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Recycling of Coal Power Fly Ash Mineral Particulate to Modify Microhardness and Tensile properties of Epoxy Polymer

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Abstract— *This project aims to convertas receivedfly ash from coal power station, as a recycled, superior and cheap materialas filler in epoxy matrix used to make carbon fibre reinforced composites in structural and infrastructural applications. Epoxy resin has excellent adhesion to other materials, has chemical and heat resistance and alsogood to excellent mechanical properties, with very good electrical insulation. Diglycidal ether of bisphenol A- (DGEBA)is the chosen resin and cycloaliphatic polyamine is the chosen hardener.*

Tensile specimens were cured at 120 C°for2 hours. The fly ash class F has been used was supplied by Cement Australia, Brisbane.The fly ash was added to the epoxy as0, 10, 20, 30, 40 & 50 wt% proportion, using hand mixing then poured carefully into silicone rubber mould with tensile dog-bone shape cavity inside.

A 60 % increase in yield strength was observed with 10 % FA addition. This fits with some models of particle inclusion in matrix materials.

Vickers micro-hardness studies undertaken at 300 g, 500 g and 1000 g loads and it was seen that indicated that the microhardness was superior at 300 gm load. As microhardness results; 30 wt% and 50 wt% fly ash-epoxy noted some increase in microhardness with fly ash addition.

Keywords— Flyash-polymer composites, Polymer Matrix Composites (PMCs), resin,DiglycidalEther of Bisphenol A –DGEBA.

I. INTRODUCTION

Fly ash (FA): is awaste-by-product produced in large quantities in coal thermal power stations. Fly ash has good to excellent properties that can be used in various applications such as reinforcement in cement concrete, flowable fill, fly ash bricks / tiles, structural fill/ embankment road base/ sub-base, roofing tiles, paints, mineral fill, blasting grit, mining applications, gypsum panel products, waste stabilization, agriculture, aggregate, and as filler in wood and plastic products [1, 2, 3]. Fly ash isvery cheap, light weight, abundantly available as waste material and equivalent or superior to other virgin material [1, 2],

Epoxy resin: is widely used as thermoset plastic in polymer matrix composites (PMC) [4]. It is a thermoset polymer formed from two materials combined together by mixing and thethen chemical reaction during curing [4]. Epoxy resins have excellent adhesion to other materials, chemical and heat resistance, good to excellent mechanical properties [4-7], and very good electrical insulating properties [4-7].Epoxy resin finds wide range of applications because of its splendid properties in fibres, optoelectronics, dentistry, industrial tooling applications and electronics. Epoxies can be used for repairing (adhesive), pottery, glass, wood, metal, and leather objects [5-7], as repair material for marine applications, in jewellerymaking, and paints and coatings [5, 7, 8, 9].

Epoxy-fly ash composites:

Fly ash has been mixed with the epoxy resin to invent light-weight material [4] with low cost [10], as well as, to enhance the matrix properties [10, 11, and 12].

Aims/objectives:

To study the effect of different weight percentages of the fly ash particles on the strength of the polymer composites and to study the micro-mechanical properties of the composites. The epoxy resin used is Diglycidal ether of bisphenol A - (DGEBA) which has base of formulated bisphenolA, the hardener used is cycloaliphatic polyamine. Barnes, NSW, AUSTRALIA, supplied the two parts of the epoxy. The epoxy liquid has clear colour and low viscosity (500-1000 mPa.s at 25°C). The hardener's viscosity is 100-300 mPa.s at 25 °C. The two parts were mixed by100:50 parts (by volume).

Fly ash

The used fly ash has been collected from Cement Australia Brisbane, Tarong power plant Queensland. Australia

Composite fabrication:

Five samples of each five composites were fabricated. The resin and hardener were made mixed in 100:50 parts (by volume),

The fly ash-epoxy composites were made by adding fly ash to the epoxy by weight percentages of 0%, 10%, 20%, 30%, 40%, and 50% respectively, and with a slow motion mixing the content with a rod to avoid entraps the air bubbles inside the mixture.

