Fifth International Conference on Sustainable Construction Materials and Technologies. http://www.claisse.info/Proceedings.htm

A STUDY ON WET CLASSIFICATION METHOD OF FLY ASH AND PHYSICAL PROPERTY OF CLASSIFIED FLY ASH

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ABSTRACT

The authors have developed an unburned carbon of fly ash removal device by flotation method. In this study, to contribute to modified fly ash slurry quality further improvement, we considered wet classification method of modified fly ash slurry and examined property of mortar with classified fly ash. About fresh properties of mortar, the use of m-FA which is smaller than average particle diameter of cement had fluidity improvement by filling void. The pozzolanic reactivity was improved due to the fact that the total proportion of the SiO_2 content and the Al_2O_3 content of m-FA increased and finely even particles concentrated, so the activity index at 28 th and 91 th used m-FA had increased. Therefore, it was shown that the quality of fly ash was possible to be improved by removing unburned carbon in the fly ash and classifying it.

1. INTRODUCTION

Fly ash, which is an industrial by-product of coal-fired power plants, can be used as an admixture for concrete, helping to reduce environmental load and improve concrete quality. In a previous study[1)], we reported a flotation method for removing unburned carbon in fly ash giving modified fly ash as slurry. Japanese Industrial Standardized (JIS A 6201) class II fly ash is classified, but the physical properties of classified modified fly ash slurry have not been clarified.

In this study, to improve the quality of modified fly ash slurry, we examined a wet cyclone classification method for modified fly ash slurry and measured the properties of mortar made with classified modified fly ash slurry.

2. CLASSIFICATION OF FLY ASH

2.1 Wet Cyclone Classification Method

There are two kinds of fly ash classification method, dry type and wet type. Dry fly ash classification methods include the gravity method, inertia method, and cyclone method, and wet methods include the gravity method and cyclone method. The wet cyclone method was used in this experiment. For classification, we used a wet three liquid hydrocyclone classification device (TR-10, Murata Kogyo Co., Ltd.). Figure. 1 shows the flow of the classification method. The classification device has bottom, middle, and top nozzles and divides particles into large, medium, and small particle diameters. When the slurry is passed into the hydrocyclone, particles with large specific gravity and particle diameter move to the peripheral wall, and particles with small specific gravity and particle diameter move to the center. A descending flow is generated along the taper of the cyclone in the peripheral wall and particles with large specific gravity and particle diameter are discharged to the bottom nozzle. A rising flow occurs in the center, and particles with small specific gravity and particle diameter are discharged to the top nozzle. Therefore, the particles can be separated, classified, and concentrate[2).

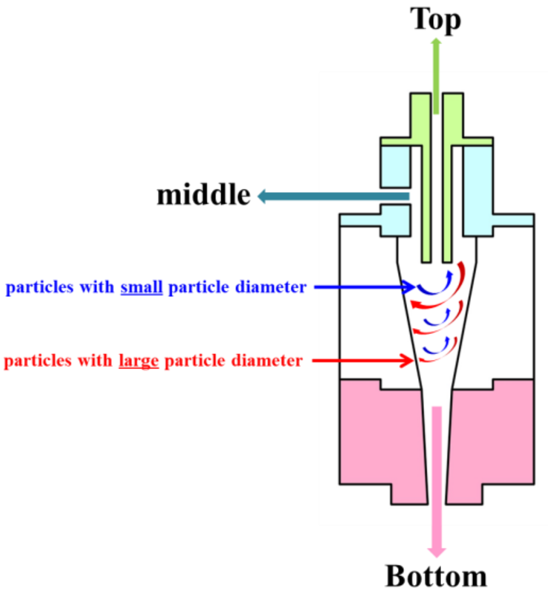


Figure. 1 The flow of the classification method[2)

2.2 Classification Experiment

Fly ash O1 was Japanese Industrial Standardized (JIS A 6201) class II fly ash, fly ashes O2 and O3 were produced at different private power plants, and modified fly ashes M2 and M3 were fly ashes O2 and O3 modified by the floatation method, respectively. The losses on ignition for M2 and M3 were less than 1.0%. b-FA, m-FA, and t-FA were fly ash samples discharged from the bottom, middle, and top of the hydrocyclone classification device, respectively. The top nozzle sizes are 3, 2.5, and 2 mm; the middle nozzle size is 2 mm; and the bottom nozzle sizes are 3, 2.5, 1.5, and 1 mm. We examined the nozzle size used in following experiment. Classification was carried out by changing the combination of nozzle sizes using slurries of fly ash O1 with a concentration of 10%. After the nozzle size was determined, fly ashes O1, O2, O3, M2, and M3 were classified.

