MECHANICAL ACTIVATION OF FLY ASH FOR MAKING HIGH VOLUME FLY ASH CONCRETE

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Abstract

Fly ash - waste product from industrial process - seldom receives proper attention during the production stage, and thus its chemical composition and other properties are varied. Quality of fly ash is determined by the efficiency of combustion and the type of coal used. It can be detected also from the value of Lost on Ignition (LOI). This paper evaluates changes on fly ash after undergone grinding using rod mill, and determines its suitability to be used in making high volume fly ash (HVFA) concrete. Samples of fly ashes were taken from four different sources, i.e. two samples from a power plant, and one each from textile factory and paper mill. Samples taken from power plant have low Loss on Ignition (LOI), while the other have very high LOIs. Fly ash samples were ground using a rod mill to evaluate the changes in the properties of fly ash and HVFA mortar. The workability of HVFA mortar was controlled by adjusting the superplasticizer content to obtain the target slump with constant water to cementitious ratio. The results shows that the specific gravity of fly ash increases after grinding. Utilizing ground fly ash ends up with more significant strength increase of HVFA mortar, especially with those of high LOI values. The strength increase of HVFA mortar utilizing ground fly ash shows that milling of the fly ash is an excellent method for beneficiation of fly ash, especially to the one with high LOI value and low specific gravity.

Keywords: *Fly ash, Mechanical activation*; *Milling, LOI, Rod Mill*.

1. INTRODUCTION

Efforts of utilizing waste material - fly ash - have been carried out by many researchers to end up with mix results. This was mainly due to the quality of fly ash used, that varies so much, depends on the industry that generate this waste material. Power plants generally produce good fly ash with low Loss on Ignition (LOI) value, due to better control on the burning process that contributes significantly to the production cost, while other industries may not so.

Good quality fly ash with low LOI is coveted by the ready mix industry as it reduce the cost of the concrete production, while giving good performance such as more workable mix, higher strength and durability, and lower shrinkage. However, there are large quantities of low quality fly ash with high LOI values available. Without any proper treatment, this kind of fly ash is hardly used in concrete production, due to its poor performance.

Beneficiation of fly ash has been studied in recent years[1-3] and several methods have been proposed to separate good quality cementitious material from the combustible one. However, the methods normally involve complex processes.

This study aims to mechanically activate fly ash by grinding it using a rod mill, to improve its quality and make it more desirable to be used as cementitious material, especially in producing high volume fly ash (HVFA) mortar.

2. EXPERIMENTAL PROGRAM

2.1 Materials

Fly ash samples for the experiment were obtained from four different sources. Two of the fly ash samples were taken from a power plant that is well known to produce good quality fly ash (coded A and B). The other fly ash samples were obtained from a textile factory (C) and from a paper mill (D). Fly ashes A and B have brown and light brown color, while fly ashes C and D show grey-blackish color.

Table 1 Chemical compound of the fly ashes

Compound (%)	Sample			
	A	B	C	D
SiO_2	42.56	43.38	44.51	39.71
Al_2O_3	26.76	18.54	22.44	16.38
Fe_2O_3	9.67	15.29	15.95	26.15
TiO_2	1.14	0.77	1.19	0.83
CaO	6.59	12.2	8.98	8.86
MgO	3.54	5.43	1.91	5.12
Cr_2O_3	0.01	0.02	0.05	0.02
K_2O	1.26	1.32	2.05	0.87
Na_2O	0.88	1.05	0.63	0.89
SO_3	7.04	1.43	1.55	0.58
Mn_3O_4	0.11	0.14	0.11	0.35
LOI	0.33	2.12	28.66	23.83

Chemical composition of fly ash was determined by X-ray Diffraction analysis and the results are presented in Table 1. The LOI values of the fly ashes show that the quality of the fly ashes vary and can be categorized into two types, i.e. the ones with low LOI's and the ones with high LOI's fly ashes.

2.2 Mechanical activation

Mechanical activation of the fly ash was performed by milling the fly ash powder using rod mill. The rod mill consists of a steel drum with diameter of 60 cm and length of 90 cm and filled with 80 kg of 12 mm diameter and 80 cm length steel rods. The rotation speed is about 40 rpm. The rod mill is able to grind 15-20 kg powder in each operation. From our previous study[4], it was found that – by using this rod mill - 8 hours milling time increased the reactivity of the cementitious powder significantly. Thus, in this experiment 8 hours milling time was chosen.

