"Synthesis of Thermosetting Composites using fly-ash as filler and study of their tensile properties"

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Abstract:

The unsaturated polyester resins is thermosetting type of polymer, its composite have been synthesized using various compositions (Wt. %) of micro sized fly-ash as filler with and without modification. The fabrication of a glass fiber reinforced thermosetting composite was possible by simple hand lay-up technique. This USP –FA composites were used to study their tensile properties such as tensile strength, % Elongation at break load, Yield stress and Young's modulus. The results obtained for these composites are of greater scientific and technological interest.

Keywords: unsaturated polyester resin, fly ash, composites, tensile properties.

1. Introduction:

Polymer composite materials have generated wide interest in various engineering fields, particularly in aerospace applications. Using fillers with composites has long been a practice in the plastics industry either to reduce cost or to impart some properties [1]. Research is underway worldwide to develop newer composites with varied combinations of fillers so as to make them usable under different operational conditions. The improved performance of polymer composites in engineering applications by addition of filler materials has shown a great promise and has become a subject of considerable interest [2]. Fly ash is a west product produced from coal fired thermal power stations during the combustion of coal. It is an alkaline gray powder with pH ranging from 9 to 9.9. Large number of coal fired thermal power plants all over the world dispose a large quantity of fly ash causing serious environmental problems [3]. Less than half of the ash is used as a raw material for concrete manufacturing and construction; the remaining is directly dumped on land side as land fill or simply piled up. Due to environmental regulations, new ways of utilizing fly ash have to be explored in order to safeguard the environment and provide useful ways for its disposal. Hence there is a considerable interest in utilization of fly ash as a raw material. For the first time fly ash was used in the preparation of cordierite [4]. Because of the presence of SiO_2 and Al_2O_3 in high proportions, the fly ash was used to synthesized zeolites [5]. Fly ash was treated hydrothermally and the performance of this material as cracking catalyst was investigated with heavy oil fraction as cracking feed stock [6]. On the other hand, there were many experimental analyses on fly ash to undertake basic compositional, physical and chemical properties for technical studies and applications [7]. Raw fly ash consists of quartz and mullets as crystalline phases some quantity of glassy phase [8]. Fly ash is an inexpensive material that can reduce the overall cost of composites. [9]. Various kinds of polymers and polymer matrix composites reinforced with fly ash particles have a wide range of industrial applications. The inclusion of inorganic fillers into polymers for commercial applications is primarily the aim is cost reduction and improvement of tensile properties of composites. Along with fiber-reinforced composites, the composites made with particulate fillers have been found to perform well in many real operational conditions. With the inclusion of micro sized particulates in to polymers, high filler content (20 vol. %) is generally required to bring the above stated positive effects into play. But at the same time , this may also have detrimental effects on some important properties of the matrix polymers, such as process ability, appearance, density and aging performance. It has also been reported that the fracture surface energies of epoxy and polyester resin and their resistance to crack propagation is relatively low. But if particular filler is added to these resins, the particles inhibit crack growth. The fracture toughness of epoxy resin could be improved by addition of fly ash particles as filler.

There are several reports in the literature which discuss the fly ash filled composites. However, very limited work has been done on glass fiber reinforced thermosetting composites filled with fly ash. The present work thus aims to develop this new class of particles filled glass fiber composites and to predict their tensile properties by experimentation. There are various techniques are available for manufacturing of composite, out of which hand lay-up technique is used for sheet preparation.

2. Experimental

2.1 Materials:

Fly ash available from the modern super thermal power plants typically contains around 1% carbon. The high velocity of the flue gases in the burning zone produce fly ash of much greater fines than were achieved earlier. Fly ash is a powdery substance obtained from dust collectors in the electoral power plants that use coal as a fuel. Fly ash sizes between 10 to 50 microns [10]. A fine fresh clean and pure fly ash powder was collected from the Paras Thermal Power Station, Maharashtra, India. The carbonaceous material in fly ash is composed of angular particles. The particle size distribution of most bituminous coal fly ash generally similar to that of silt. Although sub bituminous coal fly ashes are also silt sized, they are generally slight coarser than bituminous coal fly ashes. The specific gravity of fly ash usually ranges from 2.1 to 3.0, while its specific surface area may range from 170 to 1000 m^2/kg. the chemical composition of fly ash obtained from different coal samples are given in Table-1 [10-11]. The fly ash collected from thermal power plant was grounded and sintered at 600 ^{0}C to remove moisture content and some dust impurities present chemically.

Unsaturated polyester resin (USP), Methyl Ethyl Ketone Peroxide (MEKP) as initiator purchased from modern apparatus and chemicals pvt. ltd. Nasik (Maharashtra). Cobalt octate (Loba) was used as catalyst and accelerator for unsaturated polyester resin. Glass fibers were purchased from hard ware store.

