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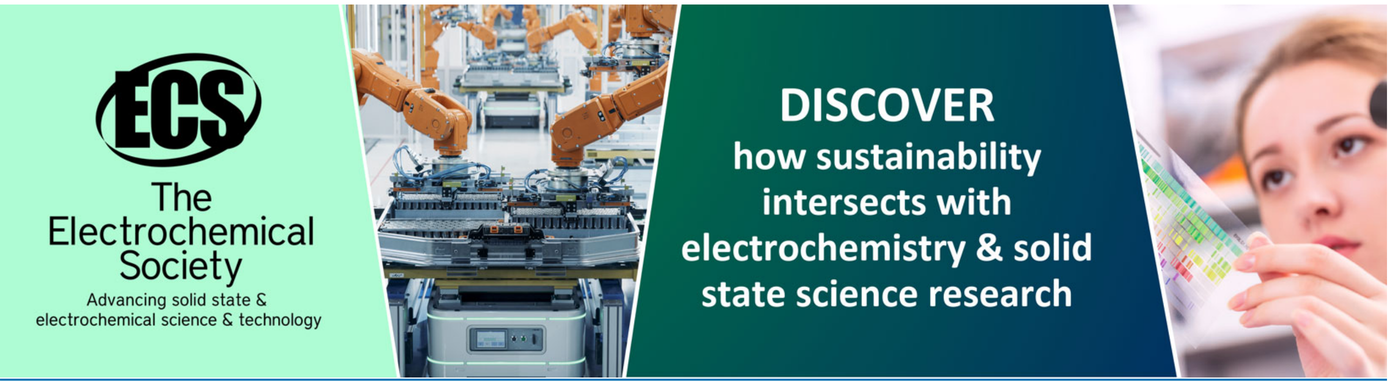

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Effects of curing conditions and addition of fine blast furnace slag powder on the initial performance of concrete using expanding material

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Abstract. In this study was investigated the effect of steam curing in the case of adding expandable material to powdery high fluidity concrete containing blast furnace slag fine powder on two kinds of expansive materials, ettringite type inflation material and lime type expansion material. As a result, the constraint expansion strain increases with the ettringite type due to the increase in the steam curing temperature. However, it was confirmed that it decreased with the lime type expansion material.

1. Introduction

In recent years, the Ministry of Land, Infrastructure, Transport, and Tourism JAPAN promotes the activities effort to improve the productivity of the construction site. The merit of use of precast concrete products is labor saving and shortening construction period, and it is drawing attention as a solution to the problem in concrete works again. In addition, since precast concrete products are manufactured at quality controlled factories, it can be considered that quality of precast concrete product is higher than that of cast-in-place concrete. [1] However, most concrete descriptions on concrete standard concrete descriptions, and quality control of Precast Concrete products differ from factory to factory in many cases and areas. [2] - [3] Meanwhile, at the Precast Concrete product factory efforts to reduce costs and improve production efficiency are being carried out daily basis, but one of such efforts is to improve form rotation efficiency. In this case, consideration is made to shorten the preliminary time, etc. [4] - [12] When a precast concrete factory is located near a residential area, high flowing concrete may be used in some cases. Compared with ordinary concrete, high flowing concrete is less time to vibration and therefore it is said to be good for noise countermeasure and so on. High fluidity concrete become contain powder such as slag and fly ash. However, since slag and fly ash have large self-shrinkage, cracks often occur in precast concrete products. In addition, precast concrete products are subjected to high temperature steam curing, so thermal stress cracks occur frequently. Therefore, an inflating agent is used as crack suppression. Therefore, attention is expansion materials and the like as concrete materials. [13] However, it is

recognized that the shrinkage distortion increases and the quality deteriorates such as cracking occurs. For this reason, it is necessary to optimize the curing condition, compounding condition, and material used, but as a result, the expanding material may be most than the general usage amount.
However, there are few investigations and studies on the influence of inflating material exerted by the preliminary time, and it is necessary to systemize it to btain efficient curing condition / compounding condition. In addition, there are cases where highly fluidized concrete, such as SCC is being adopted for labor saving, noise control, and high quality. Also, blast furnace slag fine Strain gauge being used as the material for high fluidity concrete. There is also a report that expansion of gypsum decreases when the blast furnace slag fine powder and ettringite type expansion material are used in combination and is consumed in the reaction of slag. In g temperature and preliminary time on expanding material for powdered high fluidity concrete containing blast furnace slag fine powder. In addition, from the viewpoint of quality and productivity of precast concrete products, the initial compressive strength and expansion rate, which are important performance index, were also investigated.

2. Experiment products

2.1. Materials

Table 1 shows the material used and its quality. The specific surface area of the blast furnace slag fine powder used was 4000 brains. The expansion material used was two types (Ettringite type and Lime type).

Table 1. Specimen of restraint expansion strain.

Materials	Symbol	Properties	Density (g/mm^3)
Cement	C	Ordinary Portland cement	3.16
Blast furnace slag fine powder	Sg	With plaster	2.89
Expanding material	CaO	Ettringite type	2.93
	Et	Lime type	2.19
Fine aggregate	S	River sand from Yamakita Kanagfawa	2.61
Coarse aggregate	G	Crushed stone from Sagamihara Kanagawa	2.69
Chemical Admixture	Ad	High performance AE water reducing agent	-

2.2. Mix proportions

The mix proportions of the concrete used in the experiment is shown in Table 2. High fluidity concrete with a water binder ratio (W / B) of 33.6%, various expansion materials were applied internally. The blast furnace slag fine powder replaced slag by 50% with respect to cement. The amount of admixture was adjusted so that the slump flow was in the range of 60 ±10 cm (P ×0.6% constant)

Table 2. Mix proportions.

