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Effect of Fly Ash Fineness on the Performance of Cement Mortar

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ABSTRACT

This paper investigates the effect of fineness of fly ash on the performance of cement mortar. Fly ash from thermal plant is used as partial substitute for cement. Fly ash is used as received and also processed by grinding. The study involves four replacement levels of fly ash into cement at 10%, 20%, 30% and 40% for each mix design. Mortar cubes are tested for strength, water absorption and sorption. Water absorption and sorption show a decreasing trend with the increase of fly ash fineness; whereas the strength increases with the increase of fineness. It is concluded that increasing the fineness of fly ash increases the strength and reduces absorption by 15% and hence is an effective method to improve its performance in cement mortar.

KEYWORDS: Fly ash, Fineness, Cement, Mortar, Strength, Water absorption, Sorption.

INTRODUCTION

Thermal power plant fly ash, which is available in abundance, is classified as Class F fly ash. If it can be converted into Class C fly ash, it will be useful as a substitute for cement. Incorporating these very fine particles which are obtained by grinding and/or pneumatic selection improves the performance of concrete. There are two classes of fly ash which are defined by (ASTM C618 2005); these are Class C fly ash and Class F fly ash. The main difference between these two classes of fly ash is the amounts of calcium, silica, alumina and iron contents in the ash itself. Chemical content of the coal will influence the chemical properties of the fly ash. Class F fly ash contains less than 20% of lime (CaO) and is pozzolanic in nature (Karthik, 2008). By possessing the pozzolanicity, Class F fly ash will need a cementing agent in order to react and produce cementitious compounds. The burning of the younger lignite or sub-bituminous coal can produce Class C fly ash. This type of fly ash has pozzolanic properties and has also some self-cementing properties. It contains more than 20% of lime (CaO) and will harden and gain strength over time. Unlike Class F fly ash, self-cementing Class C fly ash does not require an activator. It is the main type offered for residential applications from ready-mix suppliers. Thus, it will be useful as a substitute for cement if Class F fly ash can be converted into Class C fly ash. One way to improve Class F fly ash into Class C fly ash is by increasing its fineness by grinding.

This paper reports the investigation conducted on the effect of fineness of fly ash on the properties of mortar. Cement mortar was made with cement, sand and various percentages of fly ash with varying finenesses. The mortar was then tested for strength, water absorption and sorption.

Materials

The cement used in this research is ordinary Portland cement obtained from Tasek Corporation Berhad, Malaysia and confirms to (BS EN 196 – 1

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2005). The chemical composition is presented in Table 1 . Fly ash used in this research is the fly ash obtained from the Kapar Energy Ventures Sdn. Bhd, Kapar Thermal Power Station, Kapar, Selangor, Malaysia.

Table 1. Chemical composition of cement and fly ash

Oxide Composition	Cement (%)	Fly Ash (%)
SiO_2	21.28	56.58
Al_2O_3	5.6	27.83
Fe_2O_3	3.36	4
CaO	64.64	4.3
MgO	2.06	1.4
SO_3	2.14	-

Finenesses of cement and fly ash are reported in Table 2. It can be observed that the finenesses of cement, fly ash as collected and fly ash as processed are different. The fineness of the raw material is increasing from cement to fly ash after being processed. From the Blaine fineness test, the fineness of cement resulting is 4500.27 cm^2/g; while the fineness of fly ash as collected is 6477.93 cm^2/g. From these results, it can be seen that fly ash is finer than cement. After that, fly ash as collected was ground by placing the as received fly ash in the Los Angeles Abrasion Machine and rotating it for 8 hours at 500 revolutions per hour.

Table 2. Fineness of cement and fly ash

Material	Fineness (cm^2/g)
Cement	4500.27
Fly ash as received	6477.93
Fly ash as processed	10703.54

Mixture Proportions and Casting

There are nine mixture designs used in this investigation as indicated in Table 3. The control mix was made with a cement-to-sand ratio of 1:3 with no addition of fly ash. Cement was then replaced with fly ash as received and also processed fly ash at replacement levels of 10, 20, 30 and 40 percent by weight. The water-to-cement ratio was kept at 0.5 for all mixtures.

Table 3. Mix design

Mix	Cement(%)	Fly Ash(%)	Remark
1	100	-	Control mix
2	90	10	Fly ash as collected
3	80	20	
4	70	30	
5	60	40	
6	90	10	Fly ash as processed
7	80	20	
8	70	30	
9	60	40	

All the constituent materials were placed in a laboratory mortar mixer and mixed for three minutes. The mortar was then poured into 50 mm cube moulds and vibrated for 5 seconds using a vibrating table. The moulds were kept covered using a wet hessian for one day and then transferred into a curing water tank. Potable tap water was used in all the mixtures.

