



MECHANICAL CHARACTERIZATION OF FLY ASH/ZINC OXIDE REINFORCED EPOXY COMPOSITES

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Abstract—

This paper deals with the study of adding various fillers on mechanical properties of neat epoxy resin. Two different types of fillers i.e. Fly ash and Zinc Oxide were selected. The effect of adding them in varying percentage on the mechanical properties was studied in details. Neat epoxy resin possesses high strength and toughness but are inherently brittle. This limits their applications in various areas. To improve this, neat epoxy resin was reinforced with Fly-ash (3%, 5%), Zinc Oxide (2%, 3%, 5%) and Fly ash/Zinc Oxide (1%ZnO 2%FA, 2%ZnO 1%FA, 4%ZnO 8%FA, 6%ZnO 6%FA). This resulted in improvement of Percentage in their Tensile strength and Flexural Strength of the epoxy composite compare to neat variety. This project highlights the potential of Fly-ash and Zinc Oxide as reinforcing fillers on property of neat epoxy. Composites were prepared by Hand-Lay-up Technique. Particles size of Fly-ash and Zinc Oxide were investigated through Microtrac S3500 SI Particle size analyser and Tensile and Flexural tests were done on Universal Testing Machine Instron 3369 followed by ASTM standard. The test shows the addition of Fly ash and Zinc Oxide upto 3% in Epoxy composites increases the Tensile and Flexural Stresses of the composite

Keywords— ZnO, FA , Microtrac

I. Introduction

Fly ash is a coal combustion by-product consisting primarily of aluminosilicates. It gives better performance at a lower cost. Its application areas include brick manufacturing, partial replacement of cement, in land filling and reclamation of land, as soil fertilizer, etc. Along with these,

extensive research is going on to utilize the fly ash as filler in polymer matrix composites. Fly-ash is obtained from coal fired thermal power plant Badarpur, New Delhi [1].

In consequence, fly ash is a heterogeneous material. SiO_2 , Al_2O_3 , Fe_2O_3 and

occasionally CaO are the main chemical components present in fly ashes. The mineralogy of fly ashes is very diverse. The main phases encountered are a glass phase, together with quartz, mullite and the iron oxides hematite, magnetite and/or maghemite. Other phases often identified are cristobalite, anhydrite, free lime, periclase, calcite, sylvite, halite, portlandite, rutile and anatase. The CA-bearing minerals anorthite, gehlenite, akermanite and various calcium silicates and calcium aluminates identical to those found in Portland cement can be identified in Ca-rich fly ashes. The mercury content can reach 1 ppm but is generally included in the range 0.01 - 1 ppm for bituminous coal [2].

II. LITERATURE SURVEY

Babu et al. (2016) have observed that the maximum tensile strength is found to be more for a composite having 5% fly-ash reinforced G.F.R.E composites. The natural frequencies and damping ratios are more for composite having 5% fly-ash reinforced GFRE composites (Glass fibre reinforced epoxy).

Suresha et al. (2015) have reported a continuous increase and marginal decrease in the tensile and flexural properties with

increasing fly-ash ceno concentration in epoxy composite. The tensile properties enhanced by the presence of silanated FA-Ceno particles because matrix fracture plays a greater role in deformation and fracture of the composite under tensile loading differing trends in abrasive wear volume were seen for unfilled and F-A ceno filled epoxy composites. They found 10wt% of FA ceno filler in epoxy shows good performance to the three body abrasive wear.

Raghavendra et al. (2013) have found that due to incorporations of the fly-ash fillers in to jute composite the tensile and flexural properties are increased. The 10% of fly-ash filler reinforced composites give almost 55% of the glass fibre composite strength.

III. METHODOLOGY

Particle size analysis of Fly ash and ZnO were carried out using Microtrac S3500 SI Particle size analyser apparatus by Bluewave software was shown in Fig. 3.1. The apparatus incorporate image analysis capability with long established laser diffraction technology.



Fig. 3.1 Microtrac S3500 SI Particle size analyser apparatus

Tri-laser particle size analyser now has the added advantage of being able to view the sample using state of the art camera technology and imaging Bluewave software. The sample is dispersed in Microtrac sample delivery controller and circulated through both the image analyser and Laser diffraction particle size analyser.