Casting the composites:

As shown in Fig.1;ASTM D 638 type 1 specimen has been casted in silicon rubber mould with dog bone shape cavity inside.The dough was poured into mould cavity till it is filled and levelled.

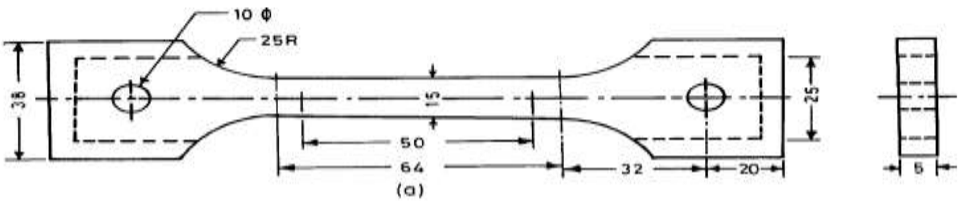

Fig.1: ASTM D638 Type 1 tensile specimen

Curingthe composites:

Curing of the composites was done at 120ºC/2 hours in theoven, then cooling down the samples and the mould inside the oven to room temperatureto move them out of the oven.The last step was to take the samples out of the mould to clean later to be ready for testing. At this stage; five tensile specimens were prepared for each of the threecompositions and ready to be tested.

II. MATERIAL CHARACTERIZATION

Vickers Microhardness Measurement (HV):

The microhardness was measured with the micro indentation device at UNSW; model numberDuramin – A300 made by EMCO TEST Company. The size of the indent is locked between the two parallel lines. The device measures the area covered and calculates the microhardness. The unit of hardness is HV.

It is important to polish the samples to mirror finish for Micro-hardness tests. The samples were held perpendicularly against the polishing paper to avoid formation of double surface. At the same time, all cautions were taken to avoid contamination during the polishing. Eventually, smooth and shiny polymer composites samples were prepared.

The loads applied on the samples were 300, 500, and 1000g respectively. Any load smaller than 300g was not able to produce a usable indent, and larger than 1000g was very large indent going beyond the microscope measurement limits.

Figure 2 shows optical image of typical micro indentation for 40% fly ash, and Figure 3 shows optical image of microindintaion for 50% fly ash.

The results are presented in Table 1, microhardness indentation under optical microscope can be shown in figs 2 & 3 and the microhardness graphs for the various composites samples under various loads and also under individual loads are shown in Figures 4 – 13. In general, the microhardness values are the highest at 300g, and lowest at 1000g.

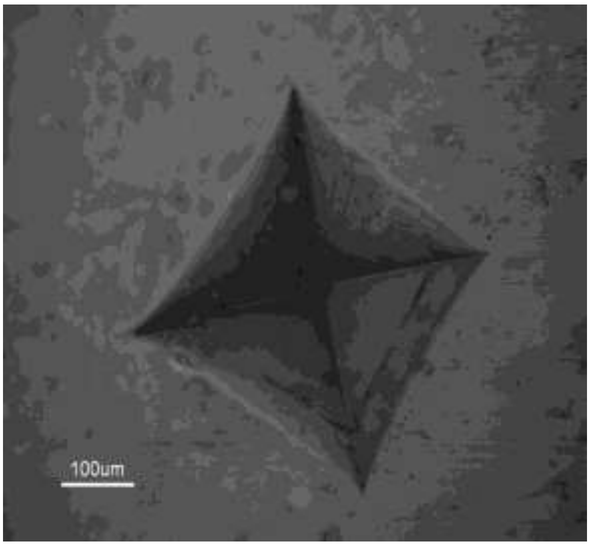

Fig.2: Optical pictures of microindentation for 40 % fly ash

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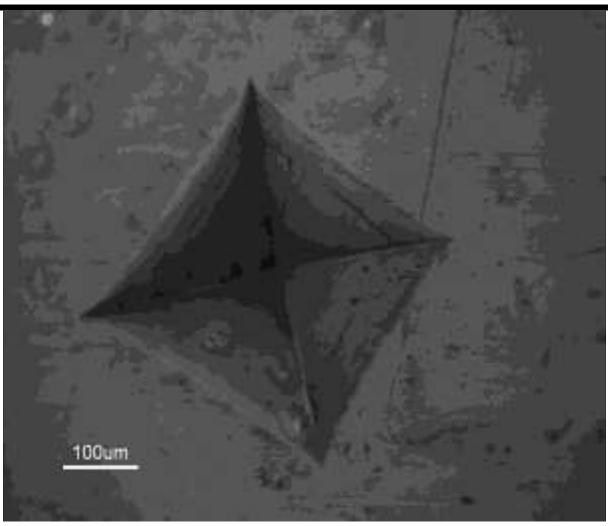

