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Basic Study on Removing Unburnt Carbon from Fly Ash by Ore Flotation to Use as Concrete Admixture

Kazuyuki Miura, Koji Takasu, and Yasunori Matsufuji

Graduate student, The University of Kitakyushu. Associate Professor, Department of Architecture, Faculty of Environmental Engineering, The University of Kitakyushu, Dr. Eng. Professor, Department of Architecture, Faculty of Environmental Engineering, The University of Kitakyushu, Dr. Eng. 1-1 Hibiikino, Wakamatsu,Kitakyushu,Fukuoka, 808-0135, Japan. E-mail: <m09e2401@hibikino.ne.jp>, <takasu@env.kitakyu-u.ac.jp>, <matsufuji@env.kitakyu-u.ac.jp>.

ABSTRACT

When we use fly ash as a concrete admixture, unburnt carbon in fly ash can't be ignore. Many quantities of unburnt carbon in fly ash inhibit air entraining performance and fluidity of flesh concrete. In this study, we made a device to remove unburnt carbon from fly ash by ore flotation and checked the performance of the device by experiments. The conclusions are as follows, it was clarified that to remove unburnt carbon, the method which circulated water was more effective than the method which didn't circulate water. The element of the tail ash was not too different from an untreated ash except for the decrease of unburnt carbon. The pH of tail ash was lower as compared with that of untreated ash. Compressive strength of mortal contained tail ash was equivalent to that of mortal contained fly ash which was able to use without being treated.

INTRODUCTION

In order to supply a basis to develop sustainable eco-buildings and eco-cities in the future, considering the resources circulation and the preservation of the environment, it is necessary to establish a building materials recycling technologies. While coal is more carbon dioxide emissions than other fossil fuels, coal reserves are rich and coal is widely reserved around the Pacific Rim. So in resource-poor Japan, coal is an important fuel for power generation. Coal consumed amount about 9,826 million tons for power generation in Japan in 2006 and it has increased about 2 times in 10 years. When burning coal, residues left about 10 weight percent. Residue remains in the boiler or is discharged outside boiler. This is fly ash and emissions have been increasing with the increase of coal consumption. In terms of environmental protection, sustainable development and construction of a recycling society, utilization of large amounts of fly ash is important subject.

The authors clarified [Matsufuji and Koyama 1997] that the concrete using fly ash as not a part of cement but a part of fine aggregate was more excellent in strength properties than the concrete using no fly ash mixture. In Japan, fly ash is standardized by its quality in JIS (Japanese Industrial Standards) and it is provided from fly ash "Ⅰ" specific to fly ash "Ⅳ"specific. When we use fly ash as a concrete admixture, we need to consider the quality of fly ash, in particular unburnt carbon in fly ash. Many quantities of unburnt carbon in fly ash inhibit air entraining performance and fluidity of flesh concrete [Architectural Institute of Japan 1999]. In this study, we made a device to remove unburnt carbon from fly ash by ore flotation and checked the performance of the device by experiments. Besides we analyzed treated fly ash to know the condition of fly ash after ore flotation and made mortar contained treated fly ash and checked the mortar's compressive strength.

EXPERIMENTAL INVESTIGATION

Materials

Table-1 shows materials. We used fly ash discharged from 3 different coal-fired power plants. Ash a-2, a-3, a-5, a-6, and ash a-7 correspond to fly ash "Ⅱ"specific, ash a-4, b-1, b-2, b-3, and ash c correspond to fly ash "Ⅲ"specific, ash a-1 corresponds to fly ash "Ⅳ"specific [Japanese Standards Association 2002]. Ash b-4 doesn't correspond to JIS standards [Japanese Standards Association 2002].

Table 1. Materials

Kinds of ash	a-1	a-2	a-3	a-4	a-5	a-6
Ignition loss (%)	0.72	0.42	1.30	6.99	3.86	2.22
Density (g/cm^3)	2.30	2.27	2.29	2.30	2.24	2.25
Kinds of ash	a-7	b-1	b-2	b-3	b-4	c
Ignition loss (%)	1.77	5.87	7.39	7.85	12.92	7.04
Density (g/cm^3)	2.19	2.12	2.27	2.37	2.24	2.07

Methods

Ore flotation

To remove unburnt carbon from fly ash, we used three devices.

