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A STUDY ON PROPERTIES OF CONCRETE WITH DRY FLY ASH AND FLY ASH SLURRY STORED WITH STIRRING

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Abstract.

In the evaluation of concrete sustainability, what constitutes "sustainable" to one region may vary from another. This often leads to methodological forms of uncertainties that makes the evaluation process more complex. As such, this paper aims to quantify the effect of uncertainties in the regional context on the sustainability evaluation of concrete materials. This is carried out by quantifying the regional context through establishing a weighting scheme and then integrating the obtained weights into the sustainability analysis of concrete materials in tandem with uncertainty analysis. Japan is used as a case study because although it relatively appears as a homogeneous country, its prefectures possess unique characteristics that may make the sustainability evaluation of concrete materials vary across prefectures. Cluster analysis is carried out in the 47 prefectures of Japan using a set of regional context indicators. Five clusters are identified with varying characteristics and these are translated into different weighting schemes. The established weights are used in the sustainability evaluation of concrete materials using multi-criteria decision-making analysis. The results showed that one mix is the most sustainable for four of the clusters and a different mix is the most sustainable for the remaining cluster. When uncertainty analysis is conducted, the effect of the weights in the sustainability evaluation is explained by examining the average scores of the concrete mixes and the variance of the scores across the five clusters. This investigation facilitated the understanding of how regional differences and the uncertainties associated with it impact the evaluation of concrete sustainability.

Keywords: Dry powder, flow, fly ash, fresh properties, slump, slurry.

1. Introduction

As a previous study, we invented a device to remove unburned carbon by Flotation Method. Since the flotation method immerses the fly ash in water for treatment, it is necessary to verify the influence of the slurry of the fly ash on the concrete. Therefore, in this study, fly ash from three different sources was stirred and stored for 1-28 days, and the physical changes of the three substances stored under this condition were recorded, and the freshness of the concrete using dry powder was confirmed. And check the usefulness of the slurry.

2. Experimental summary

2.1. Material used

Table 1 lists the different properties of the three fly ash. In this experiment, fly ash A, B and C from three different sources were used. They all conform to the class II specified in JISA6201. The dry powder and the slurry are respectively used as a mixture in the concrete, and the preparation method of the slurry is: The concentration was adjusted to $60 \pm 1\,\%$ using an infrared moisture meter, placed in a 90 L vessel, and stirred at a rotation speed of 60 rpm to prevent sedimentation. For the samples used for the slurry, the B and C ash were respectively stirred for 7 days, stored and reused, A ash was added on the 7th day, and samples were taken at 1, 3, 14 and 28 days. When used as a mixed material, after measuring the slurry concentration using an infrared moisture meter before putting it in, in order to meet the unit water volume of the preparation, add insufficient water, than start stir.

In addition, the slurry concentration before the input showed some change after the initial adjustment, but there was no particularly significant change. Table 2 shows the materials used.

We use ordinary Portland cement as cement, sea sand as fine aggregate and gravel as coarse aggregate. Concrete mixing was carried out in a mixing chamber at a temperature of $20°\,C \pm 1$ using a forced biaxial mixer with a target air volume of $4.5 \pm 1.0\,\%$ and a target slump of 18.0 ± 2.5 cm. In addition, regarding the external weight of 120 kg/m^3 , high fluidity concrete was used, and the target slump flow amount was 50 ± 5 cm. Table 3 shows the mix ratio of concrete. In this experiment, the unit water volume is 180 kg/m^3, the fine aggregate rate is fixed at 45%, and the fly ash is used as an internal substitute for cement replacement, replacing 10, 20, 30%, using 120 kg/m^3. Ash was used as a substitute for fine aggregates and experiments were performed by external replacement. In addition, in the B and C ash, the slump and compressive strength tests were carried out at an internal replacement rate of 20%.