Table 2 LOI and specific density of the fly ashes

Fly Ash	Milling time (hours)	LOI (%)	Specific gravity	Increase of density
A	0	0.33	2.7539	0.442
	8	0.01	3.1956	
B	0	2.12	2.0579	0.124
	8	0.87	2.1821	
C	0	28.66	1.6417	0.179
	8	22.71	1.8207	
D	0	23.83	1.8325	0.772
	8	19.23	2.6049	

LOI and specific gravity of fly ashes were measured for original and milled or ground fly ashes, and the results are shown in Table 2. The LOI values were slightly reduced with milling, while the density of the fly ashes was seen to be increased. However the increase does not show any pattern.

2.3 Mix design of the mortar

Water to cementitious ratio of 0.2 and sand to cementitious ratio of 2, by mass, were used for all mixtures. The cement replacement ratio was set at 50%, by mass, when investigating the effect of milling on the reactivity of different fly ashes. It was varied from 40 to 60%, by mass, to evaluate the influence of replacement ratio to the mix, for both the original and milled fly ashes. Polycarboxylate-based superplasticizer was added to the fresh mixture to obtain flow diameter of 18±1 cm in mortar flow table test. The constant workability target is important to ensure that the mortar properties are comparable in term of its compactibility and w/c ratio. Mortar specimens of 5×5×5 cm^3 were made for each mix for compressive strength test at age 14 and 28 days. Coding of the specimen was straight forward, for example A85 denotes mix using fly ash from source A with 8 hours milling time and 50% fly ash usage, by mass.

3. RESULTS AND DISCUSSION

3.1 Workability and superplasticizer demand

Superplasticizer demand for the target workability of flow diameter of 18±1 cm, measured from flow table test, is shown in Fig. 1. Superplasticizer demand is about 0.5%, by mass of the cementitious material, for original fly ashes (A and B). For milled fly ash (C and D), there is a significant increase of superplasticizer demand of up to 1.5%. This condition could be attributed to the high carbon content that could absorb some of the water and admixture, and leads to higher consumption rate. Milling fly ash increases the number of fly ash particles, and hence also the number of the carbon particles. It may affect the workability of the fresh mortar mix. Controlling the workability was carried out by adding superplasticizer, rather than adding water, to ensure that w/c was kept constant. Lack of workability of the fresh mortar mix utilizing milled fly ash could cause false result, as the high reduction of strength may happen, mostly due to difficulty in compaction rather than poor fly ash quality.

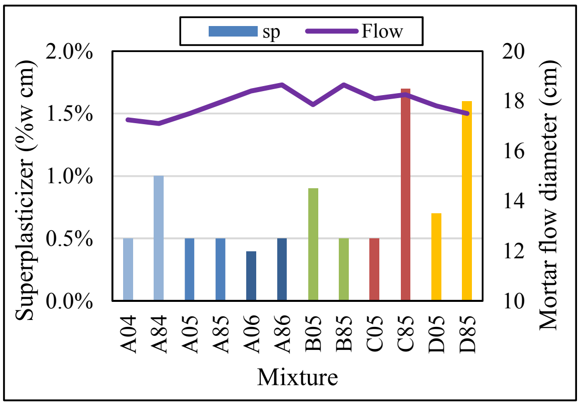

Fig. 1 The amount of superplasticizer needed to achieve target mortar flow diameter of 18±1 cm

3.2 Increase of compressive strength

The 28-day compressive strength of mortar are shown in Fig. 2 and Fig. 3. Different replacement ratios of fly ash A was employed to evaluate the effect of milling on the increase of the compressive strength.

Fig. 2 clearly shows that there is significant strength increase of mortar using fly ash that has been mechanically activated by milling, compared to the one using the untreated fly ash. The measured density of the mortar increased slightly, showing that there could be improvement on the particle packing of the mortar incorporating finer particle size.

Fig. 3 shows the effect of milling of different fly ashes at 50% replacement ratio. Although all milled fly ash shown strength increase compared to the untreated one, very considerable increase of 264% and 183% were observed for fly ash C and D. The untreated fly ashes with high LOIs (C and D) are not reactive, as can be seen from the low compressive strength of mortar utilizing them. The results confirm that mechanical activation by milling effectively increase the reactivity of fly ashes with high LOIs. Low specific gravity of untreated fly ash taking more mortar volume and reduce its density and mortar density increases considerably for mortar using milled fly ash C and D.