Fig.3: Optical pictures of microindentation for 50 % fly ash

Table.1: Fly ash percentage and the micro-hardness values using standard formula

Wt% of Fly Ash-Epoxy	Load applied (g)	Microhardness (HV), Average of 5 readings	Standard deviation
0 (fig 4)	300	18.38	±2.58
	500	15.5	±1.28
	1000	15.44	±0.71
10 (fig 5)	300	17.82	±1.54
	500	15.216	±0.53
	1000	14.06	±1.77
20 (fig 6)	300	16.56	±2.45
	500	13.42	±2.50
	1000	12.14	±1.63
30 (fig 7)	300	16.3	±0.43
	500	16.46	±1.37
	1000	15.08	±0.19
40 (fig 8)	300	18.86	±0.50
	500	15.62	±0.65
	1000	15.02	±0.80
50 (fig 9)	300	16.82	±1.01
	500	16.38	±0.75
	1000	14.84	±0.50

Graphs of Vickers Microhardness (HV) measurements

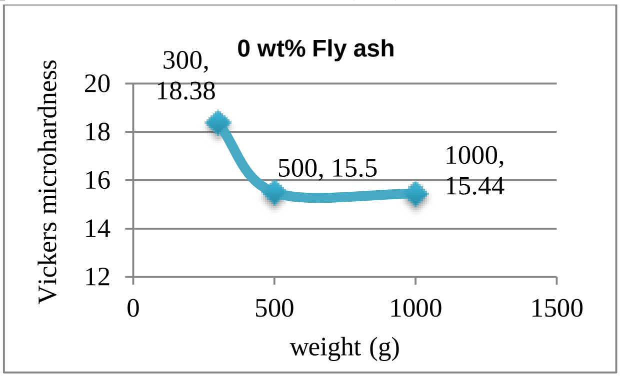

Fig (4)

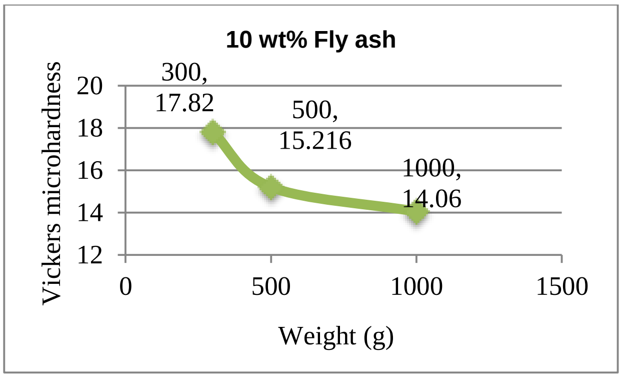

Fig (5)

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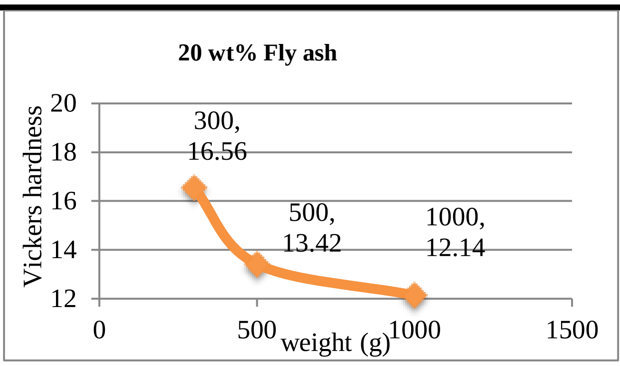
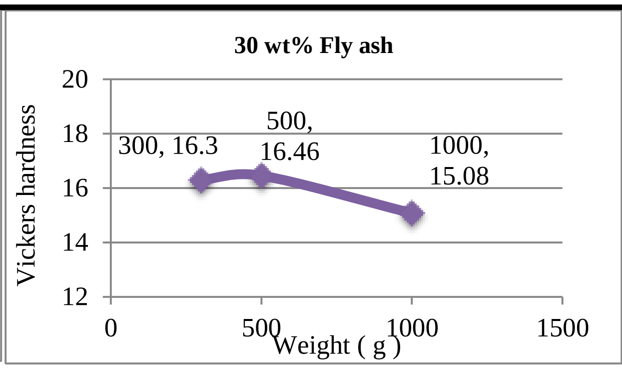


