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공기 연행 콘크리트에서의 플라이애쉬 사용에 관한 실험적 연구

An experimental study on the air-entrained concrete using fly ash

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요 약

일반적으로 플라이애쉬는 콘크리트의 여러가지 물성을 크게 개선시키는 것으로 알려져 있으나, 플라이애쉬 자체의 함유 성분에 따라서는 이러한 개선 효과가 감소하는 경우도 있다. 본 연구에서는, 플라이애쉬에 함유된 미연탄소가 공기연행 콘크리트의 물성에 미치는 영향을 규명하고, 품질관리면에서 사용상의 주의점을 지적한다.

Abstract

The quality of fly ash has great effect on the properties of AE concrete. The increase of AE admixture quantity by unburnt carbon in fly ash reduces the economical merit of using cheap fly ash. There should be no benefit in using fly ash containing a few % of unburnt carbon. In addition, since the quality of AE concrete can be varied greatly with the properties of fly ash, special attention must be paid on the uses of fly ash in AE concrete with industrial waste from a power plant.

1. Introduction

It is well known that fly ash improves the characteristics of concrete such as long-term compressive strength, flowability, permeability, chemical resistence, durability, heat of hydration, drying shrinkage and etc. Since it is also cheap as a by-product, there is a merit in the economical point of view. Therefore, many researchers have studied on the use of fly ash in concrete. However, these good aspects of fly ash are not applicable to AE(Air-Entrained) concrete with admixture since unburnt carbon in fly ash acts as an undesirable component for fly ash applications in AE concrete. In other words, this residual carbon adsorbs a considerable amount of air-entraining agent and reduces its activity.

Therefore, in the present study, the economical point of view has been checked for the use of fly ash in AE concrete (25-180-15) based on the correlative equation between the residual carbon content and the amount of admixture used in AE concrete in which air content is controlled in the range of 5±1% at W/C=65% and S/A=48%.

2. Materials and testing methods

OPC(Ordinary Portland Cement) was used for this experiment. Two kinds of fly ash from different power plants were selected. The chemical composition and mechanical properties of fly ash are shown in Table 1, 2 and 3. The particle size distribution of fly ashes measured by granulometer is shown in Fig. 2. FA(fly ash) cements were manufactured by replacing a part of cement with fly ashes of 10, 20 and 30% respectively.

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Table 1 Chemical composition of materials (unit : %)

Component / Material	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O
OPC	21.72	5.25	3.09	62.94	2.60	2.31	1.10	0.05
FA(A)	55.39	27.83	9.15	1.31	0.77	0.28	2.52	0.17
FA(B)	67.19	29.28	3.22	1.02	0.75	0.26	0.75	0.15

Table 2 Mechanical properties of materials

Component / Material	Ig.Loss (%)	Blaine (Cm^2/g)	Specific Gravity	σ (Kgf/cm^2) 7day	28day
OPC	0.96	3208	3.15	265	339
FA(A)	2.23	-	2.17	-	-
FA(B)	5.40	-	2.45	-	-

Table 3 Solubility in water of materials (unit : %)

Material / Alkali	FA(A)	FA(B)	OPC
K20	0.9	1.2	17.8
Na20	10.6	18.0	70.0

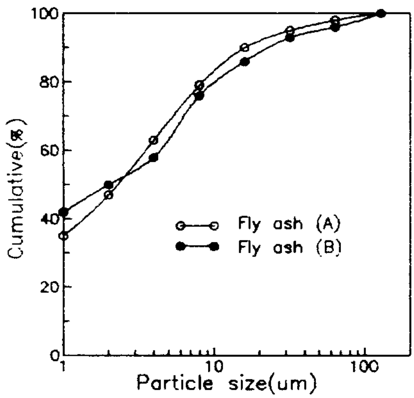

Fig.1 Fly ash particle size distribution

Table 5 Design conditions for concrete

σck (Kg/cm^2)	Slump (Cm)	W/C (%)	S/A (%)	W (Kg/m^3)	C* (Kg/m^3)	S (Kg/m^3)	G (Kg/m^3)	FA* (Kg/m^3)
180	15±1.5	60	48	177	272(1-X)	887	998	272X

* X is the replacement ratio.