A. Process

The test process involves placing the test specimen in the testing machine and slowly extending it until it fractures. During this process, the elongation of the gauge section



Fig. 3.2 cutting of sample

C. Testing

Samples were cut from Epoxy fly-ash composite, Epoxy-Zinc Oxide composite and Epoxy-ZnO and fly-ash composite. Two tests were performed on these samples namely Tensile test and Flexural test. Universal Testing Machine Instron 3369 (Blue hill Software) was used to perform these tests.



is recorded against the applied force. The elongation measurement is used to calculate the engineering strain, ϵ . The machine does these calculations as the force increases, so that the data points can be graphed into a stress-strain curve.

B. Cutting of Sample

Samples were cut according to ASTM D638 standard with the help of grinder at the Star steel shop, Abul Fazal Enclave, Jamia Nagar, New Delhi and shown in figures. Figure 3.13 shows the cutting processes of samples.

Fig 3.14 & 3.15 show the test specimen dimensions for Tensile Test (150*13.5*3) and for Flexural test (65*13.5*3). All the tests were performed in Polymer Testing Laboratory, Department of Polymer Science & Chemical Technology., Delhi Technological University, Delhi.



Fig. 3.3 (A) Tensile Test Specimen Dimensions



(B) Flexural Test specimen

D. Flexural Test

The two most common types of flexure test are three point and four point flexure bending tests. A three point bend test consists of the sample placed horizontally upon two points and the force applied to the top of the sample through a single point so that the sample is bent in the shape of a “V”. A four point bend test is roughly the same except that instead of the force applied

through a single point on top it is applied through two points so that the sample experiences contact at four different points and is bent more in the shape of a “U”. The three point flexure test is ideal for the testing of a specific location of the sample, whereas the four point flexure test is more suitable towards the testing of a large section of sample, which highlights the defects of sample better than a 3-point bending test.



Fig. 3.17 and 3.18 shows 3- point Flexure test and 4- point Flexure test respectively.

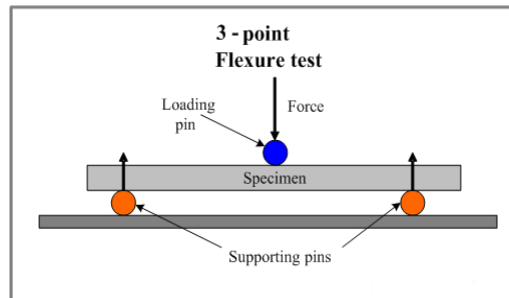


Fig. 3.4 Point Flexure test

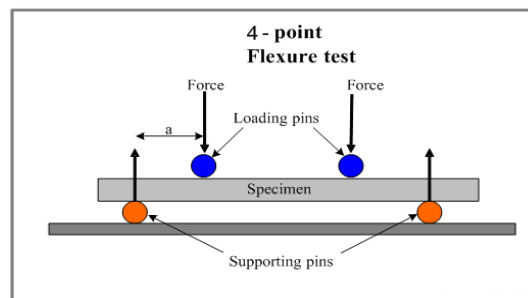


Fig. 3.18 4- point Flexure test

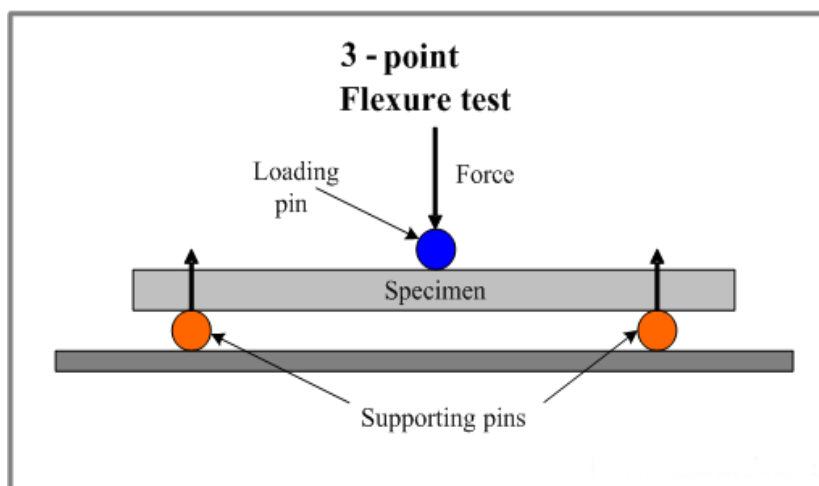
We had used 3-point loading test for flexural testing of the prepared composites. The three point bending flexural test provides values for the modulus of elasticity in bending, flexural stress, flexural strain and the flexural stress-strain response of the material. The main advantage of a three-point flexural test is the ease of the specimen preparation and testing. However, this

method has also some disadvantages: the results of the testing method are sensitive to specimen and loading geometry and strain rate.

