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EFFECT OF CLASSIFIED FLY ASH ON ALKALI AGGREGATE REACTION (AAR)

Kazuaki Ukita*, Shun-ichi Shigematsu*, Mitsuhiro Ishii*, Kazuo Yamamoto**, Kunikazu Azuma** and Masahumi Moteki**

* Shikoku Research Institute Inc. Takamatsu, Kagawa, Japan
** Tsukuba Research Institute, Okumura Corp. Tsukuba, Ibaraki, Japan

Abstract

As a method of controlling alkali aggregate reaction (AAR), Pozzolan such as fly ash and granuated blastfurnace slag are verified effective. Classified fly ash is made of usual fly ash through air current classification and its physical properties are much improved. In this paper, AAR controlling effect of fly ash as an admixture to cement is described. The effect of fly ash is shown both by the fineness of grains after classifications and replacement percentage of cement with fly ash.

1. Introduction

Fly ash is a by-product of coal electric power plants, and its efficient usage is expected. For this purpose, it is necessary to reduce the fluctuation of physical properties of usual fly ash and to improve its quality. Attention was paid to the fact that physical properties (fineness and shape) of fly ash are more improved by classifying it finely by air current. The effect of classified fly ash on alkali aggregate reaction is described based on the results of experiments on the properties of concrete admixed with classified fly ash[1].

2. Materials

(1) Cement: Ordinary portland cement (specific gravity = 3.15, Specific surface area 3210cm^2/g, R_2O = 0.69%)

(2) Admixture: Fly ash

The raw fly ash produced at Saijo Power Station, Shikoku Electric Power Co. and the classified fly ash made by the raw ash were used after classification. Figure 1 shows grain size distribution of fly ash and cement used. Tables 1 and 2 show physical and chemical properties of fly ash.

Table 3 shows alkalies in fly ash.

Raw ash (not classified) is electrostatic precipitation ash (EP ash) and ordinary for commercial use. FA20 is produced by classified in EP 2-3 steps into average diameter of 20 μm. Grains classified into max. diameter 10 μm and 5 μm are called FA10 and FA5, respectively.

Average grain diameter of raw ash is 17μm, that of FA20: 11 μm, FA10: 2.6 μm and FA5: 2.3 μm, respectively. Compared to the diameter of raw ash, that of FA20: 65%, FA10: 15% and FA5: 13%. The fineness (surface area) compared to raw ash, is FA20: 1.7, FA10: 2.6, FA5: 3.3 times as much as raw ash.

After classifying, badly shaped, distorted and cavity-ridden grains are excluded, and globe-shaped grains are increased. Specific gravity is increased (that of FA5 is increased by 10 % of raw ash). There is not so big change in chemical composition after classification.

Total alkalies in classified fly ash is almost equal to those in raw ash, but the content of available alkalies of FA5 is 1.5 times as much as that of raw ash and the content of water-soluble alkalies is increased in proportion to the fineness of grains. FA5 has water soluble alkalies by 3.0 times as much as raw ash.

(3) Reactive aggregate

Reactive aggregates are 3 kinds of andesite and 1 kind of chert. These are collected in West of Japan. To examine controlling effect in accordance with ASTM C 441, Pyrex glass is used. Table 4 shows results of chemical method (ASTM C 289) of aggregates used[2]. The aggreagtes are in the range of potentially deleterious or deleterious.

Table 1 Physical Properties

Name	Specific Gravity	Fineness (cm^2/g)	Average Grain Diameter μm
FA5	2.51	12220	2.331
FA10	2.49	9440	2.616
FA20	2.35	6230	11.543
Raw ash	2.28	3660	17.591

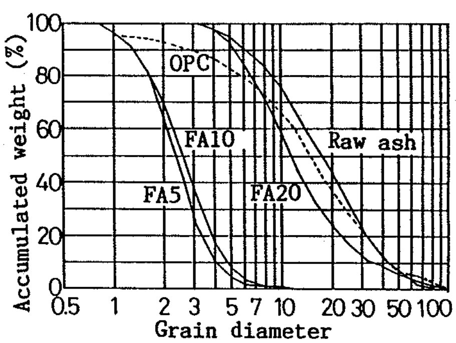

Figure 1 Grain Size Distribution

Table 2 Chemical Properties

Name	lg.loss	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	C
	Chemical Composition (%)								
FA5	5.3	49.3	37.8	3.5	1.7	0.5	0.49	0.59	3.6
FA10	4.1	49.5	38.4	3.8	1.7	0.6	0.59	0.74	2.8
FA20	4.7	49.5	37.2	3.8	2.1	0.6	0.59	0.71	3.8
Raw Ash	2.6	53.7	28.2	6.3	4.7	1.1	0.99	0.84	2.1