2.3 Results and Discussion of Classification Experiment

2.3.1 Setting the Nozzle Size

Figure. 2 shows the particle diameter distribution of O1 with different nozzle size settings, including that of ordinary Portland cement (OPC). Table 1 shows the nozzle size and physical properties of O1. Combinations of nozzle sizes satisfying the three conditions were also used in following experiments. The mode diameters of classified O1 from the top, middle, and bottom nozzles increased in the order O1-t, O1-m, and O1-b. The standard deviations of O1-t, O1-m, and O1-b were smaller than O1 before classification (standard deviation of O1: 15.39 μm) and the loss rate was small. The setting B1.5-T3 (bottom: 1.5 mm; middle: 2 mm; top: 3 mm) met the above conditions. We used this setting in subsequent experiments. t-FA, which had a low yield, was not considered.

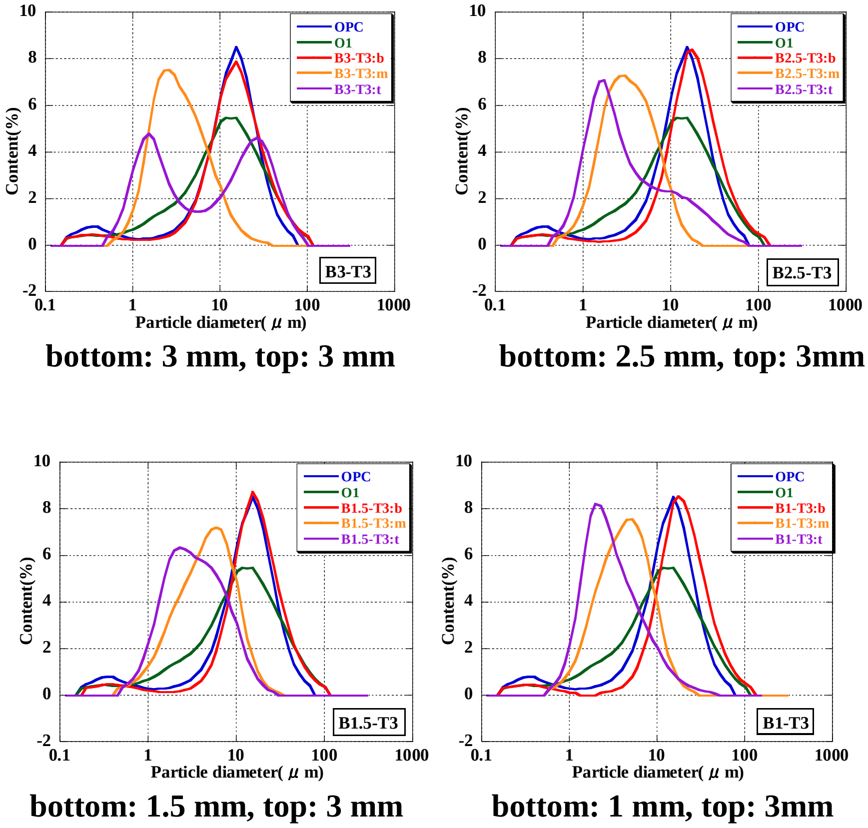


Figure 2. The particle diameter distribution of O1 with different nozzle size settings, including that of ordinary Portland cement (OPC)

Table 1 The nozzle size and physical properties of O1

	Nozzle size	Standard deviation (μm)	Mode diameter (μm)	Yield (%)	Loss (%)
B3-T3	Bottom 3mm	14.77	14.17	77.4	8.8
	Middle 2mm	3.60	2.42	12.7	
	Top 3mm	15.82	1.41	1.1	
B2.5-T3	Bottom 2.5mm	16.20	16.21	74.6	6.7
	Middle 2mm	2.69	2.78	17.2	
	Top 3mm	8.31	1.61	1.4	
B1.5-T3	Bottom 1.5mm	14.21	14.22	69.5	6.4
	Middle 2mm	3.81	5.48	21.9	
	Top 3mm	3.45	2.12	2.2	
B1-T3	Bottom 1mm	16.49	16.25	66.8	6.2
	Middle 2mm	3.37	4.78	23.5	
	Top 3mm	4.27	1.86	3.5	

