Relationship between Compressive Strength and Applied Stress of a Diallyl Phthalate Coal Ash Blend

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Summary: The compressive strength of a diallyl phthalate coal ash blend fabricated at pressures between 1000-4000 p.s.i. follows Michealais equation and shows a linear relationship between inverse of applied stress [I/V] and inverse of composite compressive strength [I/S].

Introduction

In coal combustion processes, particularly in electric power plants, 10 million tones in Japan [1] and 91 million tones in USA [2] of coal ash was produced in the year 2000. A recently planned 600MW power project at Thar-Sind province using a coal containing 8.8 % ash (average) and operating at an overall 20 % efficiency, 24 hours a day is likely to produce 0.6 million tones of coal ash per year in Pakistan. The major portion of coal ash is usually disposed off in impoundments and in landfills, while some of it is used as raw material admixture in cement industry. The disposal methods due to strict environment regulations add to the cost for its removal from the site. Thus the safe disposal and its possible utilization in various products e.g. the formation of ash plastic composites need urgent attention. Some work has been carried out on the use of glass fibres as fillers in nylon, which increased the tensile strength of the polymer considerably [3]. Moreover, claims have been made by mixing polyethylene with ash in the fabrication of 1 mm thick sheets having tensile strength up to 1200 Kg/cm^2 [4,5]. Detailed information regarding the mechanical behaviour of such composites is not available in the literature. In this investigation an attempt has been made to correlate the compressive strength of the diallyl phthalate (DAP) – ash blend with the applied stress.

Results and Discussion

As can be seen in the Table 1, the major components of coal-ash are silica, alumina, ferric oxide and calcium oxide [6]. The load bearing properties of these components can possibly be utilized in the fabrication of a high strength polymer material. In the fabrication process as the temperature of DAP – ash mixture in the mold rises to about 150 ^{0}C, which is near the melting point of DAP, the volume of polymer expands. With increasing stress on the polymer blend, the minute ash particles are forced into the polymer mass, possibly reinforcing its compressive strength. This effect is more pronounced at a higher pressure (4000 p.s.i) when the process of ash dispersion in to the polymer is likely to be further aided by the polymer expansion and decrease in its viscosity at the melting point i.e. 150 ^oC. The ash particles remain dispersed in the polymer matrix without returning to their original position when temperature of polymer blend decreases.

Table – 1: Ash Analysis and Composition

Composition	Lakhra (A) Wt. %	Lakhra (B) Wt. %	Sharigh (C) Wt. %
SiO_2	8-44	38.0	20-25
Al_2O_3	9.5-30	29.15	8-9.5
Fe_2O_3	11-30	19.0	16-21
CaO	1-12	4.17	2-30
MgO	0.9-7.0	3.24	1.8-1.9
Na_2O	0.4-3	1.4	0.2-0.3
K_2O	0.3-2	0.56	0.6-1.2

Coal A: Lakhra Coal, Sind province, Composition range.
Coal B: Lakhra Coal, Sind Province, typical coal
Coal C: Sharigh Coal, Balochistan Province, composition rage.

In a polymer – ash blend, if the applied pressure on the DAP – ash substrate (S) is increased while keeping all other conditions constant, the measured initial compressive strength of the composite.

V_i, increase to a maximum value, V_{max}, and no further increase is observed. The initial compressive strength V_i is very responsive to changes in (S) and can be expressed in an equation of the form similar to Michealais equation (1)

$$V_i = \frac{V_{max}[S]}{K_m + [S]} \qquad (1)$$

Where K_m is half maximum compressive strength

To extrapolate V_{max} and K_m from the experimental data, the equation (1) may be inverted i.e.

$$\frac{1}{V_i} = \frac{K_m + [S]}{V_{max}[S]} \qquad (2)$$

$$\frac{1}{V_i} = \frac{K_m}{V_{max}} \bullet \frac{1}{[S]} + \frac{[S]}{V_{max}[S]} \qquad (3)$$

$$\frac{1}{V_i} = \frac{K_m}{V_{max}} \bullet \frac{1}{[S]} + \frac{1}{V_{max}} \qquad (4)$$

A linear relationship was obtained by plotting a double inverse graph between the applied stress and compressive strength as shown in Figure 1. This indicates that an increase in the load bearing strength of DAP – ash blend follows a pattern which can be expressed in a form similar to Michealais equation and predicted by equation (1). The equation signifies that each ash particle attaches itself to different polymer molecules. The significant increase in load bearing property of the DAP – ash composite was similarly observed in composites made with glass fibre – nylon and fly ash – polyethylene wastes reported in literature [3-4]. A pronounced enhancement was not observed in the compressive strength of a blank polymer sample prepared at 4000 p.s.i. An increase in the composite strength thus appears to be associated with the incorporation of minute ash particles in the DAP polymer matrix.

The reinforced polyesters of phthalic acid are used in the manufacture of storage tank, drainage piping, swimming pools, boat hulls, etc as they show less blistering owing to their greater hydrolytic stability.

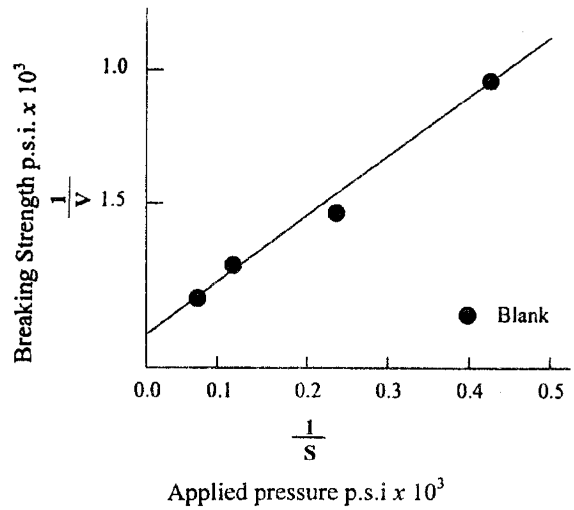

Fig. 1: Linear Relationship between the inverse of applied pressure and inverse Breaking strength.

Features of coal ash-plastic include low specific gravity, thermal conduction and water absorption. Huge amounts of coal ash generated locally combined with plastic wastes can benefically be utilized in the fabrication of high strength building material. Light weight thermoplastics can replace wood and stones as building material in frequently hit earthquakes areas of the country.

Experimental

The raw ash was subjected to grounding in a pulveriser (Mold Pulverisette, Model 02-102, USA) for 1 hour and sieved through a 200 mesh screen. Mixture of ash and polymer powder in (1:1) ratio was mixed in an extruder at 150 ^{0}C. A grinder was used to convert the resultant mass into powder. The polymer blend was hot pressed at 150 ^{0}C and at pressures varying between 1000 to 4000 p.s.i in a Specimen Mount Press Mold (Buehler, Model 20-1310, USA).

As the temperature of the polymer blend increased, a progressive backpressure was observed due to the expansion of polymer. An excessive pressure was applied in order to maintain the desired stress constant.

Diallyl phthalate (97 % purity) powder 60 mesh, was obtained from Buehler Ltd. USA. Ash was obtained by burning Lakhra coal (Sind province) in a specially designed coal oven.

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