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PROPERTIES OF STEAM CURED CONCRETE WITH MODIFIED FLY ASH CEMENT

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ABSTRACT

Blended cement with supplemental cementitious materials such as fly ash has been extensively used worldwide from environmental point of view. In Japan, however, the consumption of blended cement accounts for only about 20%. Especially, fly ash cement has rarely been used for concrete structures except for dam concrete. This is mainly because strength development of fly ash cement concrete is slower than ordinary Portland cement concrete [1].

The precast concrete products considered as an important part of the concrete industry in the world, and the use of these products is increasing year by year. Steam curing of concrete is a method preferred for accelerating strength gain (compressive strength) of concrete, and this method is widely used in precast concrete industry to rise the productivity, there are few research about using fly ash in precast concrete and there is a shortage in the information about its effect on the concrete properties, in the past few years a new modified fly ash has developed in Japan by using electric static separation method to separate the unburned carbon particles from the fly ash particles.

The purpose of this study is finding the effect of this new tape of fly ash cement on precast concrete which is prepared by steam curing method.

Several samples of cement with fly ash and high C_3S cement were manufactured and strength development and shrinkage properties were experimentally investigated. The performance of the proposed fly ash cement was compared with that of conventional cements using the steam curing method and compared with the underwater curing samples. It has been found that steam cured concrete with fly ash and high alite cement develops higher compressive strength at 1 day of age than the concrete with ordinary Portland cement. Also it has been found that steam cured concrete with fly ash has lower expansion values at the early time than those with OPC.

1. INTRODUCTION

Fly Ash is one of the coal combustion products, composed of the fine particles that are driven out of the boiler with the flue gases, the recycling of fly ash has become an increasing concern in recent years due to increasing landfill costs and current interest in sustainable development. Fly ash comes from one of the biggest sources of air pollution and carbon dioxide emissions on Earth, and yet it's considered to be a green material, the main reason that fly ash is considered to be eco-friendly when used in construction is because it's a recycled material. If power companies are going to burn coal and produce fly ash anyway, it makes sense to put it to good use, especially if it can save money and energy in the construction sector.

The quality of fly ash is important but it can vary. Poor-quality fly ash can have a negative effect on concrete.
The unburned carbon content in fly ash affects the properties of concrete and makes the quality control very difficult, trying to solve this problem a new modified fly ash with low unburned carbon has developed by using electric static separation method, but until these days the use of FA as admixture at concrete mixing plants is still rare in Japan. This is mainly because strength development of FA cement concrete is slower than OPC concrete.

Use of precast concrete products is increasing year by year, since it is effective in labor saving construction in order to cope with the declining birthrate and aging population. Precast Concrete is widely used globally for the construction of buildings, road bridges, tunnels, factories constructions, and other heavy structures.
One of the most important points to focus on in any industry is increasing productivity, and in precast concrete industry we need to use the molds as many times as possible in the shortest time. This means demolding in the shortest possible time, therefore, a suitable compressive strength must be reached to demold safely. The most common way to improve the compressive strength of the precast concrete in early age is using steam curing method, which has an effects on the physical proprieties of the concrete. Another common way to improve the compressive strength in later ages is using fly ash. However, using fly ash will slow down compressive strength development of the concrete as mentioned before. To solve this problem it is recommended to use High Alite (C_3S) cement with the modified fly ash in order to accelerate strength development of the concrete with fly ash [2].

In this research, the effect of this new tape of fly ash cement on precast concrete which is prepared by steam curing was studied. Mechanical and shrinkage properties of the proposed fly ash concrete were compared with those of concrete made by using ordinary Portland cement without fly ash.

2. MATERIALS AND MIX PROPORTIONS

Table 1 shows physical and chemical properties of binder materials, high alite cement (A), ordinary Portland cement OPC (N), which used for experiments in this study.
Table 2 shows physical and chemical properties of the modify Fly Ash (FA), that used for experiments in this study.
Table 3 shows four mix proportions of concrete, Air-entraining agent (AE); and super plasticizer (SP) were used to introduce entrained air and improve workability.
Target slump and air content for the experiments was 12±2.5cm and 4.5±1.0% respectively.
The replacement ratio of the fly Ash in the cement was taken to be 18%.