Table-1: Chemical composition of fly ash produced from different coal types
(Expressed as Wt.%)

Component	Bituminous	Sub- Bituminous	Lignite
SiO_2	20-60	40-60	15-45
Al_2O_3	5-35	20-30	10-25
Fe_2O_3	10-40	4-10	4-15
CaO	1-2	5-30	15-40
MgO	0-5	1-6	3-10
SO_3	0-4	0-2	0-10
Na_2O	0-4	0-2	0-6
K_2O	0-3	0-4	0-4
LIO (Loss- on- ignition)	-15	0-3	0-5

2.2 Modification of Fly ash:

The surface treatment of fly ash with coupling agent improves the properties of polymer. Accordingly the fly ash surface was coated with silane coupling agent by using the principle of dilution. The diluents used was methanol, 2 % solution of coupling agent was prepared in methanol and prewetting of fly ash carried out with methanol. The resultant slurry was dried at 70 0C for 1 hour.

2.3 Composite Preparation:

For preparation of thermostat composites , commercial room temperature curing grade unsaturated polyester resin is preferred. There were two batches of USP resin with MEKP as initiator and Cobalt octate as catalyst and accelerator are prepared for each modified and unmodified fly ash. The initiator 1% and catalyst 2% is used for USP batch preparation at room temperature curing. The compositions used are shown in Table-2

Table-2: Composition of composites with and without modification of fly ash

Sample. No.	Resin (ml)	MEKP (ml)	Cobalt Octate (phr)	Fly ash (phr)	Glass fiber (phr)
1	200	2	1	0	0
2	200	2	1	0	10
3	200	2	1	5	10
4	200	2	1	10	10
5	200	2	1	15	10
6	200	2	1	20	10

All samples were prepared by hand lay-up process. A coat of laminating resin system is applied by brush, roller followed by the first layer of chopped strand mat. Sufficient resin should be applied to wet out completely, so that all trapped air can be forced out by rolling action. At corner of the mold the glass mat should be cut and butted together to ensure that birthing does not occur. The resin to glass ratio at this stage should be about 2:1 once all the air has been displaced and mat thoroughly impregnated with resin. Further layers of resin and chopped strand mat are then applied using the same technique as with the first layer, thoroughly consolidating each layer before application of next. After curing of composite, it was removed from mold and then trimming of edges of composite is done by knife to study the tensile properties of composites.

3. Result and Discussion:

The tensile properties of the composites tested are shown in table- 3 and 4. The tests are carried out to bring about the accurate tensile properties of the composites. The response of a composite to tensile load is very dependent on the tensile stiffness and strength properties of the reinforcement fibers and fillers incorporated, since these are far higher than the resin system on its own. Figure – 1 and 2 shows the behavior of tensile strength of unmodified and modified fillers in composites respectively. In first case tensile strength first decrease and then increase while in second case there is decrease in tensile strength is observed. This decrease in tensile strength may be attributed to change in effective crass-sectional area brought about by fly ash in dispersed phase. The figure 3 and 4 shows the % elongation of USP resin with unmodified and modified fly ash respectively. There is marginal decrease in % elongation is observed for both. Figure 5 shows young’s modulus of USP resin with unmodified fly ash, in which continuous increase in modulus is observed as increase in fly ash loading from 0 to 20 phr as filler. Figure 6 shows young’s modulus of USP resin with modified fly ash, in which there is increase is observed up to 10 phr but for 15 phr and 20 phr, there is drastic decrease in modulus value. This decrease in modulus values at higher loading that there may be reduction in stiffness of the composite. At this loading fly ash particles may act as a lubricating agent facilitating ductility in the composite at higher loading.

Table-3: Tensile properties of USP composite with unmodified fly ash

Sample code	Glass fiber (%)	Fly ash (%)	Tensile Strength at Peak load (kg/cm2)	% Elongation at Break load	Yield stress (kg/cm2)	Young's Modulus (kg/cm2)
USP-FA-1	10	0	614.77	8.40	612.14	8285.13
USP-FA-2	10	5	570.24	7.50	625.70	10516.75
USP-FA-3	10	10	573.24	6.30	573.91	9904.00
USP-FA-4	10	15	596.87	7.30	596.87	11038.40
USP-FA-5	10	20	642.00	6.80	642.14	12921.18

Table-4: Tensile properties of USP composite with modified fly ash

Sample code	Glass fiber (%)	Fly ash (%)	Tensile Strength at Peak load (kg/cm2)	% Elongation at Break load	Yield stress (kg/cm2)	Young's Modulus (kg/cm2)
USP-FA-1	10	0	614.77	8.40	612.14	8285.13
USP-FA-2	10	5	515.60	6.70	513.40	13013.30
USP-FA-3	10	10	480.32	6.40	431.42	13032.77
USP-FA-4	10	15	517.96	6.00	514.94	11309.72
USP-FA-5	10	20	524.31	7.50	213.43	9021.40