In experiment 1, we used aeration tube. Used fly ashes are ash a-1 to ash a-6. Figure 1 shows medium flotator using 2 aeration tubes. This is the device to carry out ore flotation. We used kerosene as a scavenger which gathered unburnt carbon and pine oil as a frother. Doing ore flotation with Kerosene and pine oil makes fros ash which contains many unburnt carbon. Fros ash floated with bubble. Experimental procedure was as follows;

1. Stirred flotation agents (kerosene and pine oil) and water by this device for 5 minutes.
2. Added fly ash and stirred for 5 minutes.
3. Started aeration and removed fros ash.
4. Dried tail ash collected in the bottom of the device out and measured ignition loss.

In experiment 2, we used micro bubble generator. Used fly ashes are ash b-1 to ash b-4. Figure 2 shows micro bubble generator. Experimental procedure was as follows;

1. Put flotation agents and water into mixer and stirred 1 minute.
2. Put the solution and fly ash into beaker and carried out ore flotation.
3. Dried tail ash and measured ignition loss.

In experiment 3, we used micro bubble circulation device. Figure 3 shows micro bubble circulation device. Figure 4 shows opening and shutting unit and micro bubble generation nozzle. The mechanism of the device we made is that circulates water by pump and carries out ore flotation. Used fly ashes are the same as experiment 2. Experimental procedure is as follows;

1. Put flotation agents and water into mixer and stirred for 1 minute.
2. Put the solution and fly ash into the device and carried out ore flotation.
3. Dried tail ash and measured ignition loss.

Adopting micro bubble, fros ash floats with micro bubble without intermission and tail ash accumulates in the bottom of the device as time passes on.

In experiment 4, we carried out ore flotation in the same way of experiment 3. However, experiment 4 was different from experiment 3 in that whether we stirred solution and fly ash by mortal mixer. Experimental procedure is as follows;

1. Put flotation agents and water into mixer and stirred 1 minute.
2. Put the solution and fly ash into mortal mixer and stirred.
3. Turned the solution into the device and carried out ore flotation.
4. Dried tail ash and measured ignition loss and pH.

Fig.1. Medium flotator

Fig.2. Micro bubble generator

Fig.3. Micro bubble circulation device

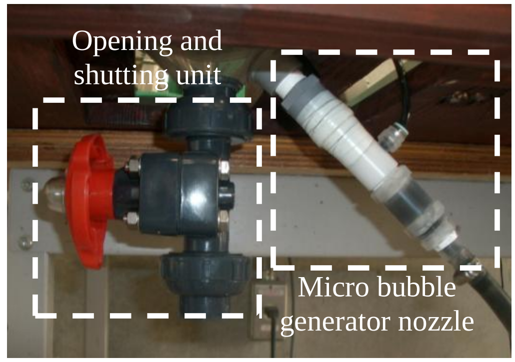

Fig.4 Opening and shutting unit and micro bubble generation nozzle

Properties of tail ash

To compare conditions between untreated ash and tail ash, we took ash a-1 as an object of analysis. We checked elements of tail ash by fluorescent x-ray analyzer. Moreover, to observe particle shapes of untreated ash and tail ash about ash b-3, we took a photo by scanning electron microscope.

Compressive strength of mortal

Materials

Table 2 shows materials. We used ash a-7 and ash c for mortal. We used ash a-7 as a state of powder, and ash c as a state of slurry. Concentration of slurry was 69.12%.

Table 2. Materials

	Type	Density (g/cm^3)	Absorption (%)	Sign
Cement	Ordinary portland cement	3.16	—	C
Water	Tap water	1.00	—	W
Fine aggregate	Sea sand	2.54(oven dry)	1.55	S

Mix proportions

Table 3 shows the mix proportions of mortal. The unit water content for all mixes was $185kg/m^3$ which was the upper limit of JASS5 (Japanese Architectural Standard Specification 5: Reinforced Concrete Work) [Architectural Institute of Japan 2009]. The water/cement ratio for all mixes was 0.65. After determination water/cement and fly ash (=W/B), we determined content of fly ash. We used fly ash as not a part of cement but a part of fine aggregate.

