FLY ASH CONCRETE ADMIXTURE

Toward Greater Usage of Additive from Coal Power Plants in Concrete

1 Introduction

Fly ash is an useful concrete additive that delivers improved fluidity, reduced cracking (as a result of lower heat of hydration), depressed alkali silica reaction (ASR), and reduced salt penetration depth[5]. To promote the use of fly ash as well as other mineral admixtures and blended cements, and thereby reducing problems with ASR in concrete, the Ministry of Land, Infrastructure, Transport and Tourism sent the chief of each regional development bureau in Japan a notification entitled “Specifications for Increased Concrete Durability”. However, despite this notification, utilization of fly ash remains low, at around 200-300 thousand tons per year. One reason for this failure is that builders and clients are both resistant, the former because of concerns about quality and the stability of supply of fly ash, and the latter because of its limited track record in actual structures. This manuscript summarizes the mechanism of the pozzolanic reaction that contributes to reduced ASR and salt penetration, as well as some efforts by suppliers to alleviate the above concerns.

2 Pozzolanic Reaction

The pozzolanic reaction occurs over the whole surface area of a fly ash particle that is covered with hydration products (C-S-H phase and calcium hydroxide)[6]. The Ca/Si ratio of the C-S-H falls as Si and Al ions dissolved from the glassy phase of fly ash particles are absorbed; that is, low Ca/Si ratio C-S-H forms from calcium hydroxide as it absorbs Si and Al ions from the fly ash particles (Fig. 1). Hydraulic pores among the hydrated phase that formed during initial hydration of the cement are depressed as the C-S-H phase grows during this pozzolanic reaction. The surface potential of the C-S-H phase decreases becomes negative when the Ca/Si ratio falls below 1.

3 Quality Stabilization of Fly Ash

Figure 2 shows the arrangement of a modern power plant fitted with equipment for collecting and ensuring

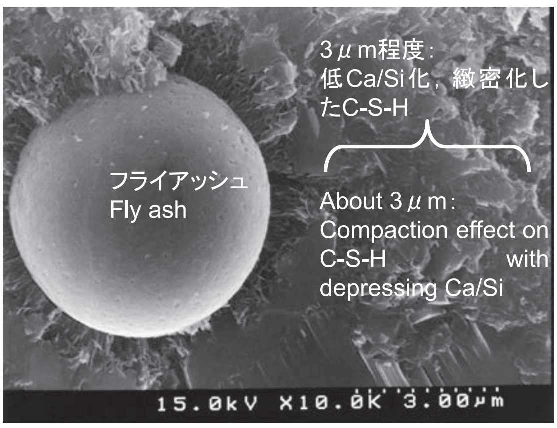

Fig. 1 Pozzolanic reaction around particle

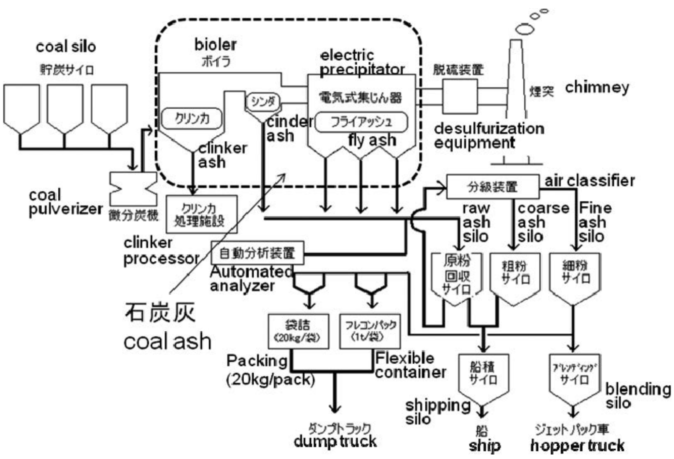

Fig. 2 Collection and quality control system at latest coal burning power plant

the quality of fly ash. Pulverized coal enters the boiler, where then the mineral content in the coal melts during the burning process. Large ash particles gather just after the boiler as cinder ash, while fine particles that drift as far as the electric precipitator are collected as fly ash. The loss on ignition (LOI), Blaine fineness, density, SiO_2 content, and also non-JIS factor methylene blue (MB) absorption are measured at this stage so as to judge whether the fly ash meets JIS standards or not. After this monitoring stage, only qualified raw fly ash is removed for storage in the raw fly ash silo. Afterword, the raw fly ash is sorted using an air flow classifier, removing large diameter particles so as to ensure a high Blaine fineness. The high Blaine fineness product and low Blaine fineness product are stored in separate silos are mixed at the proper ratio in the blending silo (Fig. 3). A typical blending silo volume is about 2,000 to 2,500 m^3, with a homogeneous mixing capacity of 1,600 to 1,800 m^3.