Symbol	Tape	State	Before the exam slurry concentration (%)	Period	Loss on ignition (%)	Density (g/cm^3)	Brain specific surface area	BET specific surface area (m^2/g)	Work up temperature ($^\circ$ C)	Slump flow (Right after)	Slump flow (30min)	Slump flow (60min)	Slump flow (90min)	Slump flow (120min)	Air volume (immediately after) (%)	Air volume Reduction rate (%)	Admixture (%)
P	–	–	–	–	–	–	–	–		18.2	17.2	17.0	14.4	13.5	5.0	50.0	0.4
A		–	–	–	1.3	2.3	4000	–		–	–	–	–	–	–	–	–
A1d-20in		S	60.5	1d	2.0	–	–	3.2		20.4	19.0	18.8	17.0	15.9	4.1	46.3	
A3d-20in		S	60.4	3d	2.2	–	–	3.1		20.3	19.7	18.5	18.0	18.2	3.5	40.0	
A7d-10in		D	–		–	–	–	–		18.4	18.2	17.9	15.3	13.3	4.0	52.5	0.4
	A	S	59.6		2.3	–	–	4.4		18.2	13.7	14.6	12.0	8.2	5.0	38.0	
A7d-20in	A	D	–		–	–	–	–		18.7	17.5	18.7	16.6	18.3	3.9	35.9	
		S	60.4	7d	2.3	–	–	4.4		19.3	16.8	17.3	15.5	15.5	4.1	36.6	
A7d-30in		D	–		–	–	–	–		19.8	19.6	18.5	17.5	16.5	3.5	40.0	0.6
		S	60.2		2.3	–	–	4.4		20.3	19.1	18.0	17.0	16.0	3.8	47.4	
A7d-120out		D	–		–	–	–	–		50.1	50.0	44.0	41.3	38.0	5.4	42.6	0.6 (SP)
		S	61.2		2.3	–	–	4.4		52.6	51.9	44.1	39.8	39.6	5.5	40.0	
A14d-20in		S	60.7	14d	2.3	–	–	2.8		18.8	16.7	14.9	9.4	9.0	3.5	37.1	0.4
A28d-20in		S	61.8	28d	2.4	–	–	3.0		20.5	19.5	18.2	15.7	15.2	4.1	53.7	
B		–	–	–	1.6	2.3	4140	–		–	–	–	–	–	–	–	–
B7d-20in	B	D	–	7d	–	–	–	–		17.7	16.7	14.5	13.3	12.1	3.5	54.3	0.4
		S	60.6		–	–	–	–		19.5	18.2	17.8	15.9	14.2	3.5	40.0	
C		–	–	–	3.0	2.2	3520	–		–	–	–	–	–	–	–	–
C7d-20in	C	D	–	7d	–	–	–	–		20.0	20.0	19.2	17.3	16.6	3.6	30.6	0.4
		S	60.8		–	–	–	–		19.0	19.0	16.6	15.9	15.0	3.6	36.1	

Table 1. Physical properties of fly ash and fresh properties of concrete.

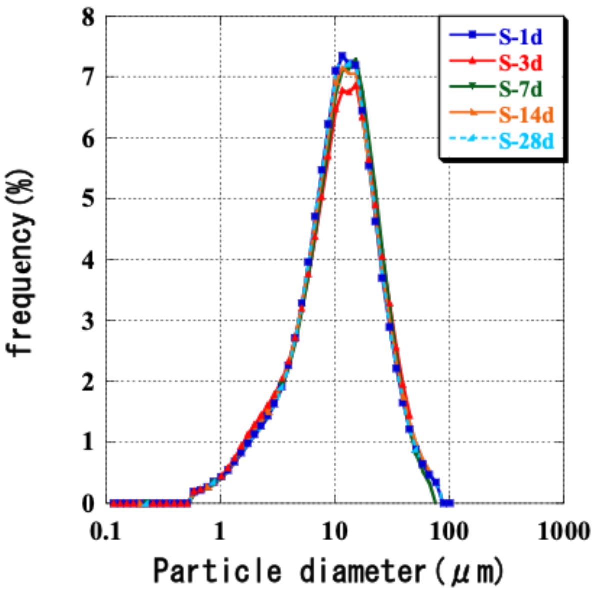

Figure 1. A ash S age every particle size distribution.