Table 3. Mix Proportions of mortal

Symbol	W/C (%)	W/B* (%)	Unit content (kg/m^3)				AD (%)
			W	C	S	FA	
65-65	65	65	185	285	841	0	0.2
N65-35		35			561	244	0.3
S65-35							0.6

*W/B: the ratio of weight of water to the weight of cement and fly ash

Method

For each mix, we used 50mm in diameter and height 100mm cylindrical moulds made of plastic and kept in a room at 20℃ and 60% RH for 24 h until demoulding. Then specimens were placed in water at 20℃ for a total curing period of 7 or 28 days. Examination of compressive strength of mortal conformed to JIS A 1108 [Japanese Standards Association 2002]. Method of mixing mortal is as follows:

1.Put cement, fly ash (fly ash slurry), sand, water, and admixture into mortal mixer and stirred at low speed (rotation speed:140±5 rev/min, revolution speed:62±5 rev/min) for 1 minute.
2.Stopped stirring for 30 seconds and stirred again at high speed (rotation speed:285±10 rev/min, revolution speed:125±10 rev/min) for 90 seconds.

RESULTS AND DISCUSSIONS

Ore flotation

Figure 5 shows the result of experiment 1. When we carried ore flotation using aeration tube, all of ignition loss of tail ash was larger than those of untreated ash. This might be because average bubble diameter which occurred from aeration tube was relatively large (about 200 micro meters), as it turned out it was difficult to catch unburnt carbon and come to the surface. So it was clarified that it was difficult to reduce rate of ignition loss by doing ore flotation using aeration tube.

Figure 6 shows the result of experiment 2. All of tail ash was lower than those of untreated ash. Different from experiment 1, average bubble diameter which occurred from micro bubble circulation device was about 40 micro meters. Accordingly, it was likely that size of bubble affected ore flotation.

Figure 7 shows the comparison of experiment 3 and 4. In the case of no stirring by mortal mixer, tail ash was a little lower than untreated ash, but not all ashes were lower than 5%. In the case of stirring by mortal mixer, all of ignition loss of tail ash was lower than 5%. In particular about ash b-4, untreated ash didn't correspond to JIS standards [Architectural Institute of Japan 1999], but ignition loss of tail ash reduced up to less than the value provided JIS standards [Architectural Institute of Japan 1999]. Therefore when we carried out ore flotation using micro bubble, it was clarified that to remove unburnt carbon from fly ash effectively, stirring fly ash before ore flotation was better.

Figure 8 shows the comparison of value of pH. All value of pH of tail ash reduced compared to untreated ash by doing ore flotation. This is because free calcium oxide in fly ash neutralized with carbon dioxide in the air. Therefore there is a possibility of effect reducing value of pH of fly ash by doing ore flotation.