And the properties of aggerate for concrete are summarized in Table 4. The aggregates are natural.

The setting time of FA cement mortars and FA concrete was checked by Gillmore method according to KS L 5103 and KS F 2463 respectively. And bleeding was according to KS F 2414.

The concrete was mixed up by a drum mixer for three minutes. The design conditions for the concrete are shown in Table 5. The amount of fly ash was calculated according to the replacement ratio. Maintaining the air content of concrete in the range of 5±1%, the amount of AE admixture was adjusted.

Table 4 Data for aggerate

Type of Agg. / Item	Gravel	Sand
Specific Gravity	2.68	2.58
Finess Modulus	7.30	2.89
Passing (#4)	0.02%	97.00%
Water absorption	1.36%	0.58%

3. Results and conclutions

3.1. Cement setting time

The cement setting time of FA cement mortars with FA replacement ratio is shown in Fig.2. As can be seen, there is little difference in initial setting time with fly ash replacement ratio as well as fly ash type.

The final setting time of FA cement(B) increases with an increase in replacement ratio. However, the final setting time of Fa cement (A) increases abruptly at 10% replacement ratio, thereafter, it remains constant. These results indicate that the effect of fly ash on the early stage of hydration is minor while its effect is appeared on the final setting.

Many researchers[1][2][3] reported that fly ash retards the activity of C_3S. However, there are two opinions for the effect of fly ash on the reaction of C_3A. Uchikawa[1] and Jawed[2] reported that fly ash accelerates its reactivity, while Fanjun[3], has a different opinion.

In the present study, no change of initial setting time provides that fly ash has no effect on the reaction process of C_3A. In addition, from the results of final setting time, it can be obtained that the effect of fly ash on the hardening process in FA cement depends greatly on the quality of fly ases. This may be attributed from the fineness of fly ash (Table 1 and 2). While the final setting time decreases with an increase in the content of alkali in fly ash, the final setting time of FA cement (A) with high alkali is longer than that of FA cement (B). This may be attributed that the

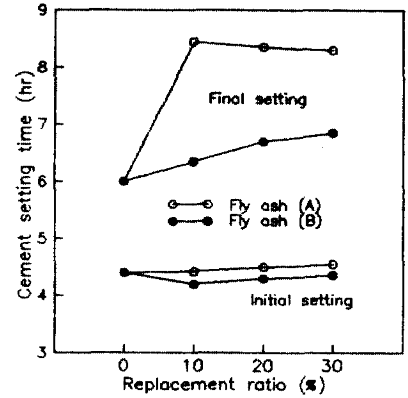

Fig.2 Cement setting time with FA replacement ratio.

effect of fineness on the final setting is greater than that of alkali due to the low solubility in water as shown in Table 4.

3.2. Setting time and bleeding of concrete

The concerte setting time with replacement ratio for fly ash (A) is shown in Fig. 3. The concrete setting time is retarded up to 15% of replacement ratio, thereafter, it is shortened. This result provides that shortening of setting time over 15% replacement ratio means the possibility of false setting due to the compact of fine powders in fly ash. This can be seen in the result of bleeding with fly ash replacement ratio (Fig.4).

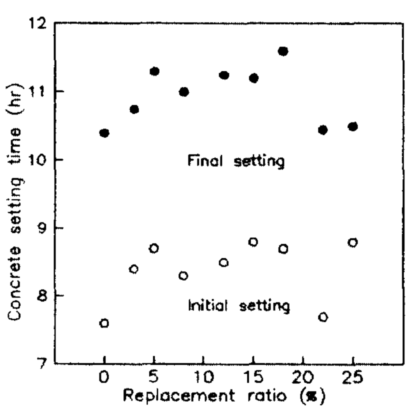

Fig.3 Concrete setting time with fly ash (A) replacement ratio.