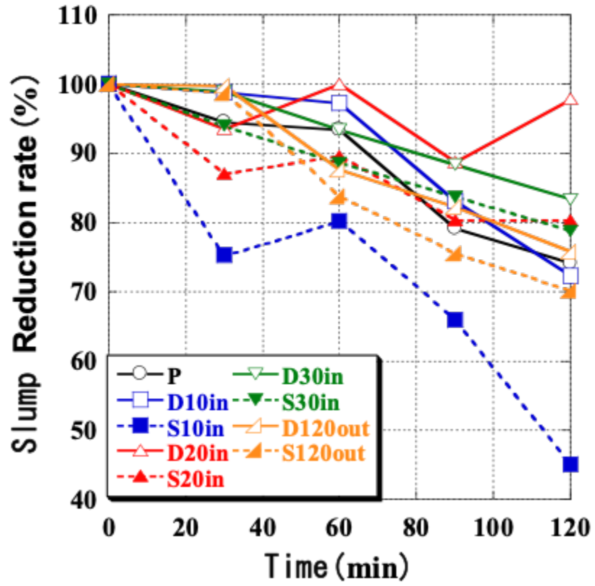

Figure 2. A ash slump.

The dry ash content of fly ash is D, the amount of slurry is S, the internal is replaced by in, and the external is replaced by out. The storage period is 1 day, 3 days, 7 days, 14 days, 28 days, respectively 1d, 3d, 7d, 14d, 28d.

2.2. Experimental project

The measurement items in this experiment are slump and flow. The concrete slump test was carried out in accordance with JISA1101. In order to confirm the change of the measured amount with time, the slump was recorded every 30 minutes for the first 2 hours after the start of the experiment. Use fresh concrete at the beginning and end of the measurement of slump. In addition, the fresh concrete is required to be carried out in a mixing chamber at a temperature of 20° C ± 1° C.

3. Experimental results and consideration

3.1. The physical properties of fly-ash

As shown in Table 1, for the A ash, the BET specific surface area and the strong heat loss were measured according to the age of the different preservation materials, and the former tends to increase as the material aged. Previous studies have shown that the rising trend of JIS II ash has not changed and a similar trend has emerged. However, the latter was the largest at 7d and no change was observed at ages other than 7d. Figure 1 shows the particle size distribution of the slurry of A ash. Previous studies have reported that particles in the range of 0.1 to 1 μm tend to increase by storing the slurry, but there is no similar tendency in the JIS II seed ash of this experiment, and there is no change in particle size.

3.2. Concrete slump-flow

Table 1 shows the results of the experiment, and Figure 2 shows the change in the slump of D of A and the change of S according to time. It can be seen that in addition to S10 in, the slump value at the time of placement was reduced to about 80% after 2 hours. It can be seen that within the scope of this experiment, the quality of the fresh property did not change even when used in D, S, although S10 had been reduced to about 50%. JASS5 (Building Standard Specification) stipulates that if the external temperature is lower than 25 ° C, it will be 120 minutes from mixing to completion, but during this period, the slump of concrete mixed with P and fly ash has the same time-dependent change. As confirmed, it can be considered that the concrete containing the fly ash mixed with S can be appropriately placed. In addition, since it is impossible to clarify the time-dependent change of S10 in slump in this experiment, it will be a future research topic including re-experiment. The A, B, and C ash drop as a function of time as shown in Figure 3 as a function of time. The B and C ash showed the same trend as the A ash 2 hours after the slump value. Within the scope of this experiment, it was found that when the ash type equivalent to the JIS II type is used, the fresh performance of the concrete mixed with fly ash in D and S does not change.