Table 1: Physical and chemical properties of binders

Name	Density	Blaine fineness	f.CaO	Clinker Mineral composition (%)			
	(g/cm^3)	(cm^2/g)	(%)	C_3S	C_2S	C_3A	C_4AF
A	3.11	5380	2.1	69.3	2.9	9.4	7.7
N	3.16	3170	0.2	61.6	15.1	8.2	9.1

Table 2: Physical and chemical properties of Fly Ash

Name	Density	Blaine fineness	SiO_2	Ig. Loss	Flow, percent of control	Strength Activity Index (%)		
	(g/cm^3)	(cm^2/g)	(%)	(%)	(%)	7days	28days	91days
FA	2.19	3490	65.3	0.9	106	74	84	99

Table 3: Mix proportions of concrete

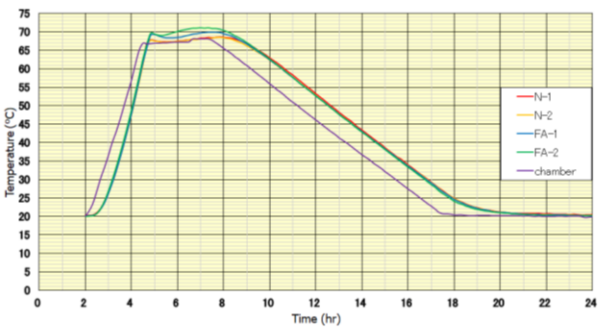
No.	Proportion	W/B	s/a	Amounts of contents (kg/m3)						Chemical Admixture (B X %)		
		(%)	(%)	Water	N	A	FA	S	G	SP	AE303	AE785
1	N	45	45	160	356	---	---	795	993	0.8	0.001	---
2	A+FA		45	160	---	292	64	783	977	0.75	---	0.03
3	N	33	43	160	485	---	---	715	967	0.88	0.0015	---
4	A+FA		43	160	---	398	87	699	946	0.8	---	0.035

3. EXPERIMENTAL PROCEDURES

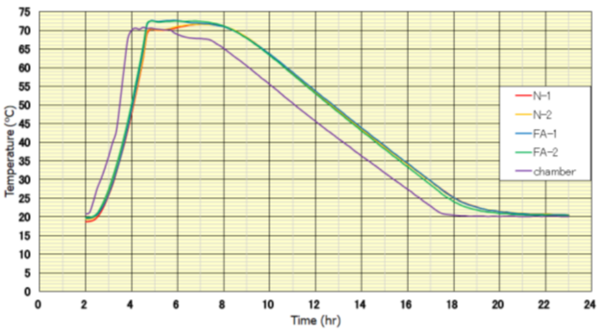
Fresh concrete properties such as slump, air content, temperature, were measured according to JIS standards [3]. Concrete strain and temperature were measured throughout the experiments using transducer strain gauges installed in central portion of beam molds measuring 100mmx100mmx400mm by connecting to data logger. Compressive strength tests conforming to JIS A 1108 [4] were conducted using cylinder molds (100mm diameter and 200mm height). Immediately after casting, all the specimens were sealed and stored in temperature controlled room at 20°C and 80%RH. Some beam and cylinder specimens for 1, 14 and 91 days compressive strength tests were then subjected to high temperature curing 2 hours after casting time. The temperature increased gradually during 2 hours and 15 minutes, up to 65°C for 3 hours, the target temperature used in the experiments was similar to steam curing in general precast concrete factories. And then the temperature reduced gradually during 10 hours to stable at 20°C for 6 hours and 45 minutes, the total time for steam curing procedure is 24 hours. Strain and temperature was measured in beam specimens as well. The specimens were demolded after 24 hours. Accelerated cured specimens were then subjected to drying condition in a temperature controlled room at 20°C and 60% RH for drying shrinkage and autogenous shrinkage measurement in beams and compressive strength in cylinders.
The other cylinder specimens were stored in water at 20°C to observe 7, 28, and 91 days compressive strength under standard condition.
Modulus of elasticity of concrete was also measured on the cylinder specimens which were used for compressive strength tests.

