# Characterization and Studies of Mechanical Properties of Fly ash/Nano clay Epoxy Resin Polymer Composites

Komal kumar B. N[1], Prajwal G[1], Prateek J. P[1], Karthik J[1] and Revanasiddappa M[2*]
[1]Department of Mechanical Engineering, PES Institute of Technology Bangalore South Campus, Bangalore-560100, Karnataka, India
[1]Email:komal11597kumar@gmail.com
[2]Department of Engineering Chemistry, PES Institute of Technology Bangalore South Campus, Bangalore-560100, Karnataka, India
[2*]Email: revanasiddappam@pes.edu

**Abstract:** Material science has been a booming field of mechanical engineering. The search for advanced composites has led to the discovery of new composites. Composites are made from two or more constituent materials having different physical and chemical properties, which when blended together exhibit a totally different properties than their individual properties. This has helped us to develop innumerable composites with desired properties because the mechanical properties of composites is due to the combined effects of matrix, reinforcement, hardener and solvents (if any) used. This paper highlights the experimental investigation on effect of fly ash concentration on ultimate tensile strength and cross breaking strength of fly ash/nano clay reinforced epoxy composite. Investigation was performed by varying the concentration of fly ash (by weight percent) keeping the concentration of nano clay constant in the epoxy matrix. The hardener used was HY951 which is hydrophilic in nature. The particles of nano clay being in the order of nanoscale adds to the enhancement of mechanical properties. It was observed that the mechanical properties enhanced for higher concentration of fly ash while decreased for lower concentration, keeping pure epoxy composite as the reference. Further characterization of the polymer composite was done by studying the morphological characteristics using the SEM, FT-IR, XRD reports.

**Keywords**: Fly ash; nano clay; epoxy; SEM; FT-IR; XRD.

## Introduction

With the advent of new technology, there is a need for materials with higher strength and light weight to replace the existing materials in industries [1-5]. The literature survey reveals that particulate composites are more efficient than the fiber reinforced composites. It is the size of the particle that makes them gain higher efficiency. One of the particulate material used in the research work was fly ash (RTR01). Fly ash is one of the residue generated from thermal power stations composed of fine particles driven out of the boiler with flue gases. Disposal of fly ash has been an alarming issue from past few decades because fly ash is hazardous to environment as well as to human health. Therefore the following research work has been carried out for utilizing fly ash in much efficient way than disposing it off. Fly ash particles are generally spherical whose size varies from 0.5 microns to 300 microns. This property make them suitable to be used as reinforcement material in polymer nano composites

Nano clay is a nanoparticle composed of several layers of mineral silicates. Montmorillonite is the most commonly used nano clay. It consists of 1 nm thick aluminosilicate layers surface-substituted with metal cations and stacked in 10 μm-sized multilayer stacks. This nanoscale structure imparts desired properties to the composite. Because of its small size, the particles tend to agglomerate in the matrix thus enhancing the mechanical properties.

A variety of matrices can be used depending on the applications of the composite. Most commonly used matrices are poly propylene, poly vinyl chloride, polyurethane, poly-ether-ether ketone, poly phenylene sulfide, poly ester epoxies, etc. The primary function of a matrix is to transfer stress between reinforcing fibers or particles and to protect them from mechanical and environmental damage [6-9]. The following research work was carried out using epoxy LY556 as matrix. Epoxies are widely used as metal coatings, electronic/electrical component, electrical insulations and also as structural adhesives. Epoxy resins are more advantageous as they have lower shrinkage during curing and higher strength and flexibility.

The hardener (HY951) used has low viscosity and helps curing of epoxy resin at room temperature. It undergoes exothermic reaction with the resin releasing heat. These hardeners being hydrophilic in nature tend to get contaminated on exposure to atmospheric moisture hence, they are stored in a dry place at room temperature in air-tight containers.

## Material and methods

The composite prepared was a particulate matrix composite. Fly ash RTR01 and nano clay were selected as the reinforcement and epoxy LY556 as the matrix. A mold of dimension 180mmX150mmX3mm made of mild steel was used. The reinforcements were sieved and the particles with size within 150 micron were collected. The fly ash/nano clay hybrid composites were prepared by varying fly ash in terms of weight percentage 15%, 20%, 30%. Initially a pure epoxy composite was prepared which was used as reference. According to the calculations performed the weight of epoxy, hardener, and nano clay was fixed to 80g, 20g, and 2g respectively. The reinforcements, matrix and the hardener were mixed thoroughly in a beaker and stirred continuously in magnetic stirrer. Acetone was slightly added for dissolving the reinforcements. The prepared mixture was poured into the wax coated mold cavity and was allowed to cure under room temperature for three days. Thus, fabrication of composites was completed.