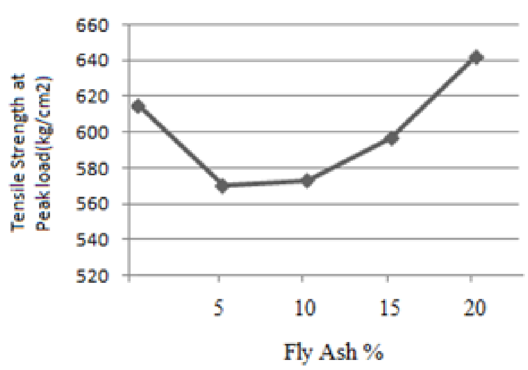

Figure: 1 Tensile strength of USP resin with unmodified fly ash at peak load

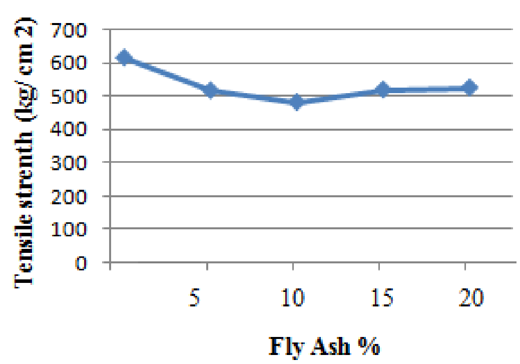

Figure : 2 Tensile strength of USP resin with modified fly ash at peak load

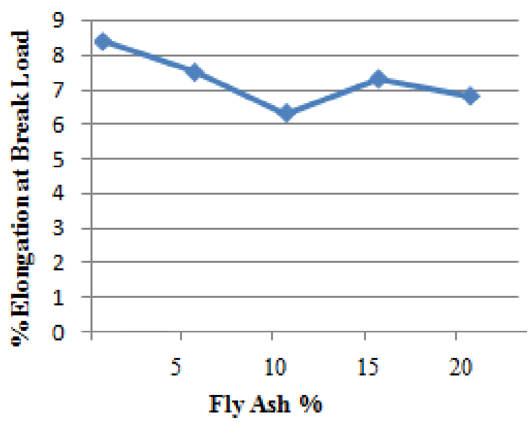

Figure: 3 % Elongation of USP resin with unmodified fly ash at break load

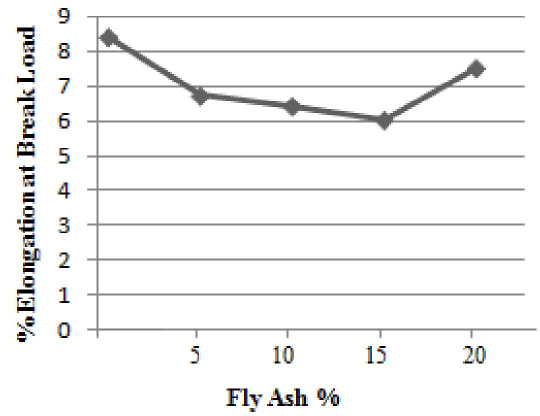

Figure: 4 % Elongation of USP resin with modified fly ash at break load

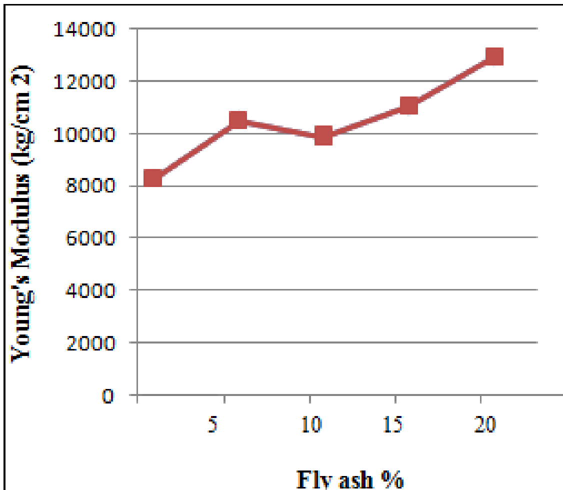

Figure: 5 Young's modulus of USP resine with unmodefied fly ash

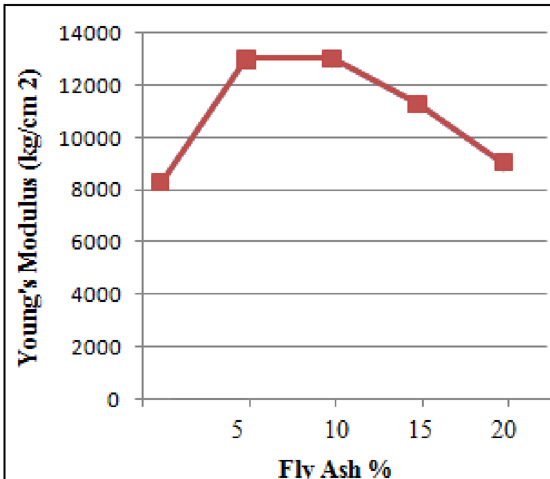

Figure: 6 Young modulus of USP resine with modified fly ash

4. Conclusion:

The analytical and experimental investigation into behavior of fly ash filled glass fiber reinforced thermosetting composites of unmodified and modified USP resin studied. This work shows that successful fabrication of a glass fiber reinforced thermosetting composites filled with micro sized fly ash is possible by simple lay-up technique. In USP resin system, the tensile properties are not significantly improved by modification of fly ash. These properties are somewhat same that are obtained without modification of fly ash.

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