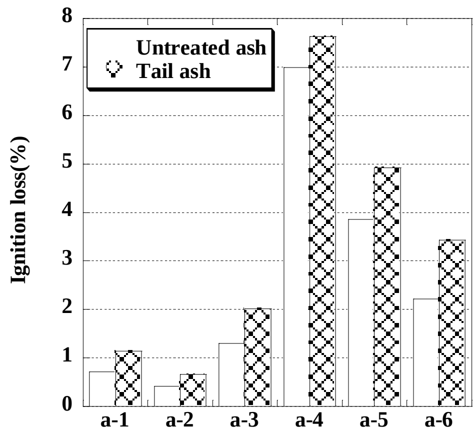

Fig.5. Experiment 1

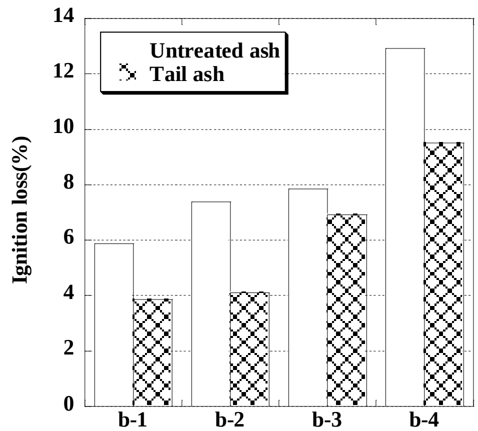

Fig.6. Experiment 2

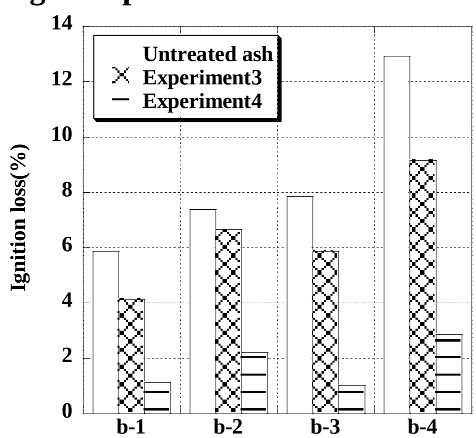

Fig.7. Experiment 3 and 4

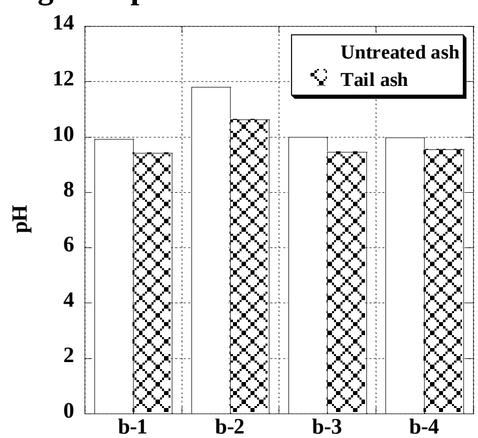

Fig.8. Value of pH

Properties of tail ash

Figure 9 shows comparison of elements between untreated ash and tail ash. We can from figure 9 that rates of iron (III) oxide and aluminum oxide of tail ash were larger than those of untreated ash. This may be because heavy elements accumulate by doing ore flotation. However, these elements don't quite affect concrete. In consequence, it was clarified that ore flotation hardly affected elements of fly ash.

Compressive strength of mortal

Figure 10 shows compression strength of mortal. Using fly ash, compressive strength of mortal was higher than that of mortal using no fly ash. There was little difference between D65-35 and S65-35. Accordingly, it was found from the result that compressive strength of mortal using fly ash which was necessary to be treated was the same as that of mortal using fly ash which wasn't necessary to be treated.

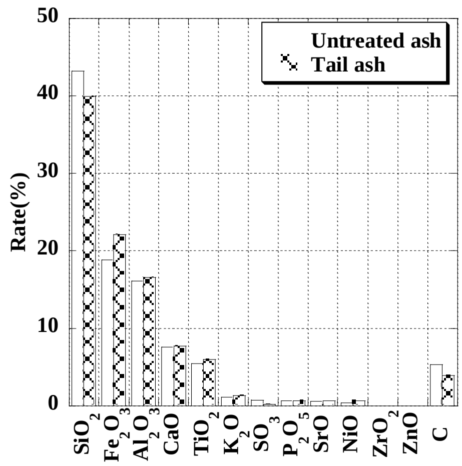

Fig.9. Elements

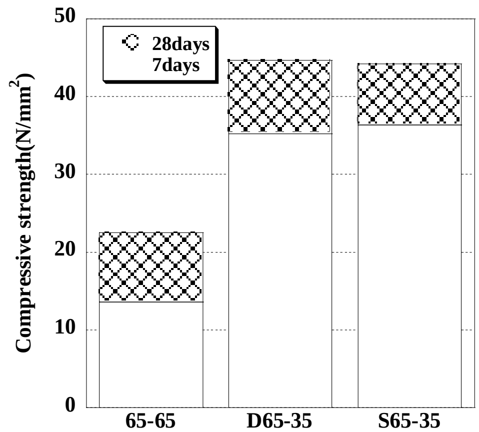

Fig.10. Compressive strength of mortal

CONCLUSIONS

The following conclusions can be drawn from the study provided in the paper:

- It was difficult to reduce rate of ignition loss by doing ore flotation using aeration tube.
- Size of bubble affected ore flotation and it was possible to remove unburnt carbon from fly ash effectively by using micro bubble circulation device.
- There is a possibility of effect reducing value of pH of fly ash by doing ore flotation.
- Ore flotation hardly affected elements of fly ash.
- Compressive strength of mortal using fly ash which was necessary to be treated was the same as that of mortal using fly ash which wasn't necessary to be treated.

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