The composites were taken out of the mold and specimens of suitable dimensions were cut using diamond tip cutter and other tools available in the workshop as shown in the fig. (1-5). The specimens were prepared according to Indian standards IS: 1998-1962 (RA 2003) Clause 6, 5 for testing the ultimate tensile strength and cross breaking strength. The edges of the specimen was filed for finishing and the mechanical properties were tested on a Universal Testing Machine (UTM)

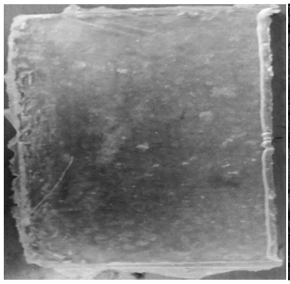
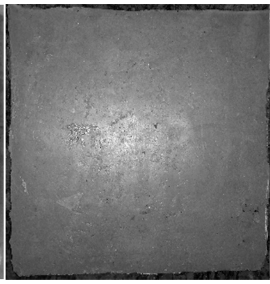
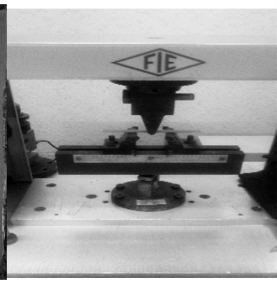
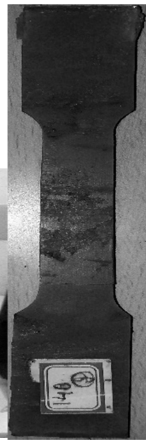





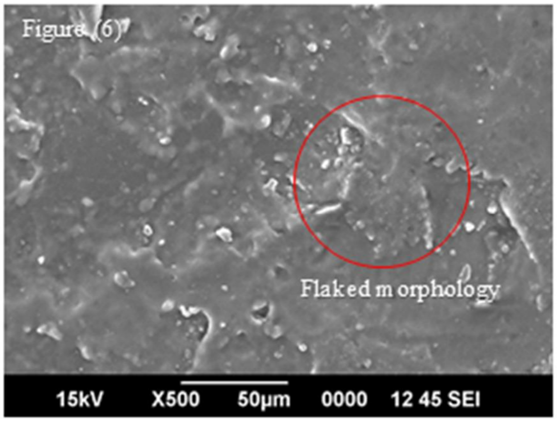

Fig (1) Fig (2) Fig (3) Fig (4) Fig (5)

Fig (1): Pure epoxy composite
Fig (2): Flyash/nanoclay reinforced composite
Fig (3): Universal testing machine
Fig (4): Tensile test specimen
Fig (5): Cross breaking strength test specimen

## Results and discussion

### SEM

The following images represent the morphological analysis of the composites synthesized and the reinforcement material used, done with the help of scanning electron microscope. Figure (6) represents the SEM image of pure epoxy composite at lower resolution(X500). The image reveals the flaked heterogeneous morphology of the surface. The heterogeneous morphology is caused due to reaction induced phase separation. Figure (7) represents the SEM image of pure epoxy composite at higher resolution(X6000). A few lump-like particles are observed which are formed due to bursting of minute air bubbles during processing. Figure (8) and (9) represent the SEM image of the fly ash/nano clay epoxy composite with 30% fly ash. Figure (9) which is at lower resolution(X500) reveals the flaked heterogeneous surface morphology similar to that the pure epoxy composite. At higher resolution(X1500) the image reveals the homogeneous mixture of the constituent particles. The cenosphere observed confirms the presence of fly ash particle. The lumped structures represent the nano clay particles formed due to agglomeration of these nanoscale particles. The image also provides a clear picture of the epoxy matrix.