2.3.2 Classification Characteristics for Original Fly Ash

Table 2 shows the physical properties of each type of fly ash. For all the types of fly ash, the loss on ignition of t-FA tended to be higher because the fine particles of unburned carbon were discharged to the top nozzle. The yields were different for each type of fly ash. O2 tended to clog the bottom nozzle and had the highest loss rate. Figure. 3 shows the particle diameter distribution of each type of fly ash and OPC. For all the types of fly ash, when the average particle diameter before classification was larger than the mode diameter, the mode diameter of b-FA was larger than the mode diameter before classification. The standard deviation after classification for O3, which had the highest loss on ignition before classification, was higher than that for the other types of fly ash, and the particle diameter range of O3 was wide.

Table 2 The physical properties of each type of fly ash

FA	Density (g/cm^3)	Blaine specific surface area (cm^2/g)	ig.loss (%)	BET specific surface area (m^2/g)	specific surface area (cm^2/cm^3)	Average particle diameter (μm)	Mode particle diameter (μm)	Standard deviation (μm)	Yield (%)	Loss (%)
O1	2.16	5540	2.12	1.1	18937	15.13	10.82	15.39	—	—
O1-b	—	4180	3.30	6.1	13179	17.96	14.22	14.21	60.1	1.5
O1-m	2.31	6580	2.89	2.9	20437	5.24	5.48	3.81	29.9	
O1-t	—	—	3.88	5.2	25646	4.15	2.12	3.45	8.5	
O2	2.11	6010	4.22	2.2	7484	29.60	36.61	29.62	—	—
O2-b	2.10	4430	4.20	3.3	6399	29.22	24.39	24.46	61.0	15.2
O2-m	2.18	7130	4.10	3.5	20808	5.07	3.65	4.78	18.5	
O2-t	—	—	5.24	4.8	40966	4.85	1.61	8.83	5.3	
O3	2.24	5050	9.03	4.4	16087	22.82	10.79	24.84	—	—
O3-b	2.18	4230	8.96	6.3	13694	29.10	14.21	27.90	67.5	2.0
O3-m	2.24	6840	8.90	3.4	34072	6.84	6.27	7.72	28.8	
O3-t	—	—	12.11	8.2	41793	5.41	1.85	7.91	1.6	
M2	2.19	7150	0.21	0.6	9702	28.93	36.61	29.98	—	—
M2-b	2.11	4310	0.24	1.0	9621	29.93	27.91	24.96	66.0	8.3
M2-m	2.24	8150	0.99	2.2	20549	4.53	4.18	3.16	13.2	
M2-t	—	—	0.89	0.7	29550	4.05	1.84	6.78	12.5	
M3	2.28	5610	0.94	2.0	24757	18.14	10.78	22.14	—	—
M3-b	2.17	4790	0.58	2.6	19227	15.75	14.12	12.38	69.2	8.0
M3-m	2.27	6830	1.68	5.3	36580	3.87	4.18	2.86	17.4	
M3-t	—	—	4.07	9.0	27643	5.27	1.84	7.79	5.4	