Method of analysis: JIS M8815 except Carbon by Element analysis

Table 3 Alkalies of Fly Ash

(Unit : %)

Item	Water-soluble alkalies*1			Available alkalies*2			Total alkalie*3		
Name	Na_2O	K_2O	R_2O	Na_2O	K_2O	R_2O	Na_2O	K_2O	R_2O
FA5	0.124	0.002	0.125	0.218	0.078	0.269	0.99	1.07	1.69
FA10	0.091	0.004	0.094	0.169	0.073	0.217	0.98	0.92	1.59
FA20	0.058	0.002	0.059	0.173	0.097	0.237	1.09	0.93	1.70
Raw ash	0.037	0.005	0.040	0.107	0.082	0.161	0.86	0.95	1.49

*1:ASTM C-114 *2:ASTM C-311 *3:JIS R 5202

3. Test Method

Tests were conducted in accordance with the Mortar bar method under The Tentative Guidelines of Ministry of Construction Japan. Size of test bars is 4x4x16cm, and three bars are used for each mix proportions. Mix proportions are made by weight ratio: cement 1 : aggregate 2.25. Aggregate is used 100% reactive aggregate. Fly ash is admixed at various cement replacement percentages. The alkali content of cement was adjusted by NaOH to Na_2O_{eq} 1.2% to the total weight of cement and fly ash, neglected alkalies in fly ash.

4. Discussion of Test Results

(1) Test I Expansion controlling effect by the fineness of classified fly ash

Figure 2 shows expansion controlling effect according to the fineness of fly ash.

The higher fineness of classified fly ash becomes, the lower expansion rate becomes. The expansion of mortar bar replaced with 15% raw ash has expansion of one fifth at the test age of 6 months compared to that without fly ash. The greater specific surface area of fly ash is, the more its effect is. Even after a long period, this effect is kept. Figure 3 shows comparison of expansion ratio at 6 months as raw ash 1.0 and the inverse ratios of specific surface area. From this, it is understood that expansion rates are reduced in proportion to the increase of specific surface area.

Table 4 Results of ASTM C-289 Test

Aggregate	ASTM C 289		
	Sc	Rc	Judgement
Andesite I Andesite II Andesite III	734 355 488	170 174 186	Potentially Deleterious
Chert	44	31	Deleterious
Pyrex glass	730	95	Deleterious

(m mol/1)

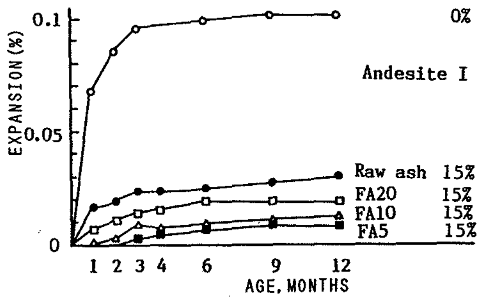

Figure 2 Expansion test results by the grain sizes of fly ash

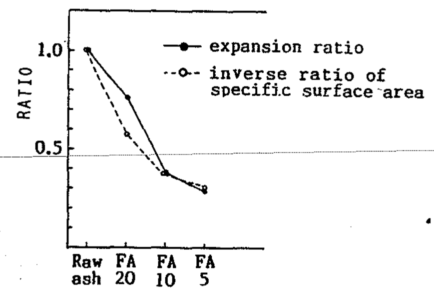

Figure 3 Comparison of expansion ratio at 6 months and invers ratio of specific surface area

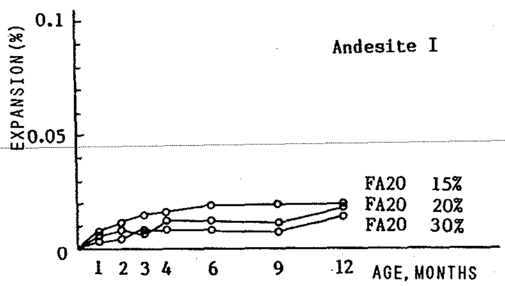

Figure 4 Expansion test results by replacement percentages

Figure 4 shows the effect of replacement of cement with different percentages of classified fly ash FA20.