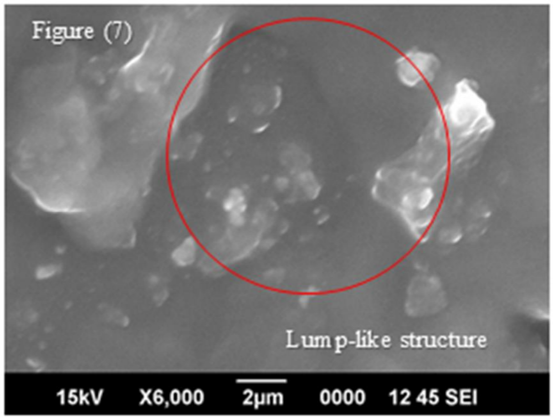
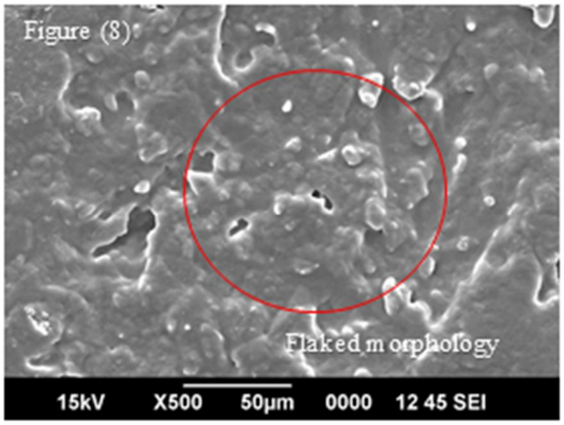




Figure (6): SEM of pure epoxy composite(X500)

Figure (7): SEM of pure epoxy composite(X6000)



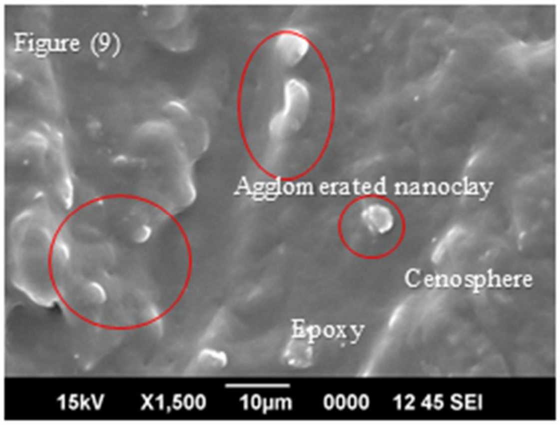
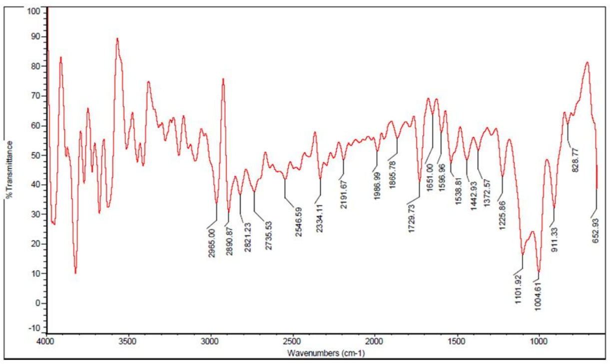




Figure (8): SEM of 30% flyash composite(X500)

Figure (9): SEM of 30% flyash composite(X1500)

**FT-IR**

Figure (10), (11) represent the IR spectra of pure epoxy composite and fly ash/nano clay reinforced (30% fly ash) epoxy composite respectively. In case of pure epoxy composite the characteristic stretching frequency was found at 2965, 1729, 828 $cm^{-1}$ for C-H, C-O-C, and C-O-O respectively. With the addition of fly ash and nano clay there is a small shift in characteristic stretching frequencies to 2900, 1726 $cm^{-1}$ for C-H, C-O-C respectively. There is a negligible shift for C-O-O linkage seen as a small shoulder in the IR spectra. This is due to increased concentration of fly ash and agglomeration of nano clay thus accounting for the increase in tensile strength and cross breaking strength. The peak found at 1083$cm^{-1}$ in fly ash IR spectra (fig (12-13)) is slightly shifted to 1083.5$cm^{-1}$ indicating the possibility of forming M-M or M=O bonds



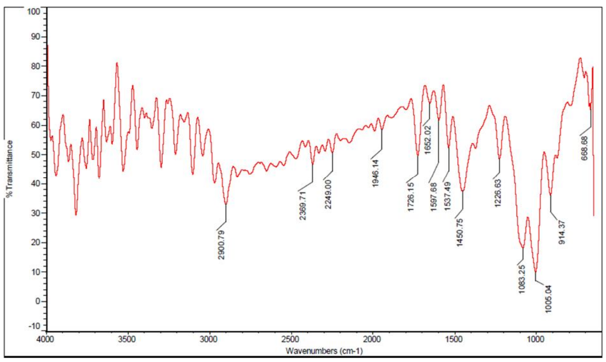
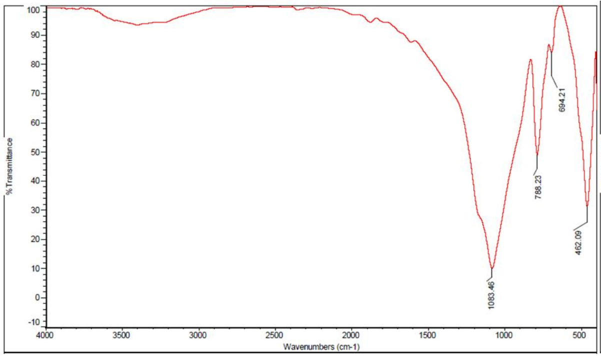