Fig (6)



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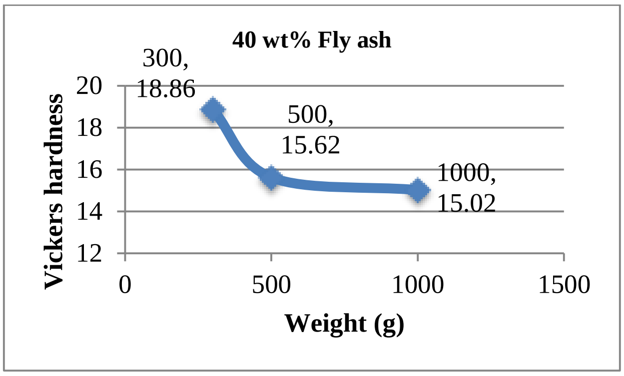

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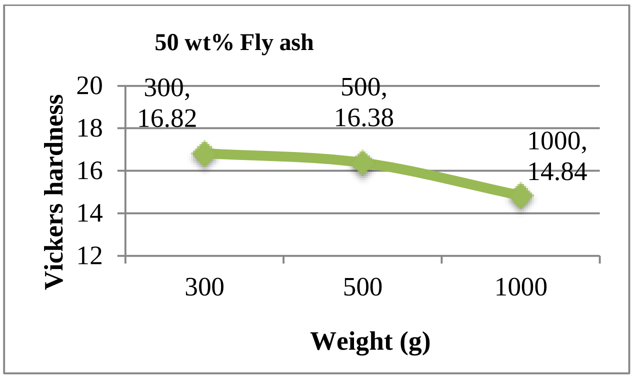

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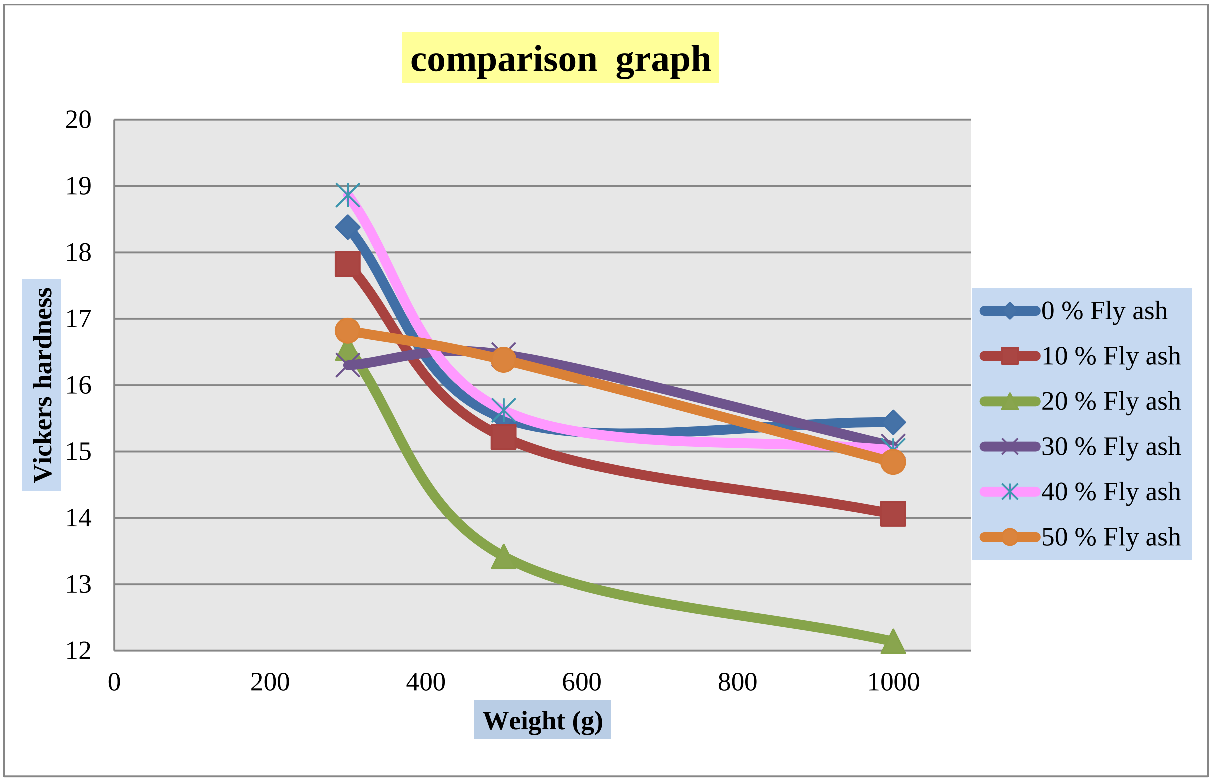