The relationship between LOI and MB absorption obtained through weekly monitoring at two power plants is shown in Fig. 4. There is no correlation between the two indexes, but the range of values for each power station is small.

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5 References

[5] Fly ash in concrete – properties and performance, Report of technical committee 67-FAB on use of fly ash in building, RILEM, 1991.

[6] Ogawa, K., Uchikawa, H. and Takemoto, K.: The mechanism of the hydration in the C_3S-pozzolan system, Cement and Concrete Research, Vol. 10, pp. 683-696, 1980.

Fig. 3 Blending silo at power plant

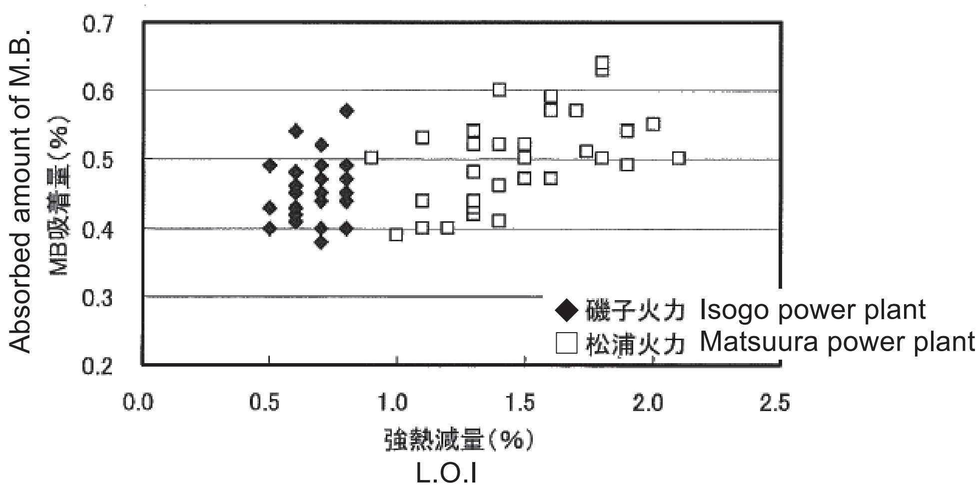

Fig. 4　Range of LOI and MB absorption

GROUND GRANULATED BLAST FURNACE SLAG

Freedom in Mix Design with Required Concrete Performance

1 Characteristics of the Material

Ground granulated blast furnace slag (GGBS) is obtained by grinding the slag which is a byproduct of manufacturing steel in a blast furnace. The quantity of ground granulated blast furnace slag sold annually as a cement ingredient (for slag cement) is more than 3 million tons, while in contrast the quantity of GGBS used as a concrete additive is about 200,000 tons, so the former is 15 times larger than the latter.[1] The reason for this imbalance is that a dedicated silo is required in ready-mixed concrete plants when it is used as an additive, with the result that GGBS as an additive is mainly limited to large-scale construction work or factory products. On the other hand, although slag cement contains an almost fixed ratio of GGBS, when it is used as an additive at the mixing plant there is the advantage that the type of cement used, the fineness of the GGBS, and mix ratio can be set as desired in accordance with a particular objective.

In recent years, the slag cement manufactured in Japan has all been manufactured by mixing cement with GGBS. Mixed grinding, as carried out previously, is no longer used.

The following is a description of GGBS as a concrete additive.

2 Development of Low Heat GGBS

The quality of GGBS is prescribed in JIS A 6206 “Ground granulated blast-furnace slag for concrete,” but in the March 2013 revision the new standard “ground granulated blast furnace slag 3000” was added. This GGBS has a specific surface area (cm^2/g) of at least 2,750 and less than 3,500 by the Blaine method. It was originally developed and manufactured for low heat slag cement and was then utilized as a concrete additive. Figure 1 shows the results of adiabatic temperature rise tests on concrete made with GGBS. It can be seen that, compared with GGBS with the smallest fineness in the past of about 4,000 cm^2/g, there is a large reduction in heat, particularly at the higher replacement ratio. Also, Fig. 2 shows the early strength development property (activity index). The strength development of GGBS 3000 is slower compared with higher fineness slag, but the activity index at 91 days is virtually 100.