Figure (10): IR spectra of pure epoxy composite

Figure (11): IR spectra of reinforced composite



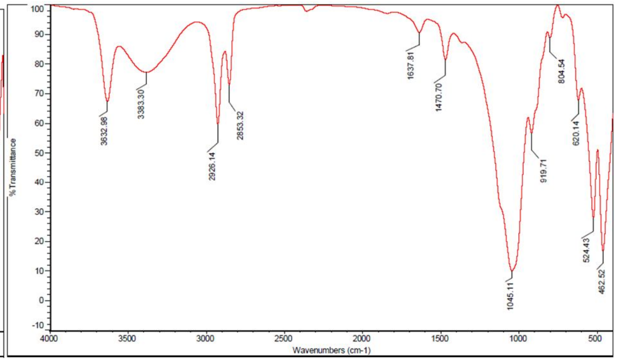




Figure (12): IR spectra of fly ash RTR01 Figure (13): IR spectra of nano clay

**XRD**

Figure. (14 and 15) Reveals the diffraction patterns of fly ash/nano clay, epoxy and nanocomposites. It is possible to identify the peak that corresponds to the basal spacing of fly ash / nano clay, which is located near 4.5°. The careful analysis of the spectra of nanocomposites and performing a comparison with the spectrum of pure epoxy resin, an increase in basal spacing is clearly visible, but without the presence of peaks, indicating that the particles are intercalated into the resin. There was a reduction in the amorphous peak similar to that observed in the 30 wt. % of fly ash / nano clay composite polymer X-ray patterns. There is a slight intensity shoulder at about 6º, more pronounced in 30 wt%, which may suggest the presence of some aggregates of fly ash / nano clays within the matrix, as seen in the SEM photographs. Figure (16), indicates the same peak pattern as in the pure epoxy polymer. Nevertheless, there was a slight shift in peak position relative to the neat polymer peak patterns, an indication of structural change in the polymer network. Figure (17) represents the XRD patterns of the fly ash. The diffraction pattern of the fly ash is characterized by a broad peak observed at 2θ value at 15-30$^0$. Minor crystalline phases such as quartz, mullite and hematite may also be observed. This amorphous nature of fly ash is slightly shifted towards higher angle at 2θ value at 30$^0$ clearly indicates the formation of an alkaline aluminosilicate. On observing the XRD pattern of reinforced composite there was a shift in peaks of fly ash which supports the IR spectra and the mechanical properties studied. At higher concentration, fly ash has been dispersed homogeneously undergo physisorption are responsible for the above pattern and enhanced mechanical properties.

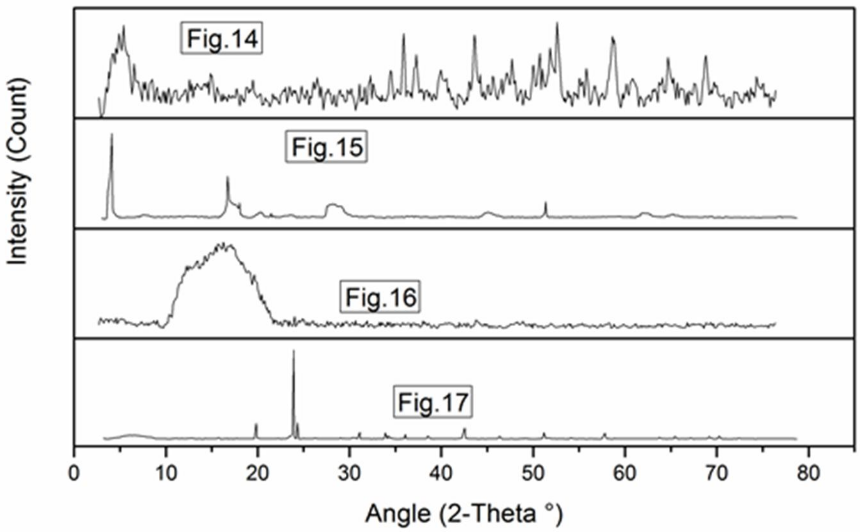



Figure (14): XRD spectra of 30% Flyash composite Figure (15): XRD spectra of pure nano clay
Figure (16): XRD spectra of pure epoxy Figure (17): XRD spectra of pure fly ash