The test method for conducting the test usually involves a specified test fixture on a universal testing machine. Details of the test preparation, conditioning, and conduct affect the test results.

iv. RESULT ANALYSIS

A. Tensile Test



The tensile test measurements were carried out for neat epoxy and ZnO/ FA reinforced composite and results are shown in

Table 4.1 Tensile Test Results

S. NO	ZnO %	FA %	Maximum Extension (mm)	Modulus (MPa)	Tensile Stress (MPa)	Maximum load (KN)
1	1	2	3.09	1039.17	11.1268	2.4788
2	2	1	8.85	1222.98	28.8637	3.7166
3	4	8	2.85	1096.2387	10.224	1.2777
4	6	6	1.5	1352.69	6.24	0.75056
5	5	-	3.249	788.925	8.975	0.86629
6	3	-	7.05	975.941	19.387	1.7601
7	2	-	4.34	1043.188	15.1558	1.72344
8	-	3	1.3	1005.025	1.27	0.2177
9	-	5	0.9	1303.84	0.91703	0.2996

10	Neat Epoxy	-	5.65	1035.851	16.8323	1.1547
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Fig. 4.1 shows the graph between tensile stress and maximum extension of ZnO/FA Reinforced composites. From Fig.4.1 it can be seen that composites which have 1%ZnO 2%FA, 2%ZnO 1%FA, 4%ZnO 8%FA,6%ZnO 6%FA,5%ZnO, 3%ZnO, 2%ZnO, 3%FA, 5%FA and Neat Epoxy composite having Tensile Stresses in MPa 11.1268, 28.8637, 10.224, 6.24, 8.975, 19.387, 15.1558, 1.27, 0.91703, and 16.8323 respectively and their maximum extensions in mm are 3.09, 8.85, 2.85, 1.5, 3.249, 7.05, 4.34, 1.3, 0.9 and 5.65 respectively.

Fig. 4.2 shows the graph between modulus and maximum extension of ZnO/FA Reinforced composites. From Fig.4.2 it can be seen that composites which have 1%ZnO 2%FA, 2%ZnO 1%FA, 4%ZnO 8%FA,6%ZnO 6%FA,5%ZnO, 3%ZnO, 2%ZnO, 3%FA, 5%FA and Neat Epoxy composite having Modulus in MPa 1039.17, 1222.98, 1096.2387, 1352.69, 788.925,

975.941, 1043.188, 1005.025,1303.84 and 1035.851 respectively and their maximum extensions in mm are 3.09, 8.85, 2.85, 1.5, 3.249, 7.05, 4.34, 1.3, 0.9 and 5.65 respectively.

It can be seen that tensile strength decreases with increasing fly ash content however modulus is increased. The decrease in Tensile stress was probably caused by an incompatibility of ash particles and the epoxy matrix, leading to poor interfacial bonding. The result also shows filling of ZnO more than 3% also reduces Tensile stress and Modulus of the composite. This could be due to cluster of fillers in the polymer matrix and non-uniformity in dispersion at higher concentration. The decrease in the value is due to the formation of chain entanglement in the ZnO/epoxy matrix due to an unequal distribution of nanoparticles into the epoxy resin.