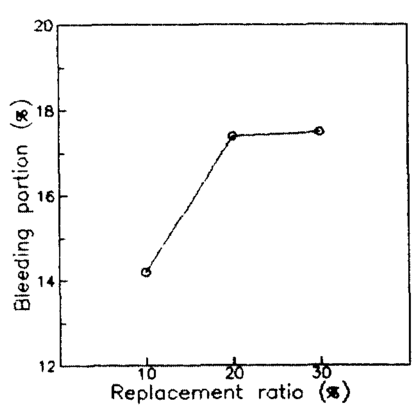

Fig.4 Bleeding portion vs fly ash replacement ratio for FA cement (A)

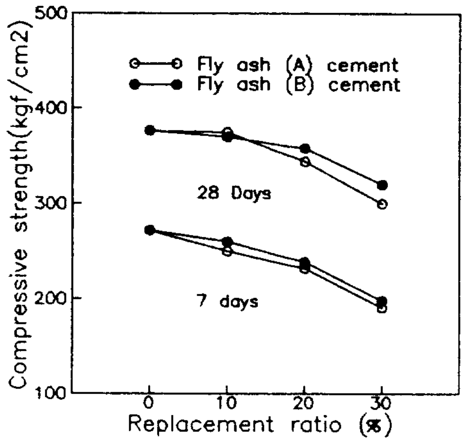

Fig.5 Cement compressive strength with fly ash replacement ratio

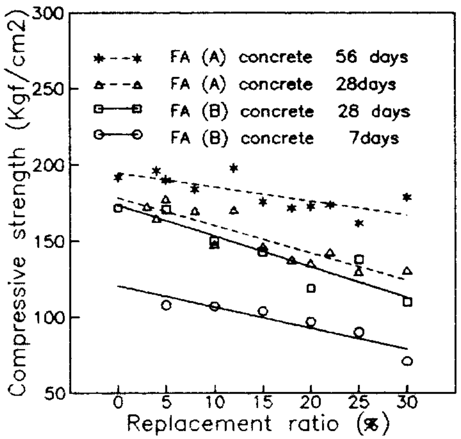

Fig.6 Concrete Compressive Strength with FA replacement ratio.

3.3. Compressive strength

The cement compressive strength with fly ash replacement ratio is shown in Fig. 5. As can be seen, the cement compressive strength decreases with an increase in replacement ratio. These results are agreement in the result of previous study(4). However, it is appeared that the compressive strength (28days) at 10% replacement ratio is almost same as OPC mortars. This gives that the effect of powder on the compressive strength may be large enough to compensate for the reduction of compressive strength which is resulted from the inactivity of fly ash at low mix propertion. The compressive strength of FA cement (B) is greater than that of FA cement (A). This may be due to the effect of powder on the setting time (Fig. 2). In addition, the trend of the compressive strength was found to be similar to that of cement mortars (Fig. 6).

3.4. Influence of unburnt carbon in fly ash

The air content of AE concrete was controlled in the range of 5±1%. Due to the adsorption of AE agents by residual carbon in fly ash, the amount of admixture increases with an increase in replacement ratio of fly ash as shown in Fig .7.

The present result in aggrement with the result of previous study[4] in which there exists a direct proportional relationship between the replacement ratio and the amount of admixture.

The admixture content with carbon content of FA cement is shown in Fig. 8, from which the regression equation by least-square method has been obtained as :

$$Y = 0.519X + 0.031 \quad (r^2 = 0.99) \qquad (1)$$

where,

Y : the amount of AE admixture(%)

X : the amount of residual carbon in FA cement(%)

From equation (1), it can be obtained that the amount of AE admixture for FA concrete containing 1% unburnt carbon is almost 18 times more than that of ordinary AE concrete without fly ash.

The amount of AE admixture is greatly influenced by the amount of unburnt carbon. Therefore, the quality of fly ash must be controlled uniformly. However, it may be difficult to control its quality because it is not a product to be controlled but a by-product or industrial waste from a power plant.