Fig.10: Vickers Microhardness 0wt%, 10 wt%, 20 wt%, 30 wt%, 40 wt%, and 50 wt% Fly ash in the composites under loads of 300 g, 500 g and 1000 g

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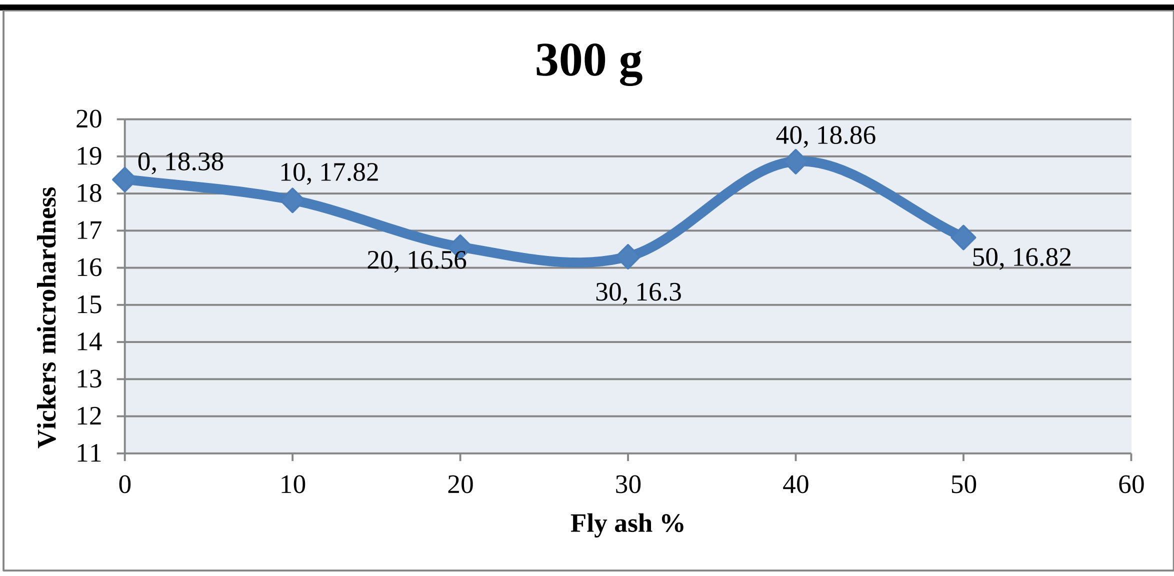