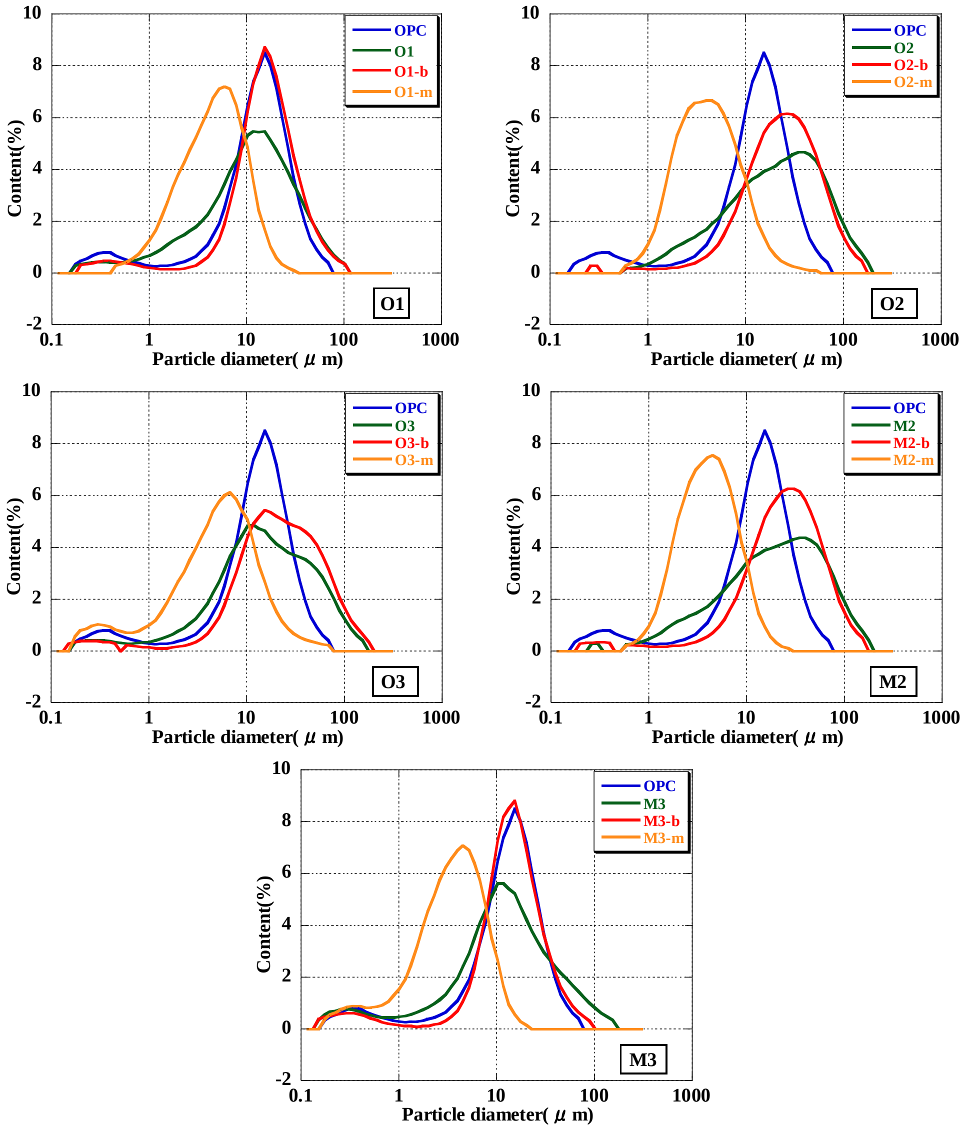


Figure 3. The particle diameter distribution of each type of fly ash and OPC

3. CHARACTERISTICS OF CLASSIFIED FLY ASH

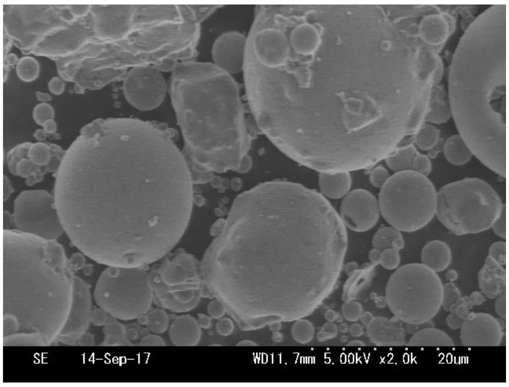
3.1 Summary of Experiments

The percent flow and activity index were measured according to JIS A 6201 Annex 2, "Test method of percent flow and activity index by mortar of fly ash". OPC, standard sand, and tap water were used to fabricate the mortar samples.