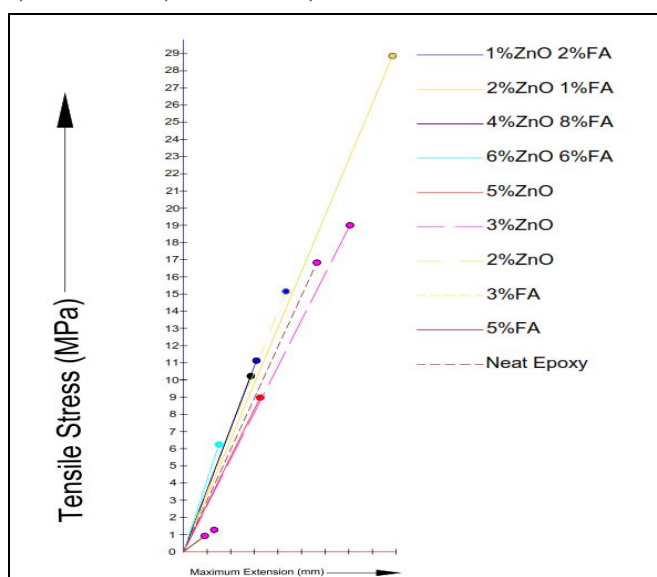


Fig. 4.1 Graph between tensile stress and maximum extension

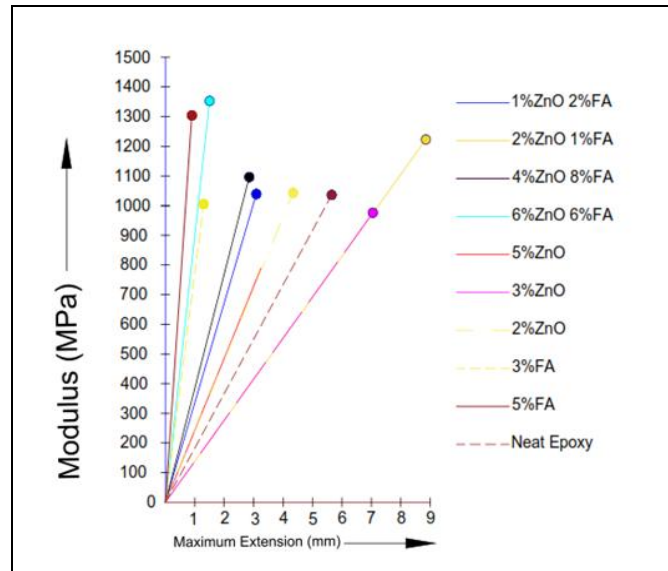


Fig.4.2 Graph between Modulus and maximum extension

Modulus of different ZnO/FA Reinforced composite is shown in chart 4.1 and it can be clearly seen that 6%ZnO 6%FA Reinforced Composite has maximum modulus

i.e.1352.69 MPa. It is due to proper dispersion of Fly ash and Zinc Oxide in epoxy composite and transformation of load on Fly ash and Zinc Oxide particle.

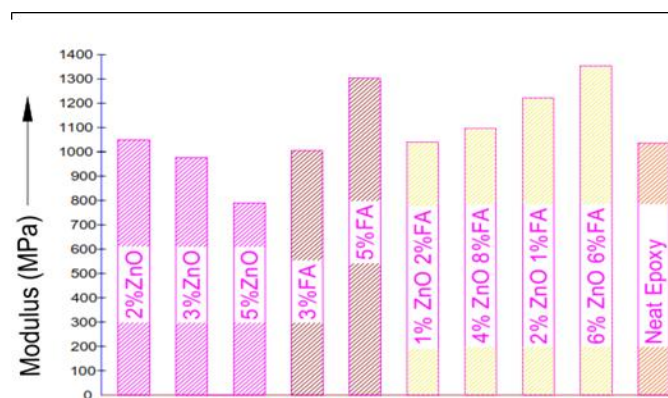


Chart 4.1 Effect of ZnO% & FA% on Modulus

Tensile stress of different ZnO/FA Reinforced composite is shown in chart 4.2 and it can be seen that 2%ZnO 1%FA has maximum Tensile Stress 28.8637 MPa. It is due to proper dispersion of Fly ash and Zinc

Oxide in epoxy composite and transformation of load on Fly ash and Zinc Oxide particle. Hence the matrix is able to withstand higher loads and therefore the Tensile strength increases.

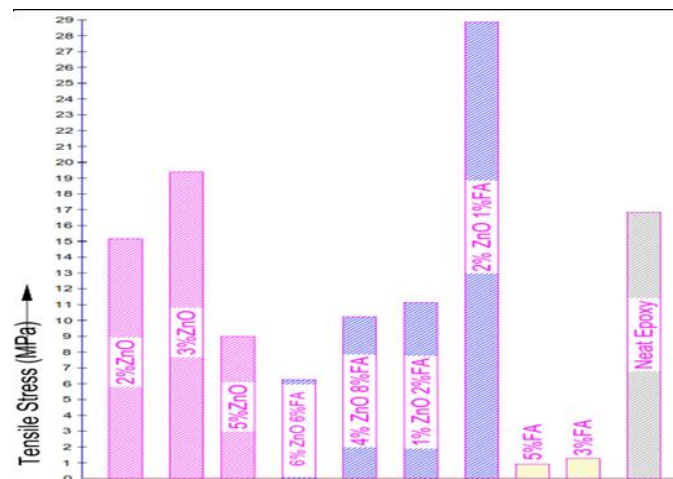


Chart 4.2 Effect of ZnO% & FA % on Tensile Stress

Maximum Extension of different ZnO/FA Reinforced composite is shown in chart 4.3 and it can be seen that 2%ZnO 1%FA Reinforced composite has maximum extension i.e. 8.85 mm during Tensile Test.