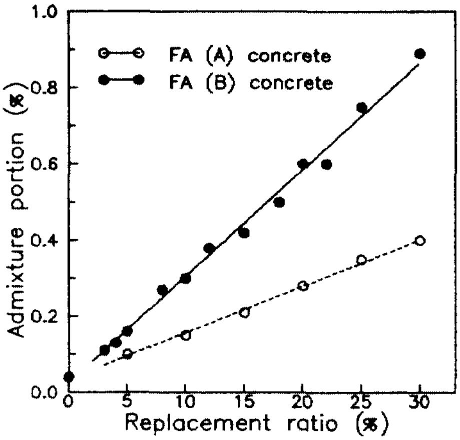

Fig.7 Admixture portion vs fly-ash replacement ratio

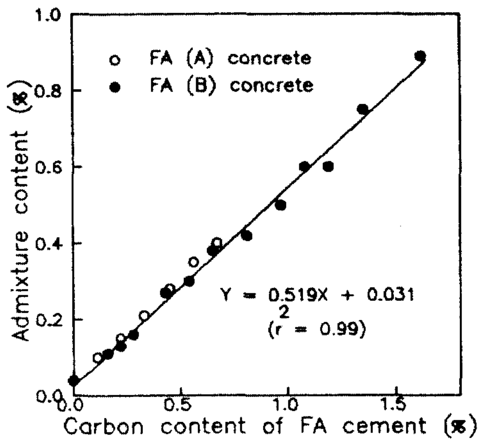

Fig.8 Admixture content vs unburnt carbon of FA cement

3.5. Economical evaluation for AE concrete with fly ash

The compressive strength of FA concrete decreases with an increase in the portion of fly ash (Fig.6). Setting aside this quality problem, the use of fly ash can be economical because the cost of fly ash is cheapper than that of cement. In this point of view, the economical evalution can be described as follows.

B (Benefit) = Cost reduced by the replacement of cement by fly ash
- Cost increased by the increase of AE admixture

$$= U \cdot R \cdot (C-F) - 0.519\, U \cdot R \cdot A \cdot L \qquad (2)$$

where,

U : the amount of cement (Kg-cement/m^3 of concrete)

R : the replacement ratio of cement by fly ash (Kg-FA/Kg cement)

C : the cost of cement (Won/Kg-cement)

F : the cost of fly ash (Won/Kg-FA)

A : the cost of AE admixture (Won/Kg-AE admixture)

L : the content of unburnt carbon in fly ash (Kg-unburnt carbon/Kg-FA)

For the case of no benefit, the equation (2) is expressed as :

$$L = \frac{C-F}{0.519A} \qquad (3)$$

From equation (3), the point of no benefit is independent of the amount of cement used in concrete (U) and the replacement ratio of fly ash (R).

For example, when U = 300Kg/m^3, C = 41Won/Kg, F = 21Won/Kg and A = 930Won/Kg, the point of no benefit can be obtained as :

$$L = \frac{50-25}{0.519 \cdot 1,000} = 0.041(4.1\%)$$

This means that when fly ash contains more than 4.1% of unburnt carbon, it is inappropriate to replace cement with fly ash for the purpose of economical additive.

4. Recommendation

Although many researchers reported the advantages of fly ash in concrete, the results of present study show that its use for AE concrete need more consideration because of the following reasons.

First, the amount of AE admixture increases in proportion to that of unburnt carbon in concrete due to its adsorption. For instance, the amount of admixture for AE concrete using fly ash containing 1% unburnt carbon is almost 18 times more than that of ordinary AE concrete without fly ash. This great increase of AE admixture reduces the advantage of the replacement of cement by cheap fly ash. In other words, there may be no economical merit in using fly ash containing a few % of unburnt carbon.

Second, the quality of FA concrete with AE admixture is greatly dependent on that of fly ash. This means that the quality of fly ash must be controlled uniformly. However, it may be difficult to control its quality because it is not a product to be controlled but an industrial waste from a power plant. Therefore, the quality of FA concrete can be varied due to the quality of fly ash which is not able to be controlled.

Third, the compressive strength at 7, 28, 56days decreases in proportion to that of fly ash. At low mix proportion, this can be recovered by the powder effect, however, this is varied by the quality of fly ash.

5. References

(1) Uchikawa, H., "The viscoelasticity and hydration of fly ash cement (Japanese)", Cement and Concrete, No.445, pp7-17 (1984).

(2) Jawed, I. and J. Skanly, "The influence of alkali Sulphate on the properties of cement and concrete", World Cement, pp325-330 (1984).

(3) Fanjun, W., M. W. Grutzeck and D.M. Rov, "The retarding effects of fly ash upon the hydration of cement pastes : The first 24 hours", Cement and Concrete Research, 15, pp174-184 (1985).

(4) Kokubu, M. ., "Principal paper of fly ash and fly ash cement", The international Symp. on the chemistry of cements", pp75-113, Tokyo, (1968).