ISSN 2229-5518

# Effect of Mica on Mechanical properties of filled Epoxy

Srinivas K and M.S.Bhagyashekar

**Abstract-**This paper reports the studies carried out on epoxy reinforced with particulates of Mica. The weight fraction of mica was varied from 10 to 40% in steps of 10%. Tensile, flexural and compression tests were conducted on Lloyd's tensile tester as per ASTM standards D638, D790 and D695 respectively. The increase in filler fraction increases density, tensile and flexural modulus of Mica epoxy composite where as degradation of hardness and strength was observed with an increase of mica. The tensile modulus predicted by analytical equations such as Maxwell, Hamilton crosser, Reuss and inverse rule of mixture was compared with experimental tensile modulus. Tensile modulus predicted by analytical equations and by experiment exhibit good correlation with each other

**Index Terms**— Epoxy composites, mica, tensile strength, tensile modulus, Flexural strength, Flexural Modulus, Compression strength

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## 1 INTRODUCTION

Epoxies are brittle in nature due to its cross linked structure and are costlier than some other thermosets. Hence reinforcing fillers serve dual purpose like modify some specific property and to reduce overall cost [1]. The reinforcing fillers modify the properties of the epoxy. Reinforcing fillers are known to improve wear resistance, thermal conductivity, tensile modulus, flexural modulus. The constituent characteristics such as type, size, shape density, strength and thermal conductivity dictate the composite properties. Filled epoxy polymer composites have many engineering applications such as electronic packaging [1], rapid tools [2], mechanical components such as gears, cams, wheels, bearings, bushes and clutches [3] . Mica is a mineral product having a sheet or plate like structure. It is a soft material with high electrical resistivity.

## 2 EXPERIMENTAL

### 2.1 Materials and Methods

Epoxy of type LY556 a RT cure is the matrix material. An amine hardener HY951 is the hardener. Both are procured from Huntsman India ltd and are mixed in the ratio 10:1. Mica particulates are procured from Indian Fine chemicals Mumbai. The sizes of mica particulate filler range from 75µm to 106µm.

### *2.2 Specimen Preparation*

The particulates and the resin were weighed in a precision balance. The particulate fillers were preheated to remove any moisture present in it. The fillers were varied from 10wt% to 40wt% in steps of 10%.The predetermined amounts of fillers were dispersed in epoxy resin, stirring continuously till the time of pouring. Before casting, the moulds were cleaned thoroughly and a gel coat was applied to the mould for easy removal of the specimens. Care was taken to avoid settling of particulates by continuous stirring. The resin particulate mix was poured into prepared moulds. The cast specimens were allowed to cure in the mould for 24 hours at room temperature. The room temperature cured specimens were removed from their respective moulds and were post cured for the following schedule $50^0$ C for 30 minutes, $70^0$ C for 60 minutes and $85^0$ C for 120 minutes. Density of the composite material was determined by water displacement method. Further density determined by experiment was compared with density predicted by rule of mixture. Test specimens and test methods for evaluating tensile flexural and compression properties were made as per ASTM D 638, ASTM D 790 and ASTM D 695 standards respectively. Test specimens and test methods for evaluating tensile flexural and compression properties were made as per ASTM D 638, ASTM D 790 and ASTM D 695 standards respectively.
Tensile strength is evaluated using the equation

Tensile strength St = P/b d…………………….. (1)
Where, $S_t$ = ultimate tensile strength (MPa),
P = maximum load (N)
b = width (mm) and
d = thickness (mm)

Young's modulus
$E_t = (\Delta P/\Delta L)*(L/b\ d)$…………………………… (2)
Where, $E_t$ = modulus of elasticity (G Pa)
$\Delta P / \Delta L$ = slope of plot of load as a function of deformation with in the linear portion
b = width (mm)
d = thickness (mm)

The flexural strength is evaluated using the equation
$S_f = 3PL / 2bh^2$ ……………………..……… (3)
Where, Sf = ultimate flexural strength (Mpa),
P = maximum load in Newton
L, b & h = length, width and thickness of the specimen in mm,

Flexural modulus is evaluated using the equation
$Ef = ml^3/ 4bh^3$ ……………………………….…… (4)
Where Ef = flexural modulus (GPa)