Figure 4 shows the change in 20 in slump over time for S, which was stored for 1, 3 and 14 days with stirring, except for the 7 ash A ash. As a result, the slump value of S using 14d was significantly lowered. From Table 1, the BET specific surface area of each S material age was confirmed, but the S value of 14d was the lowest. Generally, the larger the BET specific surface area, the higher the adsorption rate of the mixture, and the fluidity becomes worse. Further, in the previous study 3), fly ash having a BET spe-

Materials	Type	Physical property	Symbol
Cement	Ordinary portland cement	Density: 3.16 g/cm^3	C
Water	Tap water	–	W
Fine aggregate	Sea sand	Dead density: 2.59 g/cm^3 Water absorption rate: 0.76 % Coarse grain rate: 2.4 Performance rate: 61.2 %	S
Coarse aggregate	Crushed stone	Dead density: 2.59 g/cm^3 Water absorption rate: 1.41 % Coarse grain rate: 6.9 Performance rate: 56.7 %	G
Admixture	High performance AE water reducing agent	Polycarboxylic acid ether system	SP
	AE agent	Alkyl ether anionic surfactant	AE

Table 2. Materials used.

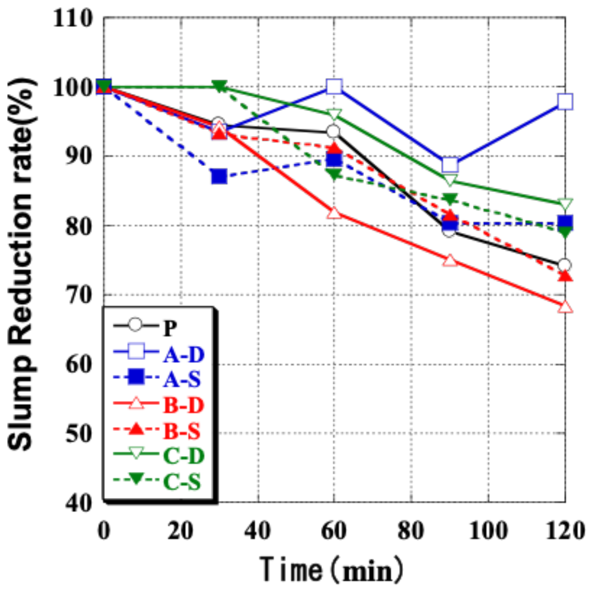

Figure 3. A ash, B ash, C ash, 20in slump.

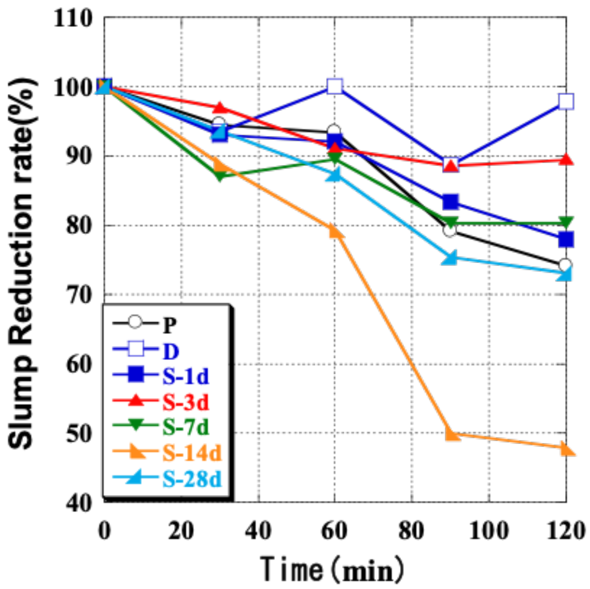

Figure 4. A ash S age every 20in slump.

cific surface area of 3.6 m^2/g or more was considered to be caused by deterioration of fluidity. However, in the 14d having the lowest BET specific surface area, the fluidity deteriorated due to aging. Further, the value of the BET specific surface area fell within the range of the previous study, and the Păof 7d was 4.4 m^2/g, which showed other S ages have the same slump change. From this, it can be considered that the deterioration of the fluidity of S 14d is the most serious, and it is necessary to study this in the future.