Fig.11: Fly ash wt% vs Vickers microhardness under load 300 g

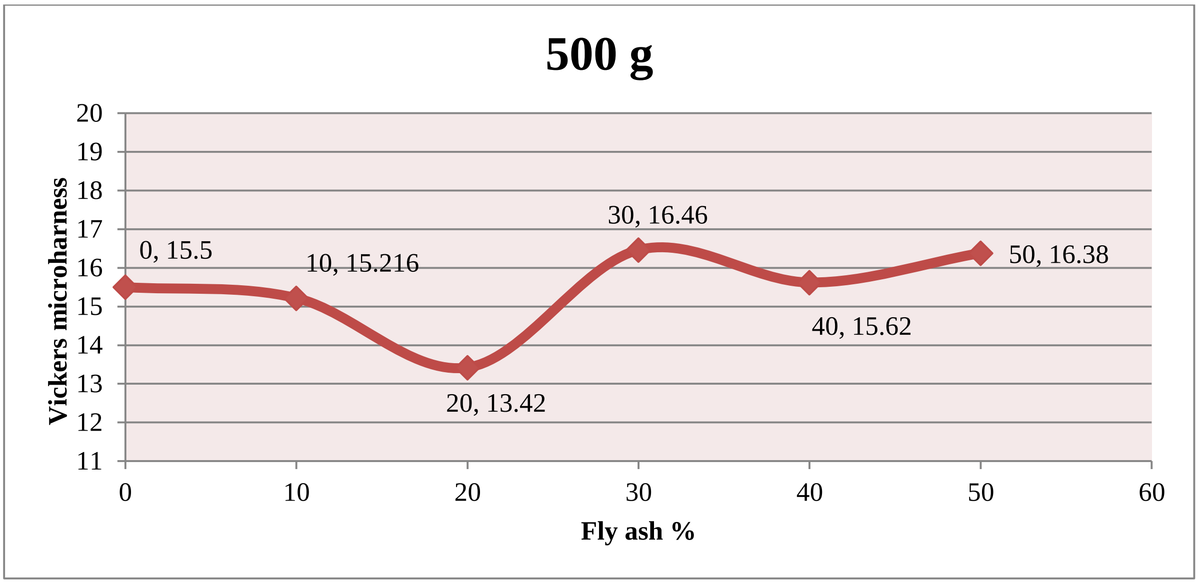

Fig.12: Fly ash wt% vs Vickers microharness under load 500 g

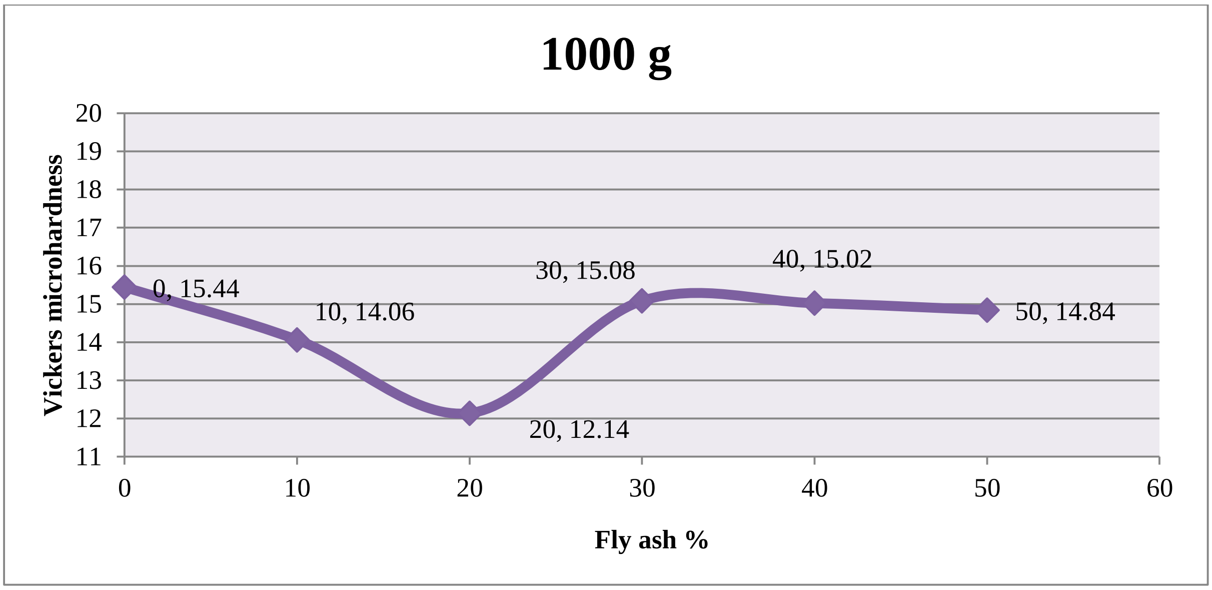

Fig.13: Fly ash wt% vs Vickers microhardness under load 1000 g

III. SUMMARY OF MICROHARDNESS TESTING

From the above information, three composites i.e.30 wt%, 40 wt% and 50 wt% fly ash show some increase in microhardness with fly ash addition this is because the addition of the hard particles fly ash makes the soft and ductile epoxy into more brittle with adding more of the fly ash.

Tensile test

The mechanical properties of composite films were determined from stress–strain relationship tests using an Instron 5982 - Load 5 kN- with crosshead movement 1mm/min. Tensile testing ASTM D638 samples used for this test to evaluate