Testing

Mortar cubes were tested for strength and Ultrasonic Pulse Velocity (UPV) up to 28 days, as well as for water absorption and sorption at 28 days. Compressive strength test was carried out in accordance with (ASTM C 109 2005) using a compression testing machine of 1000 kN capacity. Three cubes were tested and the average value was reported. Water absorption test was conducted according to (ASTM C 1403 2005) at 28 days. The cubes were dried in an oven at 110°C for 24 hours and then cooled in a dessicator before the test. Sorption test was carried out after 28 days of curing in the curing water tank for each mix design. The weight was measured and recorded after the curing session. The samples were then kept in a tray in such a way that the bottom 3 mm depth of the sample was kept under water. The increases in weight of the samples were recorded once every 30 minutes up to 4 hours. The value of sorption was the slope of the graph with increase in weight on the Y-axis and square root of time on the X-axis (Neville, 1996).

RESULTS AND DISCUSSION

The results of strength, water absorption and sorption are indicated in Table.

Table 4. Strength, water absorption and sorption values of mortar

Mix	Strength (MPa) at day			Water Absorption (%)	Sorption (g/min^½)
	7	14	28		
1	18.79	20.54	21.77	0.74	3.48
2	15.12	17.31	22	0.94	3.89
3	13.18	17.7	24.72	0.95	2.31
4	13.03	16.67	23.11	0.57	3.57
5	11.37	14.19	20.65	0.59	3.35
6	12.79	17.01	25.37	0.69	2.82
7	11.77	14.37	26.52	0.78	2.69
8	11.08	15.37	22.43	0.46	2.44
9	7.61	12.34	23.18	0.69	2.82

Compressive Strength

The relationship between strength and age of the samples is given in Figure 1. Strength increases with age for all mixtures. This is because of the hydration of cement (Neville, 1996). The strength is more at 7 days for mix 1; whereas the strength is the lowest for mix 9. Mix 1 has no fly ash content and mix 9 has a maximum of 40% of fly ash. Hence, it is clear that the addition of fly ash reduces the strength at early ages. This is because the addition of fly ash reduces the amount of tri-calcium silicate C_3S in the mix which reduces the heat of hydration and hence reduces strength (Shan Somayaji, 2001). It is also indicated in Figure 1 that 7-day strength is lower when fly ash fineness increased. Hence, it is concluded that increasing the fineness of fly ash reduces early age strength (Prinya et al., 2005).

The average 28-day strength of all mixtures made with unground fly ash is 22.62 MPa and the same for ground fly ash is 24.38 MPa as reported in Table 5. It is observed that increasing the fineness of fly ash increases the strength at 28 days. This is because the finer the fly ash, the smaller the particle size and the larger the surface area for hydration and pozzolanic reaction, and hence the strength will increase (Prinya et al., 2007). Hence, it is concluded that increasing the fineness of fly ash increases its pozzolanicity. However, more detailed investigation is necessary in order to better understand the pozzolanic behavior of fly ash.

Sorption

The sorptivity of mortar is presented in Figure 2. From the figure, we can conclude that the finer the fly ash, the lower the rate of sorption. Besides, the higher the fly ash/ cement ratio, the lower the rate of sorption. This is because when there is more fly ash, it will fill up the empty voids in the mortar cubes; thus there are no voids for the water to sip through to increase the weight of the cubes (Prinya et al., 2005).