3.3. Compressive strength

Figure 5 shows the D and S concrete compressive strengths of A-ash. For 10in and 20in concrete, the initial strength is lower than that of P, At 91 days strength, compressive strength equivalent to P was shown by the pozzolanic reaction of FA. 120out showed greater compressive strength than P due to fine aggregate replacement. A-ash showed a slight difference at 91 days of age, but the compressive strength tended to be higher when it was mixed with concrete in S. Figure 6 shows the compressive strength of 20inch concrete with B and C ash in addition to A ash. In the case of B ash, the compressive strength was higher when mixed with D than when mixed with S, and the results were opposite to those of A and C ash. Figure 7 shows the compressive strength of A ash for each age of slurry agitation storage. By compressing and storing the slurry, the compressive strength increased up to 3 days, and slightly decreased from 7 days, but the value tended to decrease as the storage period became longer. However,

Preparation	s/a %	W	Unit mass (kg/m^3) C	S	G	FA
P			360	773	978	0
FA10in			324	768	971	36
FA20in	45	180	288	763	965	72
FA30in			252	758	958	108
FA120out			360	635	978	120

TABLE 3. Mix proportion.

Acceleration			
Symbol	Condition	W/B (%)	Neutralization rate coefficient (mm/$\sqrt{\text{week}}$)
P	–		3.70
A7d-10in	D		4.76
	S		4.24
A7d-20in	D	50	4.72
	S		4.69
A7d-30in	D		7.13
	S		6.96
A7d-120out	D	38	4.98
	S		4.45

TABLE 4. Neutralization rate coefficient.

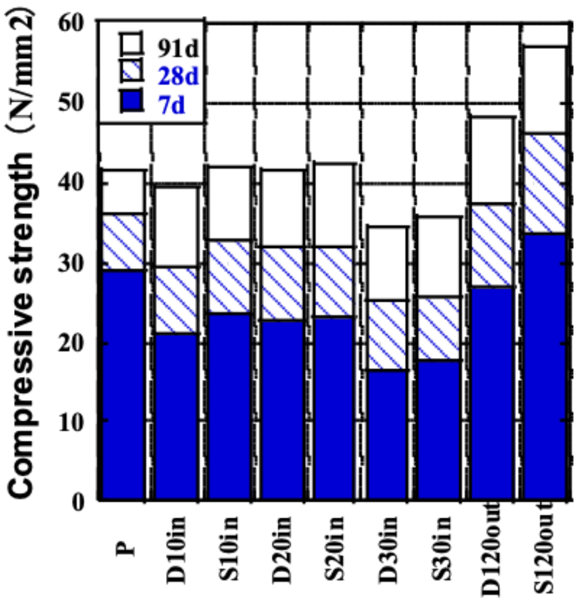

FIGURE 5. A ash compressive strength.

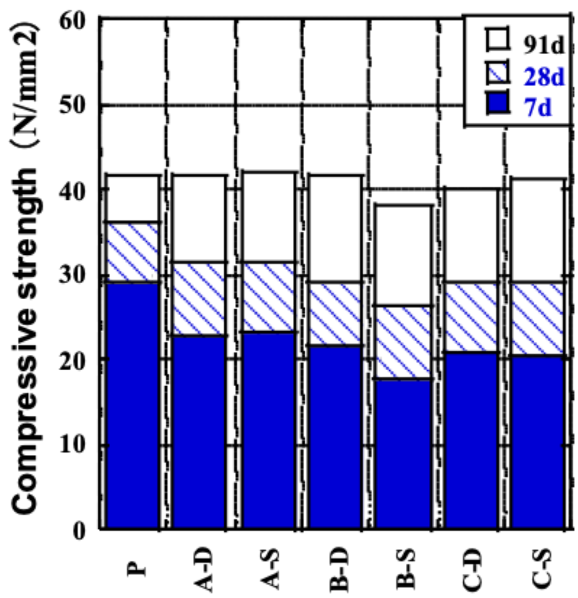

FIGURE 6. A, B, C ash 20in compressive strength.

it showed almost the same compressive strength as P at all ages. As in the case of the slump test, it was clarified that, even within the range of this experiment, the performance was equivalent to that of D even when stored under stirring with S.