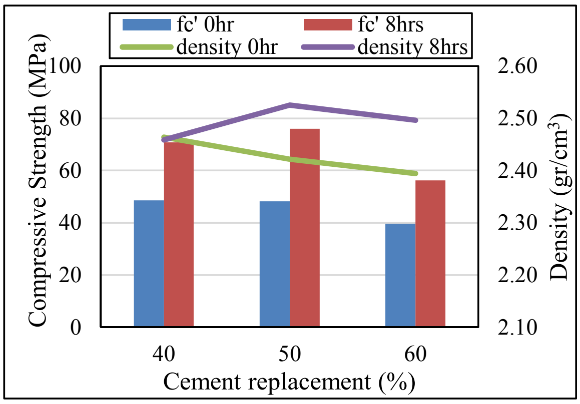

Fig. 2 Compressive strength and mortar density of the fly ash A at 28 days

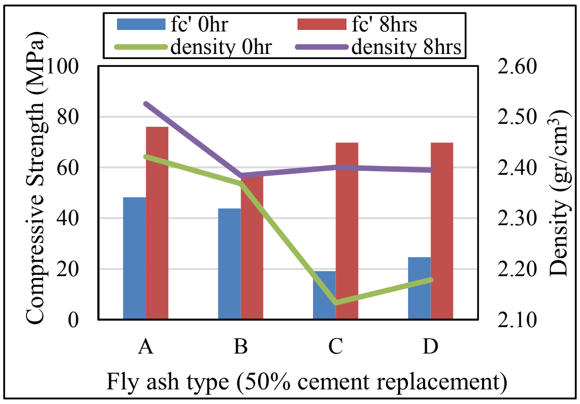

Fig. 3 Compressive strength and mortar density with 50% replacement ratio at 28 days age

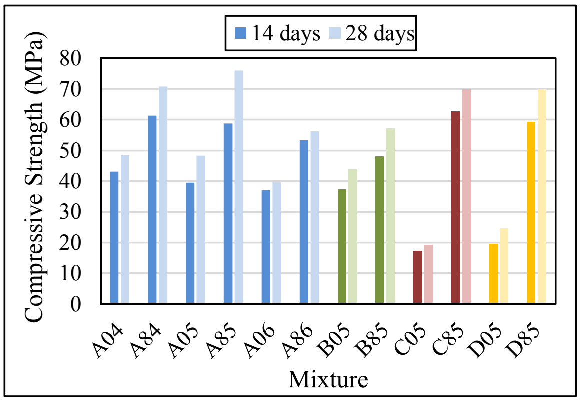

Fig. 4 Compressive strength result of the mixture for 14 days and 28 days age

Fig. 4 shows the 14-day and 28-day compressive strength of mortar specimens. In general, it indicates higher increase in the compressive strength of mortar using milled fly ash when compared to one with the untreated fly ash. This result confirms that by milling, the reactivity of the fly ash is improved.

3.3 Fly ash LOI, specific gravity and mechanical activation

Relationship between mortar density and its compressive strength is shown in Fig. 5. It shows that there are significant differences on the density and compressive strength of mortar incorporating fly ash A and B, compared to the ones using fly ash C and D.
Fly ashes C and D with LOIs higher than 20% are eligible to be used as cement replacement material with 50% replacement ratio, to produce comparable strength of mortar utilizing fly ash A and B. Mechanical activation by means of milling can be the best alternative in an attempt to utilize the undesired high LOI fly ash in concrete industry.

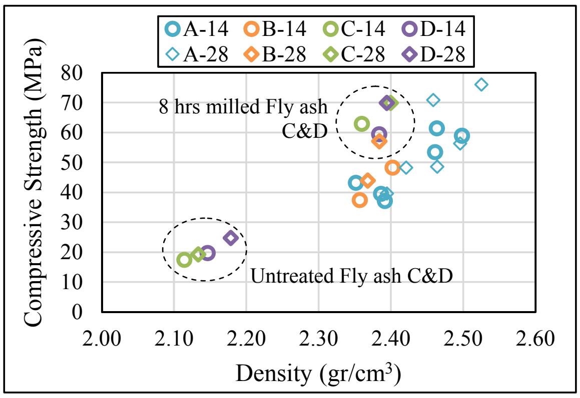

Fig. 5 Relationship between the density and strength of mortar at 14 and 28 days

4. CONCLUSIONS

1. Mechanical activation by milling of fly ash using a rod mill improves its reactivity, increases the density, and makes it suitable to be used in making HVFA concrete.
2. Compressive strength of the high volume fly ash mortar is higher for the one using milled fly ash material than untreated one. The strength increase is very significant for fly ash with high LOI.
3. Change of the particle shape and size also affects the rheological behavior of the fresh mortar mix. This is indicated by the superplasticizer requirement to obtain the same workability.

5. ACKNOWLEDGEMENTS

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