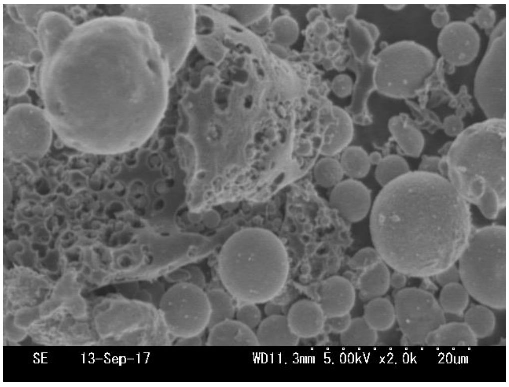
3.2 Experimental Results and Discussion

3.2.1 Physical Properties

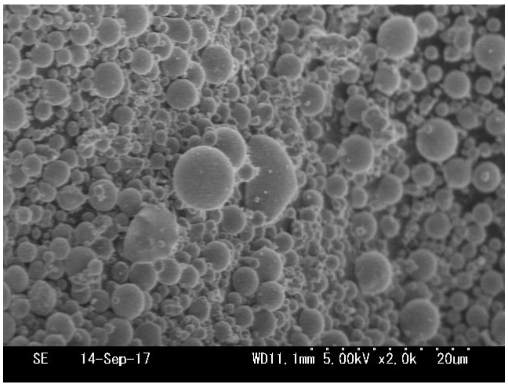
Table 2 shows that for all the types of fly ash, after classification, the Blaine specific surface area of b-FA decreased and that of m-FA increased. The loss on ignition of M2-m and M3-m tended to increase. Figure. 4 shows the scanning electron microscopy image of M3. Modification reduced the number of porous particles and smoothed the particle surface. For all the types of fly ash, particles with large particle diameters gathered at bottom nozzle and fine and homogeneous particles gathered at the middle nozzle during classification. In general, chemical reactions accelerate when the particles are finely and homogeneously distributed. Therefore, classification of modified fly ash is expected to improve pozzolanic reactivity.



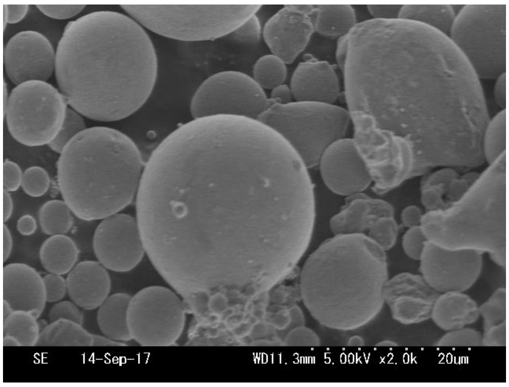
O3



M3



M3-b



M3-m

Figure. 4 The scanning electron microscopy image of M3

3.2.2 Chemical Properties

Figure. 5 shows the chemical composition of the samples. The total proportions of SiO_2 and Al_2O_3 were higher in b-FA than in m-FA, except for fly ash O3. The proportions in the original fly ash and classified fly ash for O1 were slightly lower than in other fly ashes. In general, because of the high amount of SiO_2 and Al_2O_3 in b-FA, it had higher pozzolanic reactivity than m-FA[3].