2%ZnO 1%FA shows good compatibility in epoxy resin and when acted upon stress tend to elongate before breaking and this increases the elongation of the composite.

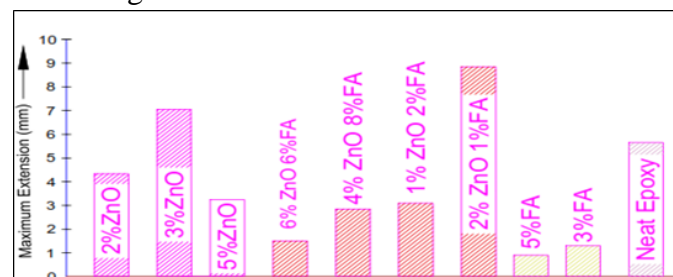


Chart 4.3 Effect of ZnO% & FA% on Max. Tensile Extension

The flexural test was carried out for neat epoxy and ZnO/FA reinforced composite .The results were shown in Table 4.2

B. Flexural Test

Table 4.2 Flexural Test Result

S. NO	ZnO %	FA %	Maximum Flexural Load (KN)	Flexural Stress (MPa)	Maximum Flexural Extension (mm)
1	1	2	0.1964	75.53	4.85
2	2	1	0.4594	127.6109	6.00
3	4	8	0.159	69.27	4.699
4	6	6	0.126	45.776	3.449

5	5	-	0.095	41.571	10.8
6	3	-	0.09628	80.8903	13.80
7	2	-	0.269	109.863	9.45
8	-	3	0.175	52.921	6.55
9	-	5	0.0407	37.387	4.55
10	Neat Epoxy	-	0.04717	64.7107	14.05

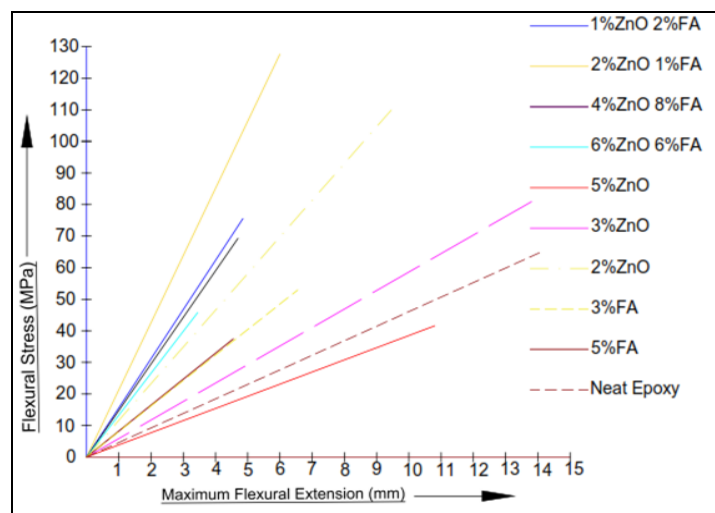


Fig 4.3 Graph Between Flexural Stress and Maximum Flexural Extension.

Fig. 4.3 shows the graph between Flexural stress and maximum Flexural extension of ZnO/FA Reinforced composites. From Fig.4.3 it can be seen that composites which have 1%ZnO 2%FA, 2%ZnO 1%FA, 4%ZnO 8%FA, 6%ZnO 6%FA, 5%ZnO, 3%ZnO, 2%ZnO, 3%FA, 5%FA and Neat Epoxy composite having Flexural stress in MPa 75.53, 127.6109, 69.27, 45.776, 41.571, 80.8903, 109.863, 52.921, 37.387 and 64.7107 respectively and their maximum flexural extensions in mm are 4.85, 6.00, 4.699, 3.449, 10.8, 13.80, 9.45, 6.55, 4.55 and 14.05 respectively.

The result shows the inclusion of fly ash reduces the flexural strength of composite. There can be two reasons for this decline in the strength property. One possibility is that the chemical reaction at the interface between the filler particles and matrix may be too weak to transfer the Flexural stresses. The other is that the corner points of the irregular shaped particulates result in stress concentration in the epoxy matrix. The compatibility of fly ash particles in epoxy matrix seems to be not good and as a result of which the percentage reduction in Flexural strength is highest. The result also shows filling of ZnO more than 3% also reduces Flexural stress and of the composite.