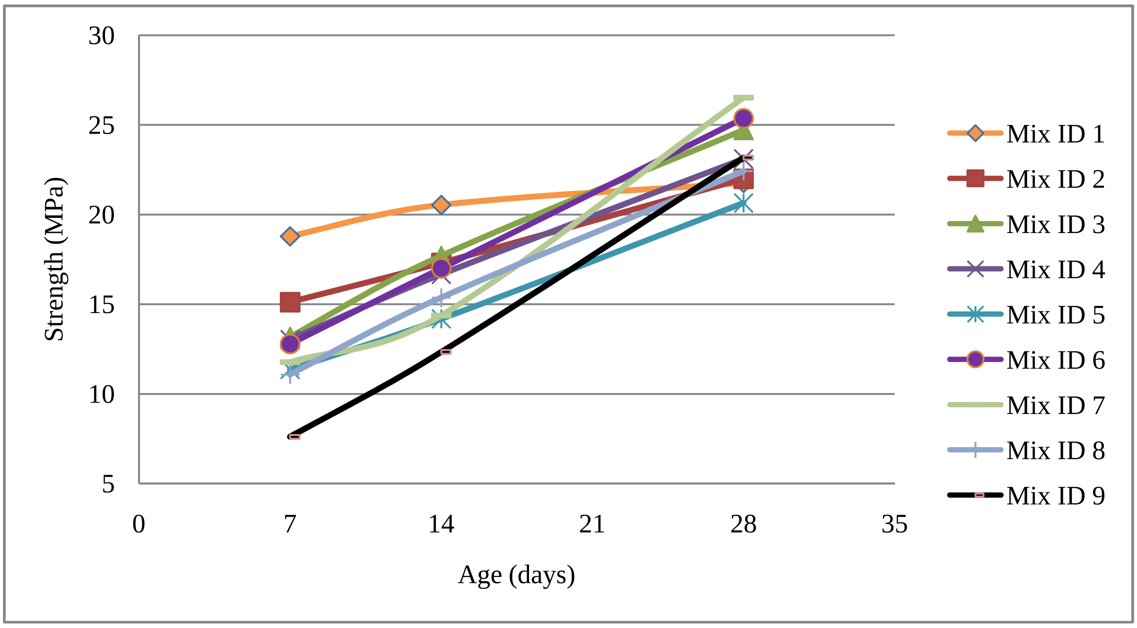

Figure 1: Relationship between compressive strength and age

Table 5. Average strength of mortar cubes after curing

Age (days)	Average Strength (MPa)		
	Control Mix	6477.93 cm^2/g fly ash	10703.54 cm^2/g fly ash
7	18.79	13.18	10.81
14	20.54	16.47	14.77
28	21.77	22.62	24.38

Water Absorption

Figure 3 presents the water absorption values for various mixtures. It is indicated that when the fly ash is getting finer, the rate of water absorption is lower. Furthermore, the higher the fly ash/ cement ratio, the lower the rate of water absorption. This is because when the volume of fly ash is increasing, it will fill the voids, increasing the density and hence preventing water absorption (Prinya et al., 2007).

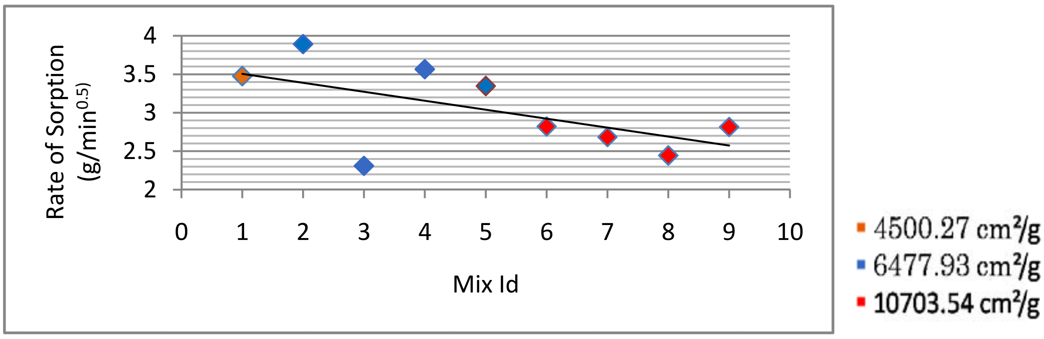

Figure 2: Rate of sorption for various mixtures

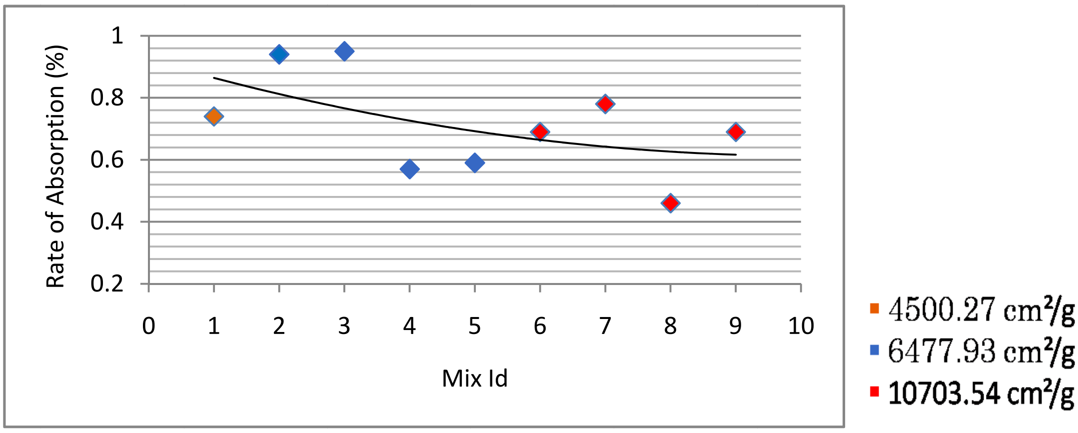

Figure 3: Water absorption

CONCLUSIONS

Fly ash as received and also as processed by grinding was used at four replacement levels in mortar. The 7-day strength decreased as the fineness of fly ash increased, while the 28-day strength increased as the fineness of fly ash increased. The durability properties such as water absorption and sorption showed a decreasing trend with the increase of fly ash fineness, in agreement with previous works. Hence, it is concluded that increasing the fineness of fly ash increases its pozzolanicity, and, hence, grinding is an effective way to enhance the performance of fly ash received from thermal power plant.

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