When the replacement percentage of classified fly ash becomes high, the expansion rates is lowered. Mixed with FA20 30%, expansion is reduced by half of 15% mixing. It is, as shown in Figure 2, nearly equal to that of FA5 at 15% mixing, and specific surface area of FA5 is two times as much as that of FA20. This means that the effect of classified fly ash in controlling expansion is gained in proportion to specific surface area.

(2) Test II Expansion controlling effect by replacement percentages

In this test series, 2 kinds of classified fly ash, raw ash and FA10, are used. Tests are done to observe expansion rates by changing mixing rates. The reason to have conducted these tests with small amount of replacement, i.e. 3% or 5%, is to certify pessimum percentage.

Figure 5 shows the expansion test result by replacement percentage in 4 kinds of Aggregates.

In case of Andesite I, the same expansion controlling effects are gained both in case of 5% mixing and 15% mixing.

In case of Andesite II, expansion amount is reduced by replacement with raw ash or FA10. Enough expansion controlling effect is gained with 10% and more admixing. If expansion rate must be less than 0.1%, replacement with small amount such as 3% or 5% is not enough. Therefore, replacing

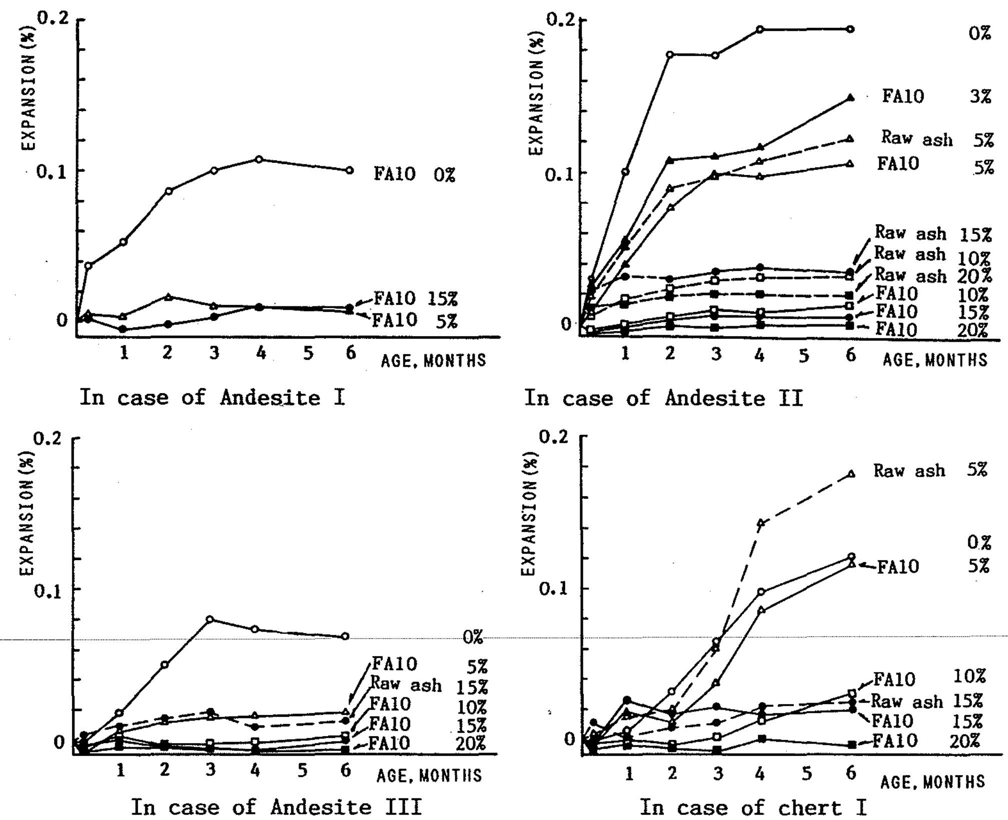

Figure 5 Expansion test results by replacement percentages

percentages more than 10% is necessary. It is clearly seen FA10 has higher reducing effect compared to raw ash.

It is reported in other experiments, for example References 3)-4), that the amount of admixture necessary to control reaction depends on the content of alkalies. It must be added that the result of this test is gained in the conditions that base concrete contains maximum alkalies of 1.2% Na_2O_{eq}. Therefore, if the content of alkalies is less, it is considered that replacement percentage necessary to expansion control will be different.