3.4. ACCELERATED NEUTRALIZATION

Figure 8 shows the results of the accelerated neutralization test for concrete mixed with D and S in Aǎash, and Table 4 shows the neutralization rate coefficients for each. Compared with P, the carbonation of concrete containing FA was more likely to increase in both D and S. It is considered that the alkali component in the concrete decreased due to the decrease in the amount of cement, and the progress of neutralization was accelerated. Further, In the accelerated neutralization test, a long-term increase in strength due to a volcanic ash reaction was observed in high concentrations of carbon dioxide from an early age, this is probably because the densification of the or-

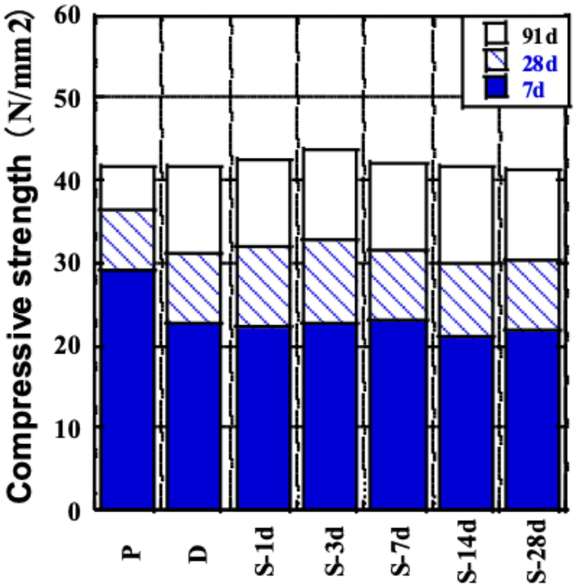

Figure 7. 20-in compressive strength for each age of A-ash S.

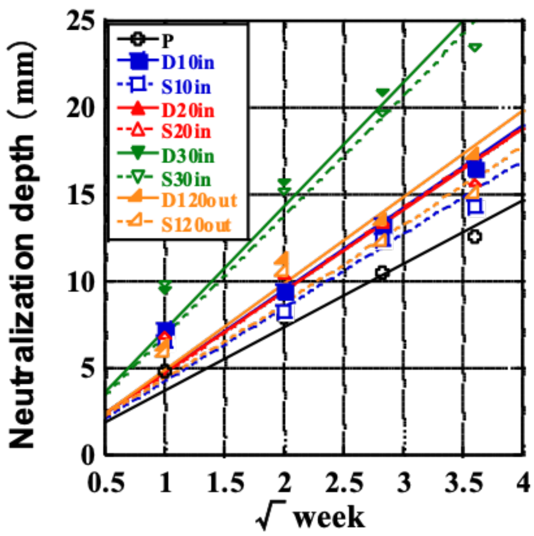

Figure 8. A ash accelerated neutralization.

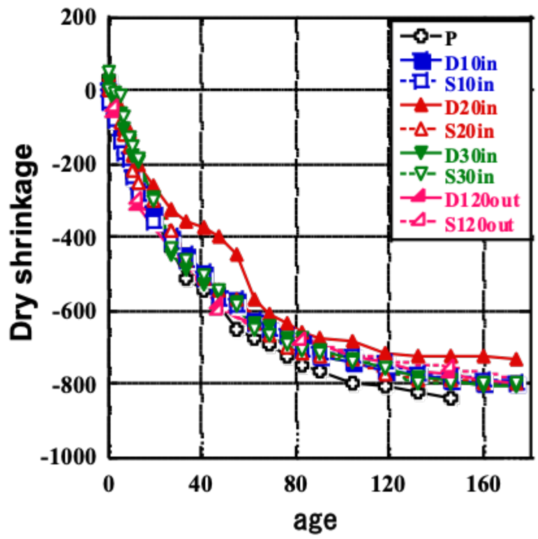

Figure 9. A Ash drying shrinkage.

ganization was not considered.

3.4.1. Drying shrinkage

Figure 9 shows the results of the concrete drying shrinkage test mixed with D and S of the ash. Both D and S showed the same tendency in all formulations from the initial drying shrinkage value to about 4 months. Although slightly smaller than P, the dry shrinkage value tended to be smaller when FA was mixed in all the formulations, indicating the effect of reducing the dry shrinkage of FA.

