoxy + 10wt% of marble powder	2
C4- 85wt% of epoxy + 15wt% of marble powder	2

- Due to Interfacial bonding in between the Particulate fillers and matrix material
- The corner points of the regular shaped particulates result in less stress concentration in the matrix base.

IV. CONCLUSIONS

The experimental investigation on the effect of fiber loading and filler content on mechanical behavior of fiber reinforced epoxy composites were conducted. Properties such as the Tensile strength, flexural strength, Impact energy were evaluated from various experiments. The experiments lead us to the following conclusions obtained from this study:

The successful fabrications of a new class of epoxy based composites reinforced with marble powder with varying compositions have been done.

Mechanical characterization has been done and Tensile strength and tensile modulus is more for 5wt% marble powder filled epoxy composites when compared with the other composites

It has been observed from this work that the Flexural Strength, ILSS and compression strength is maximum for unfilled epoxy

Possible use of these composites such as pipes carrying coal dust, low cost housing etc. is recommended. However, this study can be further extended in future to new types of composites using other inorganic materials/fillers and the resulting experimental findings can be similarly analyzed.

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