The compressive strength is evaluated using a formula
Sc = P/A………………………………………….. (5)

Where Sc = strength in compression,
P = Load,
A= area

### 2.3 THEORETICAL MODELS TO PREDICT TENSILE MODULUS

Following analytical equations are used to predict tensile modulus [4],[5].
***Reuss Equation***: The tensile modulus of a particulate filled polymer composite is given by the equation

$$Ec = \frac{EmEp}{Ep(1-Vp)+EmVp} \quad (6)$$

Where Ec = modulus of composite
Em = modulus of matrix
Ep = modulus of reinforcement
Vp = volume fraction of reinforcement

**Maxwell Equation**
The tensile modulus is given by the following equation

$$E = Ec\{1+1.5[\frac{(Ed-Ec)}{(Ed+2Ec)}]\phi\} \quad (7)$$

Where E= tensile modulus of the composite
Ec = Tensile modulus of epoxy
Ed = Tensile modulus of reinforcement
$\phi$ = Volume fraction of reinforcement

***Iso Stress Equation***:

$$\text{Ec} = \left[\frac{Vm}{Em}+\frac{Vp}{Ep}\right]^{-1} \quad (8)$$

Where Ec, Em and Ep are respectively modulus of composite, matrix and reinforcement
Vm = Volume fraction of matrix
Vp = Volume fraction of reinforcement

## 3 RESULTS AND DISCUSSIONS

The density of Mica-Epoxy composites is shown in figure 1. Density of neat epoxy was found to be 1.17 gms/cc. Density of mica filled epoxy composites increases with increased mica particulate fillers. 40% filled mica epoxy composites exhibit 1.52gms/cc. Further, the density predicted by rule of mixtures is in agreement with density found by experiment. Figure 2 presents the hardness of mica filled epoxy composites. Hardness decreases with increased mica particulate filling. This is due to layered structure of mica which makes them soft. The experimental values are summarized in table 1.
The variation of tensile strength of Mica-Ep composites for variation of mica from 10 to 40% is presented in figure 3. The unfilled epoxy exhibits a tensile strength of 39 MPa. Tensile strength reduces to 31.85MPa for 10% filled mica epoxy composite. Further tensile strength marginally reduces to 31.24MPa and strength remains at 30.77MPa and 30.28MPa for 30% and 40% filled mica epoxy composites. This can be attributed to low density of mica. For a given weight fraction, more particulates will be filled. Further at higher fraction of fillers, more mica particulate fillers have to be accommodated leading to less coverage of resin. This weakens the interfacial strength of matrix and filler. Further, inherent strength of mica particulate fillers are low due to its layered structure. Hence when they are combined with epoxy, composite strength decreases. Further fillers reinforced with brittle matrix acts as a stress raisers causing weakness in the structure [6]. Particle size higher than 80nm makes adhesion poor at the interface leading to poor strength of the composites [7], [8], [9]. Further filler concentration above 10% makes the stress transfer ineffective also the dispersed particulates in epoxy have

different moduli and poison's ratio from the resin, creates stress concentration and this magnifies the stress surrounding the particle leading to lowering of strength [10].Hence maximum degradation of strength was observed at 40wt% filler loading.

The tensile modulus of mica filled epoxy composite is shown in figure 4. Neat epoxy exhibits a tensile modulus of 2.52GPa. Tensile modulus increases gradually with increased mica filling. 40% filled mica exhibits maximum tensile modulus of 3.01GPa. Increased mica content increases the stiffness of the composite. Prediction of tensile modulus by Maxwell and Reuss is inline with experimental modulus up to 20% mica filling and deviates marginally for 30 and 40% mica filled epoxy composites where as iso strain equation predicts lower tensile modulus after 20% mica filling.

Figure 5 present the flexural strength of neat epoxy and mica epoxy composites. The flexural strength of neat epoxy was found to be 66.66MPa. Flexural strength decreases with an increase in mica content up to 20%. Further flexural strength increases to 60.16MPa for 30% filled mica and 64.89 MPa for 40% filled mica. Further, the addition of fillers creates the stress concentration at the interface of filler and matrix [11].