3.5. Pore structure

Figure 10 shows the change in pore size distribution of A ash 20in, 120out, B ash and C ash 20in with time, divided into four ranges: 0.003μm - 0.05μm, 0.05μm - 0.5μm, 0.5μm - 5μm, 5μm - 100μm. It can be seen that the total pore volume tends to decrease with age for most formulations and ash types. In addition, it can be seen that in all mixtures and ash types, the value of the number of pores in the range of 0.5 to 5 μm and 5 to 100 μm hardly changes as the material ages. In the range of pore diameters from 0.003 to 0.05μm, A-ash 20in showed a slight increase tendency, but B-ash and C-ash did not show any increase or decrease. It can be considered that due to the hydration reaction, large pores with a diameter ranging from 0.05 μm to 0.5 μm transition to small diameters, and the number of pores has not changed significantly, and a similar trend has been observed in previous studies. In addition, it can be seen that the pore volume decreases most in the range of 0.05ăμm to 0.5 μm with the age of the wood, depending on the composition and ash type. From the above, it is inferred that the pore volume in the range of 0.05 μm to 0.5 μm is related to the compressive strength.

Figure 11 shows the relationship between the amount of pores in the range of 0.05 μm to 0.5 μm and the compressive strength. It can be seen that the relationship between the range of 0.05 μm to 0.5 μm and the compressive strength is high in all cases, regardless of the state, type, and composition of the FA. There is a possibility that the compressive strength is increased by decreasing the amount of pores in this range due to the hydration reaction and making the structure denser. Previous studies have shown aă-correlation with compressive strength in the range of 0.03 μm to 0.3 μm, confirming a similar relationship with pore volume. Also, when comparing the amount of pores with the same level of compressive strength, if the amount of pores is the same, the compressive strengths are almost the same. Therefore, it was shown that the pore volume could be inferred from the compressive strength even if the state of FA was different.