- Yield strength,
- Strain to failure, and
- Modulus of elasticity.

For more accurate results on the modulus of elasticity, a laser extensometer was used to determine the elongation. Five samples were tested in each category and the results are considered as the average values.

The yield strength of fly ash / epoxy composites in average of 5 samples, showing that the maximum strength is achieved at 10 % FA by weight

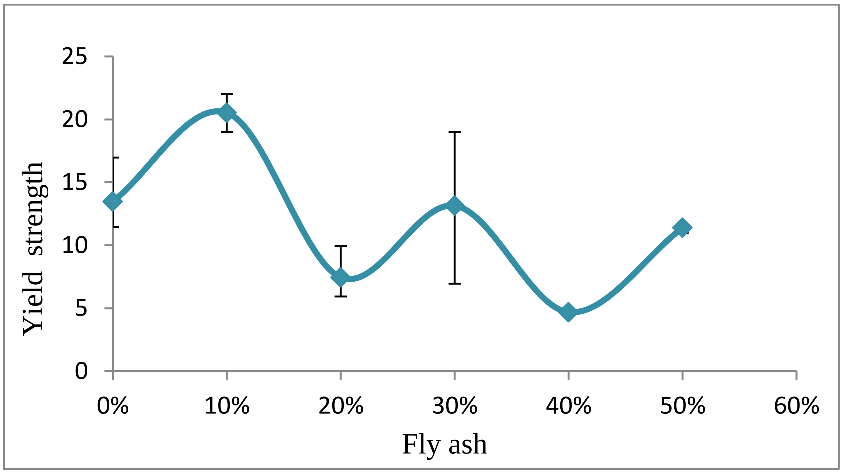

Fig.14: Yield strength, MPa vs. fly ash wt%

- The strain to failure values of the composites are shown in (figure 15) showing highest value for the neat epoxy, and then rapidly reducing with FA content, eventually showing a maxim at 40 % fly ash, the lowest strength is achieved at 40 % FA. So there is a very good correlation between the strength and ductility data in this work.