The flexural modulus of neat epoxy and epoxy composites filled with mica particulates is presented in figure 6. Neat epoxy exhibits a flexural modulus of 1.31GPa. Flexural modulus gradually increases with an increase in mica content. Increased mica content increases the stiffness of epoxy composites. It is also observed that once the filler content crosses 20% flexural modulus increases for all composites. Further, agglomeration of particulates at higher particulate loading reduces the flexural strength of filled polymer composites [12], [13].

The compression strength of epoxy and mica filled epoxy composites are shown in figure 7. Neat epoxy exhibits a compressive strength of 117MPa. Compressive strength decreases to 81.5 MPa for 10% mica filled epoxy. Increased mica content decreases the compressive strength of mica epoxy composites. Compressive strength remains constant at 90.51MPa and 90.32MPa for 20% and 30% mica filled epoxy composites. Compressive strength increases to 95.38MPa for 40% filled mica.

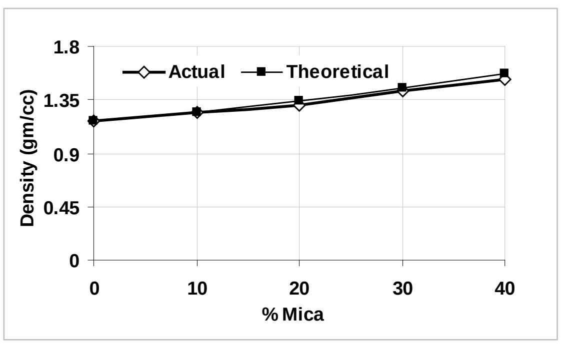
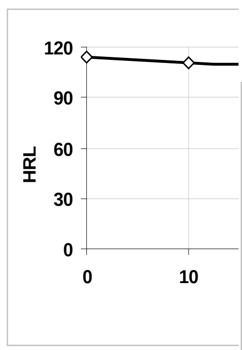