Based on these characteristics, GGBS 3000 has been used mainly for structures or members where there is concern over the occurrence of thermal cracking.

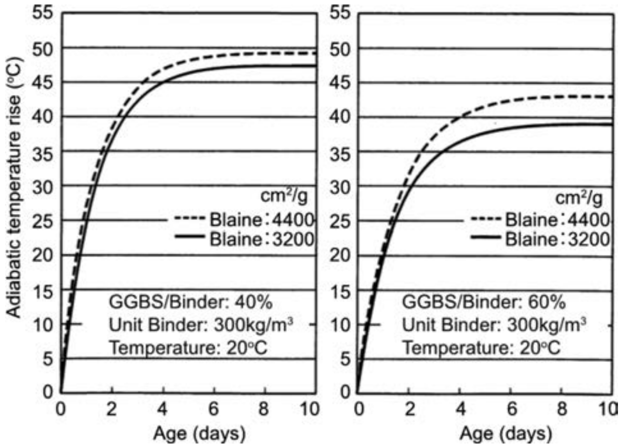

Fig. 1 Examples of adiabatic temperature rise

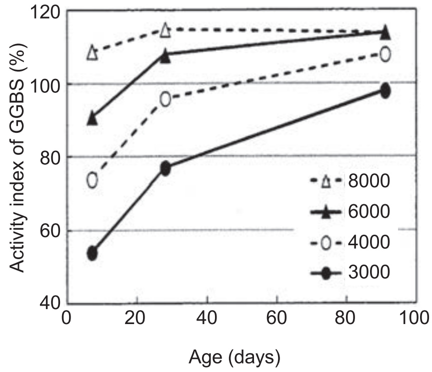

Fig. 2 Activity index of GGBS

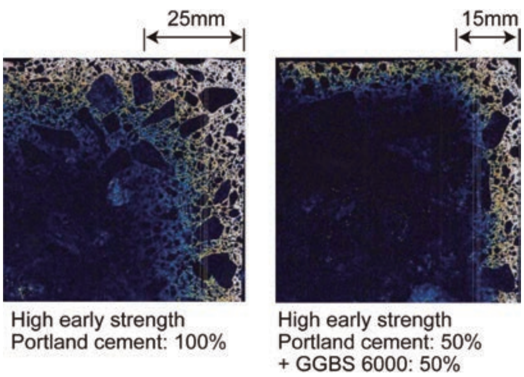

Fig. 3 Chloride penetration into steam-cured concrete measured by EPMA

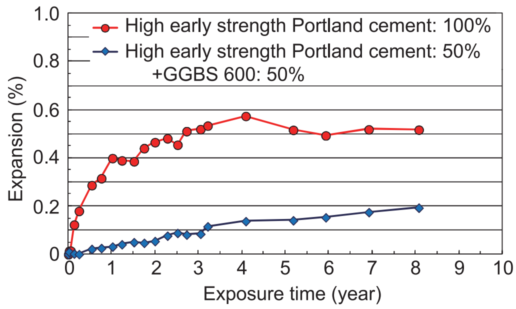

Fig. 4 ASR expansion of PC beam made with reactive aggregate

Fig. 5 Three span jointed pretensioned T-shaped girder bridge

Fig. 6 PC precast deck

3 Improving Early Strength

It is known that concrete using GGBS generally has better durability, but on the other hand, depending on fineness and temperature, strength development might be slow. For this reason, GGBS has not been used much in PC structures where development of early strength is a requirement. However, in recent years precast PC members have come to be manufactured using a binder that is a mixture of equal quantities of high fineness GGBS (GGBS 6000) and early strength Portland cement, with the objective of improving early strength.

These members are produced by steam curing, and it has been reported that there is no major reduction in early strength development, while resistance to chloride penetration remains excellent (Fig. 3), ASR suppression is good (Fig. 4), and resistance to leaching of calcium hydroxide caused by de-icing salt is high.

This material has already been used in more than 300 projects throughout Japan, mainly for members such as pretensioned beams (Fig. 5) and slabs (Fig. 6), post-tensioned simply supported beams and segmented hollow slab bridges (Fig. 7) (research by the BSPC research Group).

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Fig. 7 Post-tensioned PC hollow-deck bridge