4. RESULTS AND DISCUSSIONS

Fig.1 shows the temperatures of the specimens during the curing time and it is similar to the target temperature profile in the main plan.



(W/B=45%)



(W/B=33%)

Fig.1: Temperature History of Steam Curing

4.1 Compressive strength

It can be seen from Fig.2 that the steam cured concrete with fly ash and high alite cement develops good compressive strength at one day of age and more than the normal concrete. Under water cured concrete with (N) always shows higher compressive strength than (A+FA). From these experimental results showed that steam cured concrete with fly ash and high alite cement develops higher compressive strength at 1 day of age than the concrete with ordinary Portland cement. The early strength development of the proposed FA cement is desirable property for precast concrete factories, because the capability of early demolding is often required for production of precast concrete.

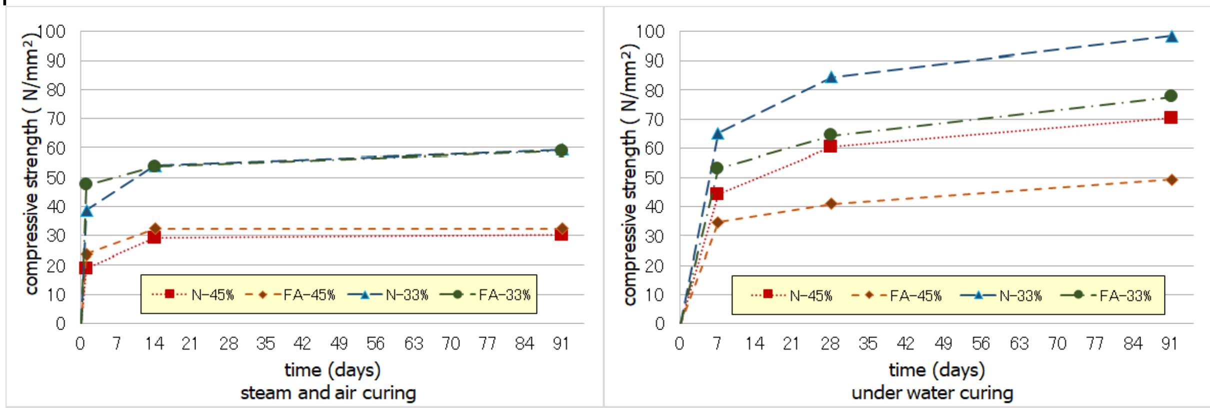


Fig.2: Compressive Strength

4.2 Autogenous and Drying Shrinkage

The initial setting time which is defined as the starting point of autogenous shrinkage was 3.5 hours after casting time. Coefficient of thermal expansion of concrete was assumed to be $10x10^{-6}$/°C in accordance with JCI (2016) [5], and we observed the total strain from which the thermal strain was subtracted to find Autogenous shrinkage. It can be seen from Fig.3 that mix proportions with (N) showed higher expansion at early age than mix proportions with (A+FA).

Drying shrinkage of concrete after steam curing was also shown in Fig.3. For concrete with (W/B=45%), mix proportion with (N) showed larger drying shrinkage than with (A+FA). However with mix proportions (W/B=33%), (A+FA) showed larger drying shrinkage than (N), but the difference was not so large.