In case of Andesite III, reducing effect is also gained in accordance with mixing rates.

In case of Chert I, the expansion is bigger in case of mixing raw ash by 5 % than in case of no replacement, and with mixing FA10, almost same expansion rate as with no replacement. This means there exists pessimum percentage as is known from others' studies[3)-4)]. In this case, with 10 % or more replacement, expansion controlling effect is gained. Therefore, replacement percentage of 10% or more is necessary.

Figure 6 shows the test results using Pyrex glass. As Pyrex glass has high reactivity, the test is done to certify standard line of expansion controlling effect in accordance with ASTM C 441.

It shows the highest expansion of 0.4% with no replacement. Even mixed with classified fly ash FA10, it has expansion ratio of more than 0.1%. However, expansion controlling effect is surely gained, as expansion amount is reduced to one half by mixing FA10 5% or 10% ; to one third by mixing 15% or 20%.

Figure 7 shows relation between replacement percentage of fly ash and expansion at test age of 6 months made from test results of each aggregate.

Owing to the kinds of aggregates, the controlling effect becomes different: with replacement of under 5%, expansion rate can or cannot be controlled under 0.1%. With replacement of 10%, expansion is controlled under 0.03%; enough controlling effect is gained. According to the increase of replacement to 10%, 15% and 20%, expansion is reduced. The controlling

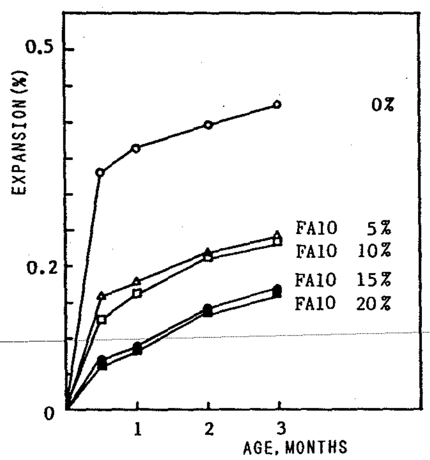

Figure 6 Expansion test results by replacement percentages In case of Pyrex Glass

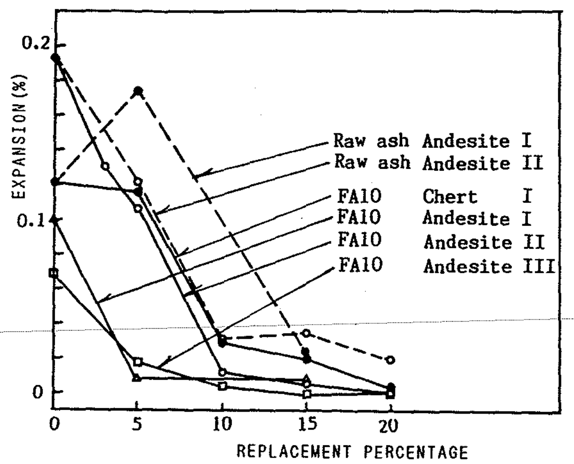

Figure 7 Replacement percentage & expansion at 6 months

effect of FA 10 is higher than that of raw ash. The same effects are gained both in case of replacement raw ash 20% and mixing FA10 10%.

5. Conclusion

Based on the test results presented in this paper, the following conclusions are gained.

Classified fly ash has an excellent expansion controlling effect on alkali aggregate reaction on small replacement percentage by its large specific surface area, and expansion controlling effect of classified fry ash is certified by mixing it to several kinds of aggregates distributed in West of Japan. Though the reasons are not yet perfectly resolved, the following items are suggested.

In this experiment, the total alkalies in mortar was adjusted to 1.2% neglecting content of alkalies in fly ash to avoid to be diluted. On the result, the partial replacement of cement by fly ash reduced the expansion. It is considered that fly ash has expansion controlling effect by available Pozzolan even if it has diluting effect. The same thing is reassured from the expansion controlling effect which is gained in proportion to specific surface area by grain sizes of fly ash.

With the fine, classified fly ash, strength and low permeability of concrete are improved, these properties enhance the expansion controlling effect on alkali aggregate reaction. It can be concluded that classified fly ash is useful as an admixture. Further studies in details are expected.

6. Acknowledgement

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