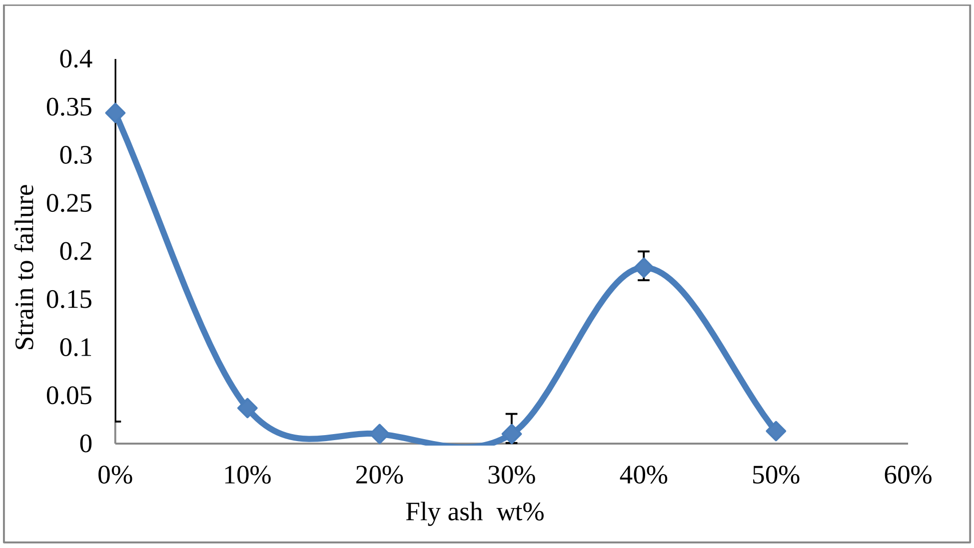

Fig.15: Strain to failure vs. fly ash wt%

- The 40 % composite yield strength and yield strain data also match with the modulus values as shown in (figure 16). The modulus of elasticity values show an interesting decreasing trend which could be either a) due to presence of voids because of FA particles, or b) FA particles interfering with the curing of the present epoxy material used in this study, as discussed later showing FTIR peaks of epoxy cured with and without fly ash. Between 10 – 30 weight% FA, the modulus of elasticity increases linearly so both phenomena fitting with normal rule of mixture[12, 13].

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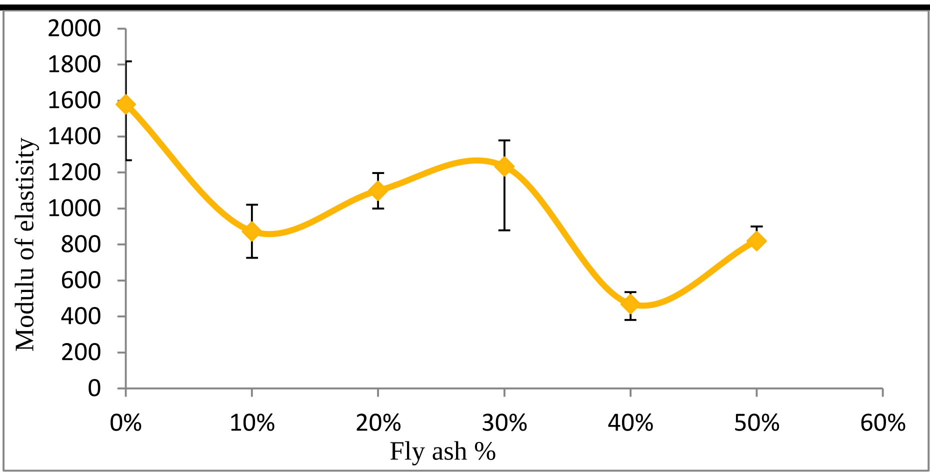

Fig.16: Modulus of elasticity as a function of fly ash content

Fig.17: Separation after failure in 10 %FA-epoxy, but no separation in 40%FA-epoxy

IV. CONCLUSIONS

- As received fly ash waste was found very attractive as an additive in epoxy resin up to 50 % reducing the cost of the used matrix by about 50 % and achieving a range of superior properties. New research techniques
- As received Fly ash – epoxy composites were fabricated using DGEBA epoxy and crosslinking agent cycloaliphatic polyamine cured at 120 ºC for 2 hours - using as-received Australian fly ash (Tarong, Hopper 4) in the proportion 0, 10, 20, 30, 40 and 50 weight %.
- 2. Mechanical properties such as yield strength and strain to failure at room temperature were evaluated.
  - 10 % addition of as-received fly ash enhanced the yield strength by 60 %

  - Fly ash in the ranges of 10, 20, 30, 40 and 50 % provide an acceptable ductility (strain to failure) of 2 to 4 %.

- 3. Vickers Microhardness of the epoxy and the composites show load-dependent micro- hardness values resulting between 12 to 19 MPa. The loads used were 300 g, 700 g and 1000 g. The highest micro-hardness was exhibited by the 40 % fly ash epoxy composite at 300 g load (which was only marginally higher than that of the cured neat epoxy).

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