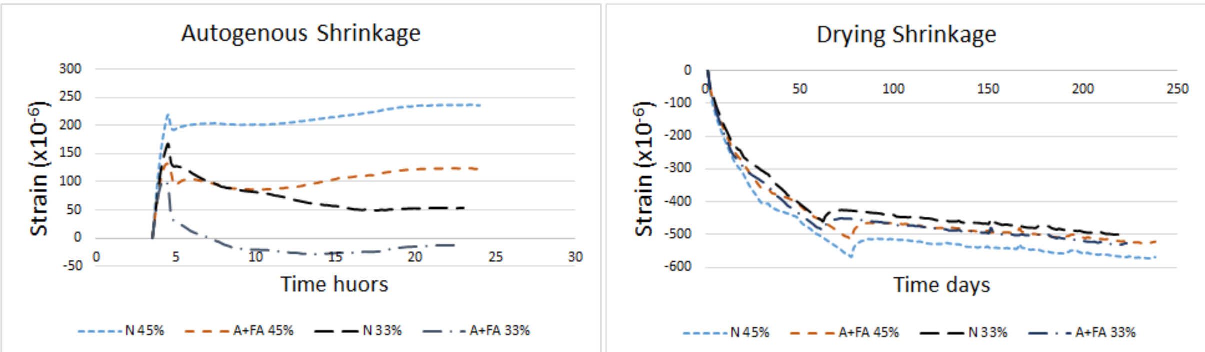


Fig.3: Autogenous Shrinkage and Drying Shrinkage

4.3 Modulus of elasticity

Fig.4 shows the results of modulus of elasticity comparing with JCI model [6] and AIJ Model [7], and the results are very close to AIJ model. In the most ceases modulus of elasticity of mix proportions with (N) and with (A+FA) are similar in relation to compressive strength.

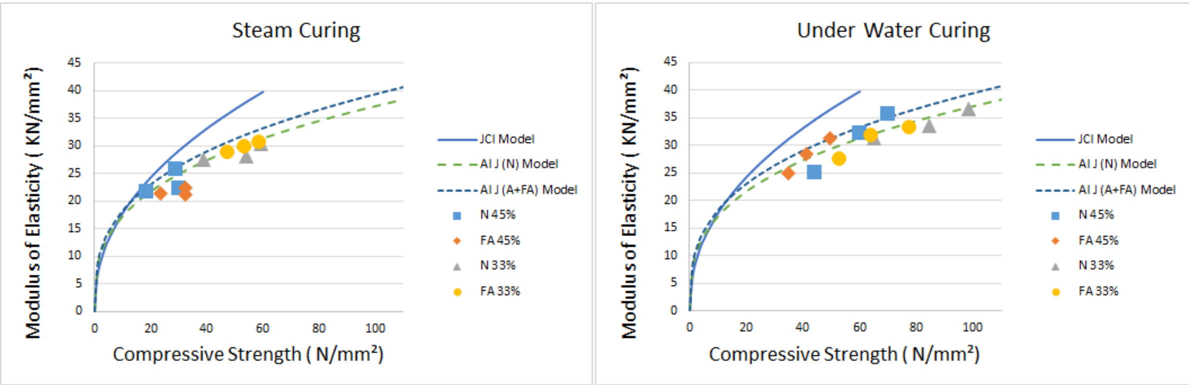


Fig.4: Modulus of Elasticity

5. CONCLUSIONS

1- Steam cured concrete with fly ash and high alite cement develops higher compressive strength at 1 day of age than the concrete with ordinary Portland cement, which is what pre-cast concrete factories looking for, because they want to demold the concrete as soon as possible without any side effects.
2- For the steam cured concrete with fly ash the specimens with W/C=33% shows a quick drop from expansion to shrinkage due to autogenous shrinkage. The effect of autogenous shrinkage on the cracking of the concrete should be studied.
3- The concrete with fly ash has larger drying shrinkage values than the normal concrete when (W/B=33%), but when we increase W/B to 45% the drying shrinkage of the concrete with fly ash was less than it was in the concrete with (N)
4- There are not big differences in the modulus of elasticity between the steam cured concrete and the underwater cured concrete regardless of fly ash addition.

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