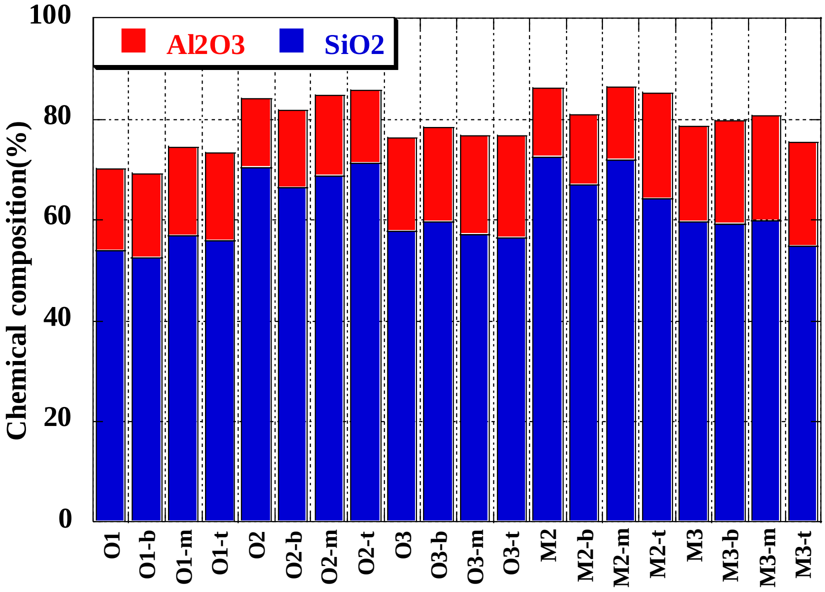


Figure. 5 The chemical composition of the samples

3.2.3 Percent Flow and Activity Index

Figure. 6 shows that, except for M3, the percent flow of m-FA was higher than that of the fly ash before classification. Figure. 7 shows the relationship between average particle diameter and percent flow. The broken line indicates the average particle diameter of the cement (14.36 µm). For all the types of fly ash, the percent flow of m-FA was higher than that of b-FA. m-FA improved fillability and increased fluidity m-FAbecause it has had a smaller average particle diameter than cement. Figure. 8 shows the relationship between the Blaine specific surface area and percent flow. The broken line shows the Blaine specific surface area of the cement (3480 cm2/g). For all the types of fly ash, the percent flow of m-FA, which had the smaller Blaine specific surface area than b-FA, was higher than that of b-FA. It was difficult to evaluate the percent flow with respect to fillability because the Blaine specific surface area of cement was smaller than that of all the types of fly ash.

Figure. 9 shows the activity index of the samples. O1 is Japanese Industrial Standardized (JIS A 6201) class II fly ash; however, the activity index at 28 days of only O1-m was more than 80%. When the curing temperature was 20 °C, after 28 days, the pozzolanic reactivity rate of fly ash was only a few percent. Therefore, a standard value of 80% or more is a strict specification[4]. Except for O1-b and M2-b, the activity index at 91 days conformed to JIS class II or class I equivalents. Figures. 10 and 11 show the relationship between the average particle diameter and the activity indexs at 28 and 91 days, respectively. The activity index at 28 days of m-FA, which had a smaller average particle diameter than b-FA, was higher than that of b-FA. The same trend was observed for the activity index at 91 days, except for O3. As mentioned in the previous section, the pozzolanic reaction was accelerated because the total proportion of SiO_2 and Al_2O_3 in m-FA was high and m-FA was fine and homogeneous. The total proportion of SiO_2 and Al_2O_3 in O1 was lower than in the other types of fly ash, and the pozzolanic reaction did not progress; thus, the activity index of O1 did not increase from 28 to 91 days.