**Mechanical properties**

Fig (18) shows the variation of ultimate tensile strength with concentration of fly ash. The ultimate tensile strength of the pure epoxy sample was higher compared to other sample containing varied amount of fly ash. The 15% fly ash reinforced composite shows 37.18% decrease in tensile strength with respect to pure epoxy composite. While the 20% and 30% fly ash reinforced composites show 39.93% and 25.82% decrease in tensile strength respectively with respect to pure epoxy composite. It is also observed that the tensile strength has increased by 19% when amount of fly ash is increased from 20% to 30%. Thus, it can be concluded that the tensile strength of the fly ash reinforced epoxy composite decreases for fly ash amount up to 20% and increases with the further increase in amount of fly ash. At lower concentration of fly ash (below 15%) separation of layers was observed whereas at higher concentration of fly ash, particles were distributed homogeneously accounting for increased tensile strength values were recorded in table.1.

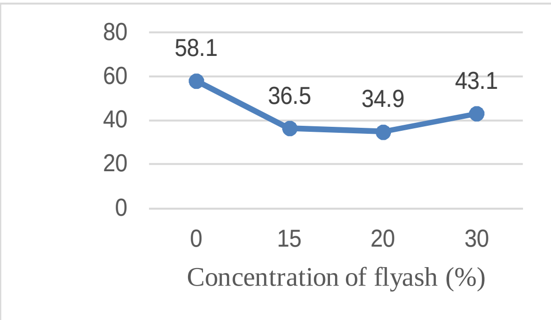
Fig (19) reveals the variation of cross breaking strength with concentration of fly ash. Similar observations were made here as well. The cross breaking strength of the pure epoxy sample was greater than the other samples with varying amount of fly ash. The 15% fly ash reinforced composite shows 38.53% decrease in cross breaking strength, while the 20% and 30% fly ash reinforced composites show 34.12% and 17.85% decrease in cross breaking strength respectively. It is also observed that the 20% and the 30%fly ash composites show 7.04% and 33.63% increase in cross breaking strength with respect to 15% fly ash reinforced composite. Thus, it can be concluded that the cross breaking strength decreases up to 15% fly ash and increases further with the increase in percentage of fly ash. Homogeneous distribution of fly ash at higher concentration (above 20%) and agglomeration of nano clay particles accounts for the increase in cross breaking strength values were tabulated in table.2.

Tab 1: Variation of tensile strength with amount of fly ash

| Amount of fly ash (%) | Tensile strength (MPa) |
|---|---|
| 0(pure epoxy) | 58.1 |
| 15 | 36.5 |
| 20 | 34.9 |
| 30 | 43.1 |

Tab 2: Variation of cross breaking strength with amount of fly ash

| Amount of fly ash (%) | Cross breaking strength (MPa) |
|---|---|
| 0(pure epoxy) | 92.4 |
| 15 | 56.8 |
| 20 | 60.8 |
| 30 | 75.9 |



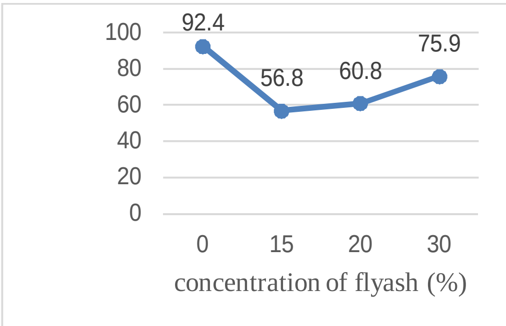




Figure (18): Variation of tensile strength with flyash flyash

Figure (19): Variation of cross-breaking strength with

## Conclusion

From the above invstigations it can be concluded that higher concentration of fly ash imparts enhanced mechanical properties to the composite. It is the size of these particles responsible for special characteristics. When we look at future of composites, the advanced composite market is expected to rise at a healthy rate. The aerospace market for composite materials is anticipated to grow at elevated rates in comparison to years past. As time progresses, these lighter weight, incredibly strong materials will dominate the materials used in almost any given industry With increased demand for these specialty materials, prices will be forced down, and the technology to make these advanced materials will become more readily available.These epoxy polymer composites can be used in real time technological applications.

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