Fig 1 Density of mica-epoxy composites



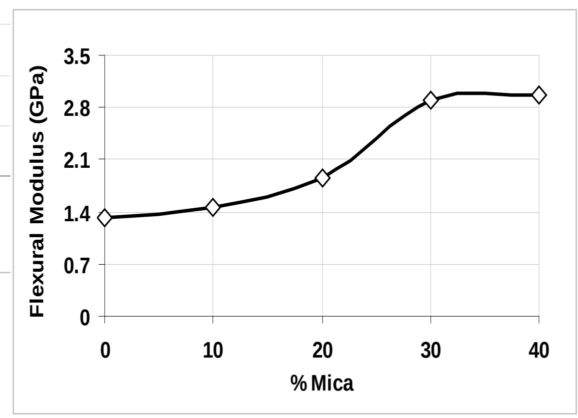




Fig 2 Hardness of mica-epoxy com

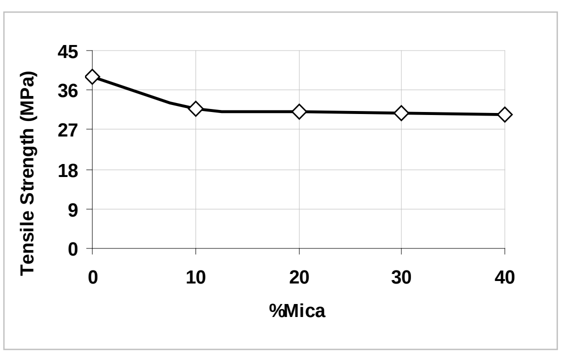



Fig 3 Tensile strength of mica filled -epoxy composites

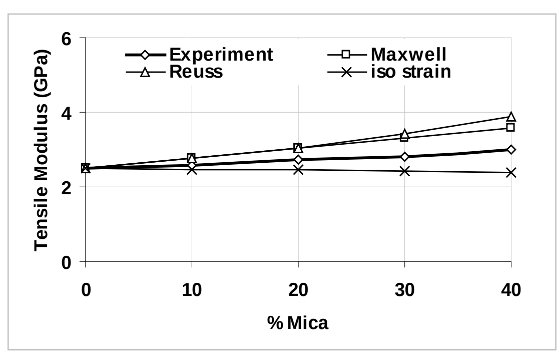


Fig 4 Tensile modulus of mica filled-epoxy composites

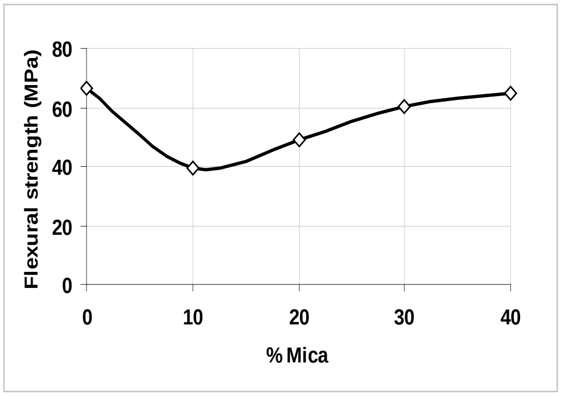



Fig 5: Flexural strength of mica-epoxy composites

Fig 6: Flexural modulus of mica-epoxy composites

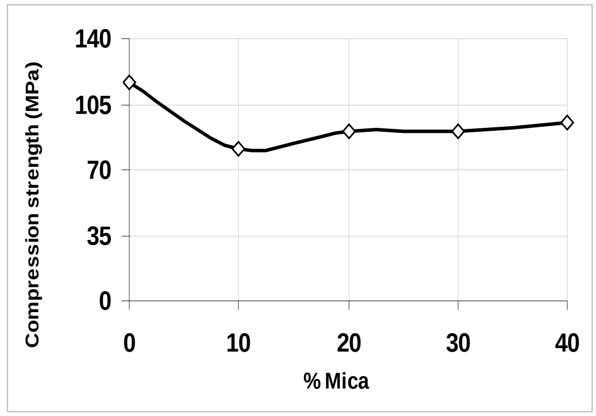



Fig 7: Compression strength of mica-epoxy composites

**Table 1Properties of Epxy-Mica composites**

| % Mica in Epoxy | 0 | 10 | 20 | 30 | 40 |
|---|---|---|---|---|---|
| Density-Experiment | 1.17 | 1.24 | 1.3 | 1.42 | 1.52 |
| Density-Prediction | 1.17 | 1.25 | 1.34 | 1.45 | 1.57 |
| Hardness-HRL | 114 | 111 | 107 | 92 | 81 |
| Tensile Strength (MPa) | 39 | 31.85 | 31.24 | 30.77 | 30.28 |
| Tensile Modulus(GPa)-Experiment | 2.52 | 2.56 | 2.75 | 2.82 | 3.01 |
| Tensile Modulus(GPa) Reuss | 2.52 | 2.76 | 3.05 | 3.41 | 3.87 |
| Tensile Modulus(GPa) Maxwell | 2.52 | 2.78 | 3.04 | 3.31 | 3.57 |
| Tensile Modulus(GPa)-Iso strain | 2.52 | 2.48 | 2.45 | 2.42 | 2.38 |
| Flexural Strength(MPa) | 66.66 | 39.45 | 49.17 | 60.16 | 64.89 |
| Flexural Modulus (GPa) | 1.33 | 1.46 | 1.86 | 2.89 | 2.96 |
| Compression Strength (MPa) | 117 | 81.5 | 90.51 | 90.32 | 95.38 |

## CONCLUSION

Following conclusions can be drawn from the above studies on mica filled epoxy composites.
Density of mica filled epoxy composites increases with an increase of mica fillers.
Hardness of mica epoxy composites decreases with an increase in mica fraction.
Tensile strength decreases with an increase in mica content, but remains almost same with 10%, 20%, 30% and 40% mica content.
Tensile modulus increase with increased mica fraction and the rise in modulus is not high.
Flexural strength decreases with increased mica fillers. However flexural modulus increases with increased mica fraction.

ISSN 2229-5518

Compression strength decreases marginally with increased mica fraction.

## ACKNOWLEDGMENT

The authors wish to thank the management of Don Bosco institute of technology and Raja Reddy institute of technology.

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