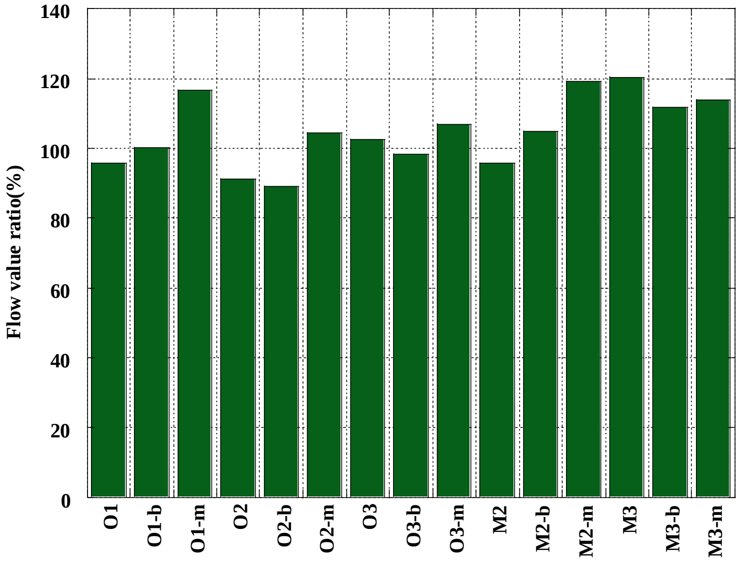


Figure 6. Percent flow of the samples

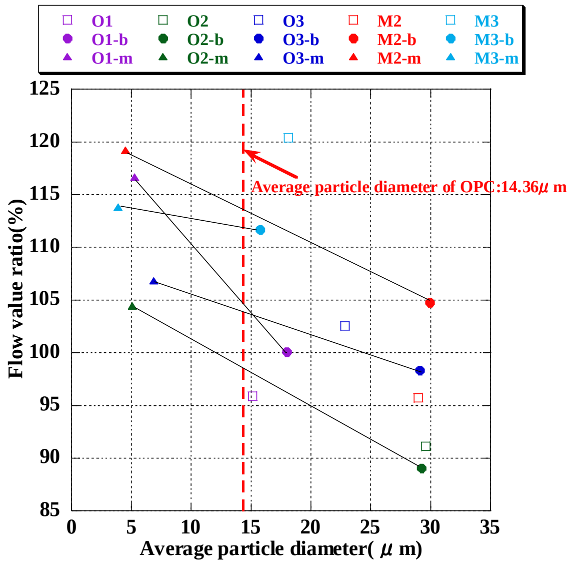


Figure 7. The relationship between average particle diameter and percent flow

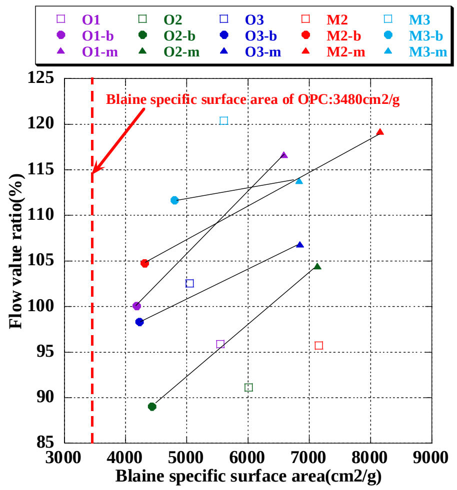


Figure 8. The relationship between the Blaine specific surface area and percent flow

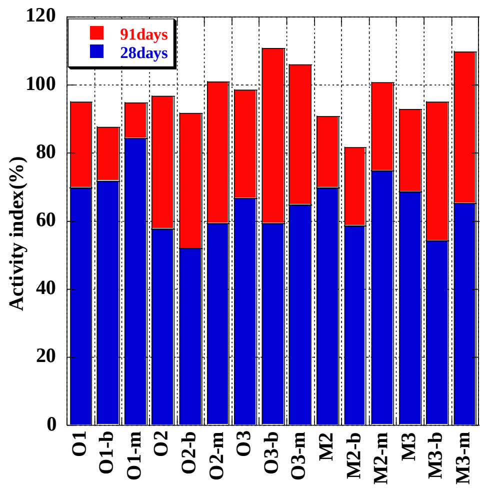
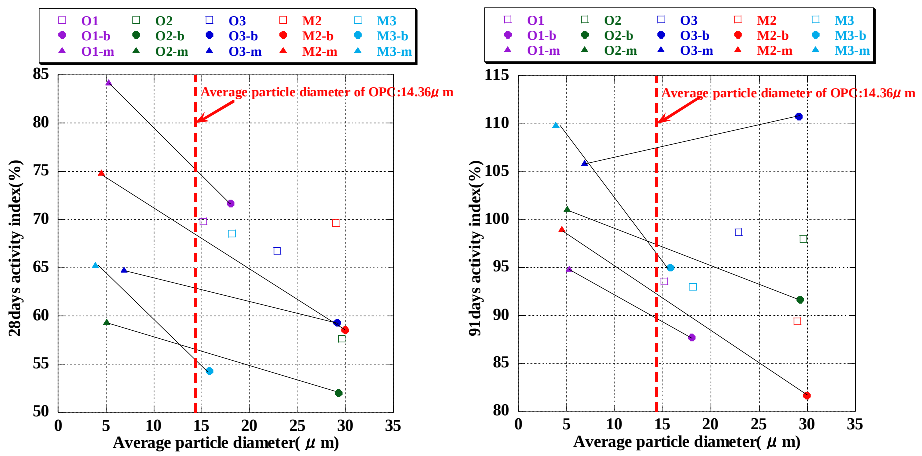


Figure 9. The activity index of the samples



Figures 10 and 11. The relationship between the average particle diameter and the activity indexs at 28 and 91 days

4. CONCLUSION

In this study, we examined a wet classification method for fly ash slurry and measured the properties of mortar made with classified fly ash. For all the types of fly ash, the loss on ignition of t-FA tended to be higher because the fine particles of unburned carbon were discharged from the top nozzle. In fresh mortar, m-FA improved fillability and increased fluidity because m-FA had a smaller average particle diameter than the cement. The pozzolanic reaction was accelerated because the total proportion of SiO_2 and Al_2O_3 in m-FA was high and m-FA was fine and homogeneous. Thus, the activity index of m-FA at 28 and 91 days were higher than those for b-FA. Our results showed that the quality of fly ash could be improved by removing unburned carbon in fly ash and classifying the fly ash further.

ACKNOWLEDGEMENTS

This research was financially supported by Environmental Restoration and Conservation Agency (ERCA) No.3-1703 “Development of advanced recycling technology for fly ash to enable cement-free concrete”. The authors acknowledge the assistance in this work provided by Mr. Eiji Mikura, Mr. Masaru Fukuda.

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