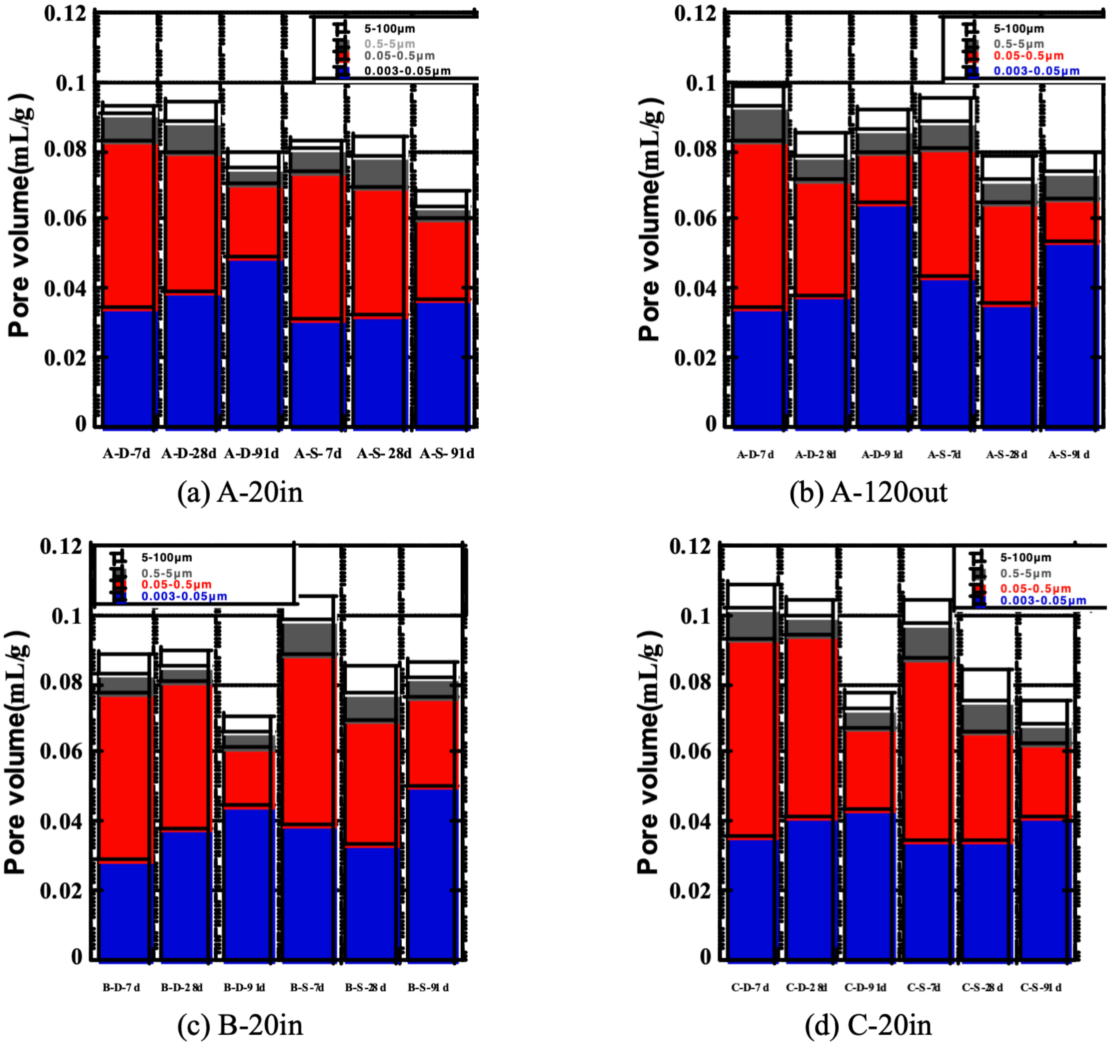

Figure 10. Pore size distribution.

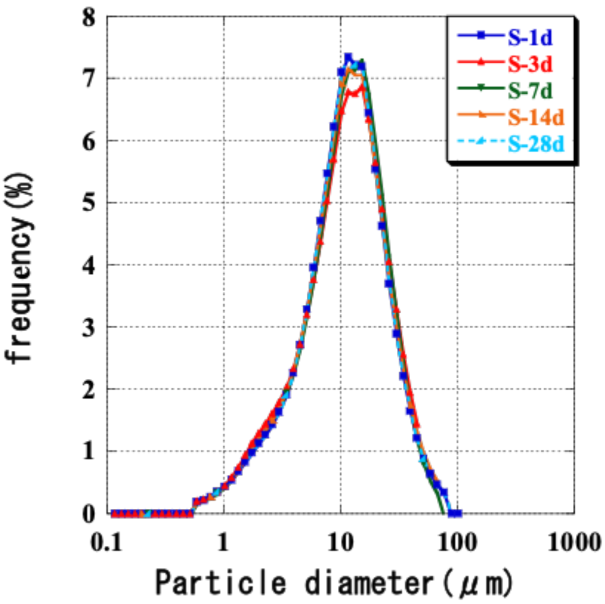

Figure 11. Compressive strength and pore volume (0.05 - 0.5μm).

4. Summary

Concrete slumps showed no difference within 2 hours regardless of the FA condition. It is considered that there is no difference in slump properties within the range of this experiment even when S is continuously stirred and stored. Regarding the compressive strength, regardless of the state of FA, the long-term strength of 10in and 20in showed the same compressive strength as that of P, and it was shown that the compressive strength manifestation may be higher when S is mixed. Regarding the neutralization rate coefficient, the result was larger when FA was mixed regardless of the FA state. The neutral acceleration coefficient tended to be smaller when S was mixed. From the relationship between the compressive strength and the amount of pores, it was shown that the compressive strength could be increased by decreasing the amount of pores in the range of 0.05 to 0.5 μm regardless of the state of FA. The drying shrinkage shows almost the same tendency regardless of the fly ash condition. In addition, it was confirmed that the drying shrinkage reducing effect of fly ash showed the same tendency regardless of the state.