This could be due to cluster of fillers in the polymer matrix and non-uniformity in dispersion at higher concentration. The decrease in the value is due to the formation of chain entanglement in the ZnO/epoxy matrix due to an unequal distribution of nanoparticles into the epoxy resin.

Fig 4.3 Graph Between Flexural Stress and Maximum Flexural Extension

Chart 4.4 shows Flexural stress of Neat Epoxy and different ZnO/FA Reinforced composite. 2%ZnO 1%FA has maximum Flexural stress i.e. 127.6109 MPa. It is due to proper mixing of fillers in epoxy resin and in result of which load is transferred throughout the whole composite thus increasing Flexural strength.

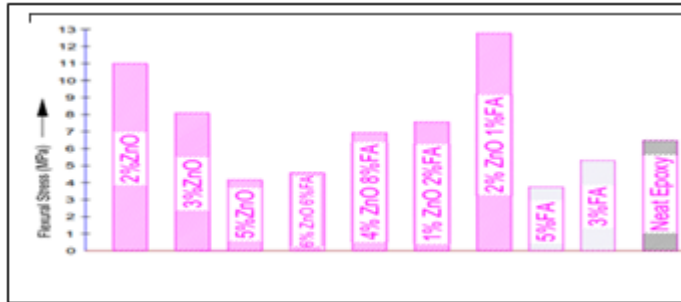
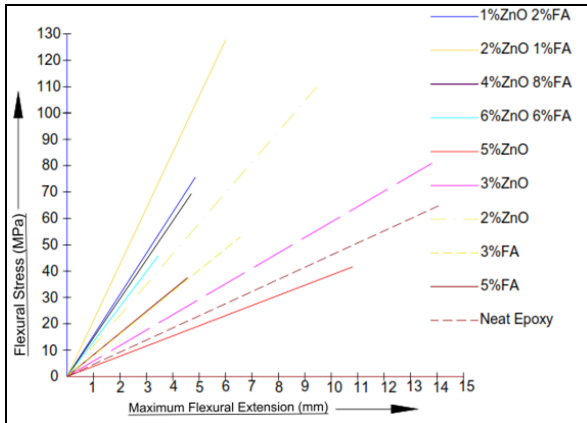


Chart 4.4 Effect of ZnO% & FA% on Flexural Stress

Chart 4.5 shows Maximum Flexural Extension of Neat Epoxy and different ZnO/FA Reinforced composite. 3%ZnO reinforced composite shows maximum Flexural Extension i.e. 13.8 mm. It is due to

3% ZnO shows good compatibility in epoxy resin therefore increasing plasticity of composite hence Flexural extension maximized.

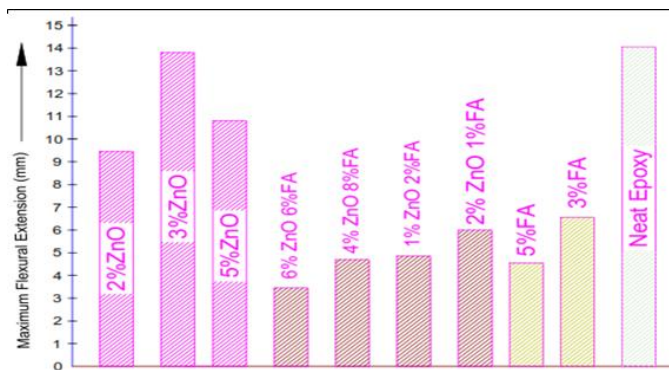


Chart 4.4 Effect of ZnO% & FA% on Max. Flexural Stress

V. CONCLUSION

From the investigation carried out in this project, following conclusions are made:

- ❖ With the addition of fly-ash in epoxy resin fly ash composite the Modulus increases however Tensile stress decreases. Flexural Stress also decreases with the addition of fly ash.
- ❖ Modulus decreases with the addition of ZnO in ZnO reinforced composite and Tensile stress increases upto 3% of ZnO in ZnO epoxy composite, later decreases. Flexural Stress decreases with the increment of ZnO.
- ❖ With the addition of ZnO and decrement of Fly-ash in ZnO/Fly-ash reinforced composite, Tensile stress, Modulus and Flexural Stress increases.
- ❖ 2%ZnO 1%Fly-ash, reinforced epoxy composite shows good improvement in Modulus, Flexural Stress and Tensile Stress.

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