No.	W	C	Sg	CaO	Et	S	G
PL	168	250	250	-	-	764	822
CaO		233	233	35	-	778	838
Et				-	35	799	893

2.3. Curing Parameter

The curing temperature diagram is shown in Fig.1. The preliminary time (pre-curing) was set to three levels, 0.5h, 1.5h, and 2.5h. In addition, the maximum temperature of steam curing was set to 3 levels of 45 °C, 55 °C, and 65 °C. The steam curing was conducted until demolding time (20 h), and thereafter it was kept in an environment of 20 °C. and 60% relative humidity.

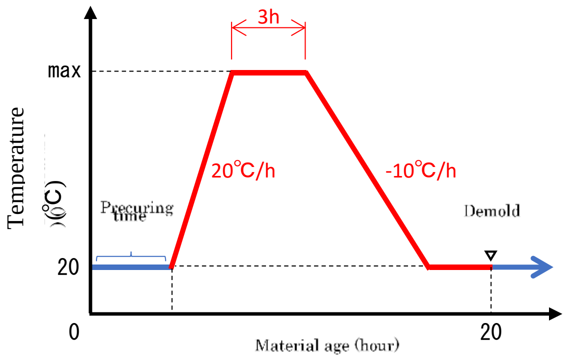


Fig.1. Curing pattern.

2.4. Test Items

Test items were checked for compression strength and length change. The change in length was a constraint expansion strain according to JIS A 6202 B method, and it was measured with the specimen shown in Fig.2. S crew cut steel bars attached two train gauges on the center portion (see Fig.2) were arranged in specimen. Time-dependent change of the strain during steam curing process was also measured. To cancel the thermal expansion of the restraint device, the strain was measured simultaneously in the steam curing chamber at the same time as the dummy restraint device, and it was subtracted from the strain of the concrete specimen.

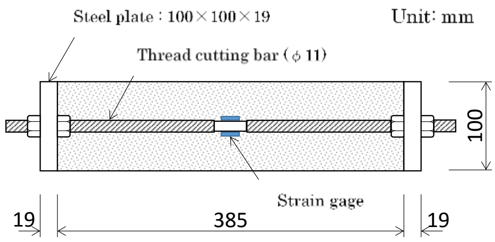


Fig.2. Specimen of restraint expansion strain.

3. Experiment results and discussion

3.1. Compressive strength

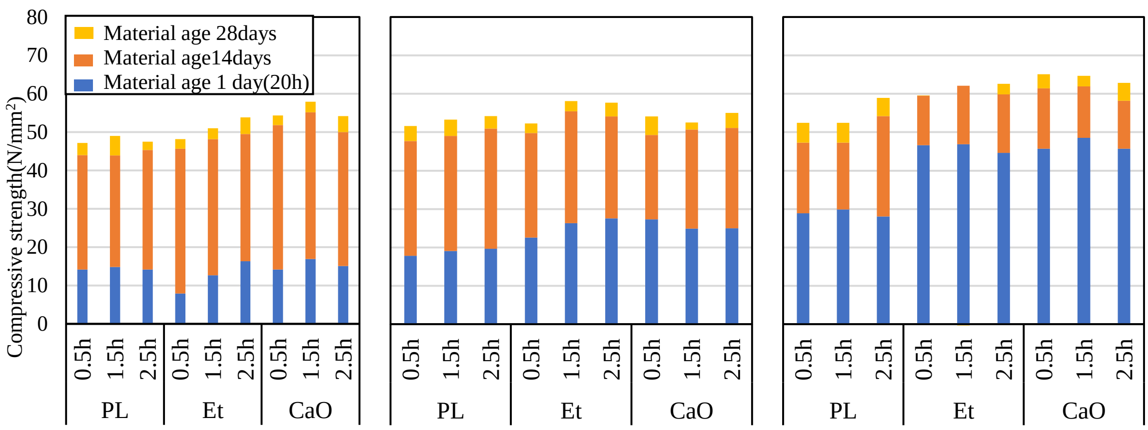
Fig. 3 shows the compressive strength test results for each maximum steam curing temperature. First of all, in the case of the maximum temperature of 45 °C, each compounding showed almost the same performance at the compressive strength (material age 20 h) at the time of demoulding. However, after 14 days of age, the compressive strength was somewhat larger in the case of adding the expandable material. When the maximum temperature is 55 °C, the strength is enhanced by the addition of the expansion material at the stage of demolding. Even at the maximum temperature of 65 °C, the same tendency as at 55 °C was observed, but the strength enhancement at the time of demolding became more prominent. For this reason, in the case of 45 °C, it is considered that compressive strength (material age 20 h) enhancement appeared after demolding. In the case of precast concrete products, since demolding is one day, it was found that a curing temperature of at least 55 °C. or higher is required under the curing condition in this study to obtain the effect of enhancing the strength by the expansive material.

Next, Fig.4 shows the relationship between the preliminary time and compressive strength at the time of demolding (material age 20 h). In the PL formulation and the CaO formulation, no significant difference due to the preliminary time was confirmed, but at 45 °C. and 55 °C. in the Et formulation, the compressive strength tended to increase as the preliminary time increased. Next, Fig.4 shows the relationship between the preliminary time and compressive strength at the time of demolding (material age 20 h). In the PL formulation and the CaO formulation, no significant difference due to the preliminary time can be confirmed, but at 45 °C. and 55 °C. in the Et formulation, the compressive strength tended to increase as the preliminary time increased. It is also possible to be affected by the preliminary time only when using ettringite type expansion agent. However, it was found that there was a possibility that a certain accumulated temperature and an effective material age might be necessary, as this tendency is not seen at 65 °C and strength enhancement did not appear at 45 °C during demolding It was.

3.2. Length change test

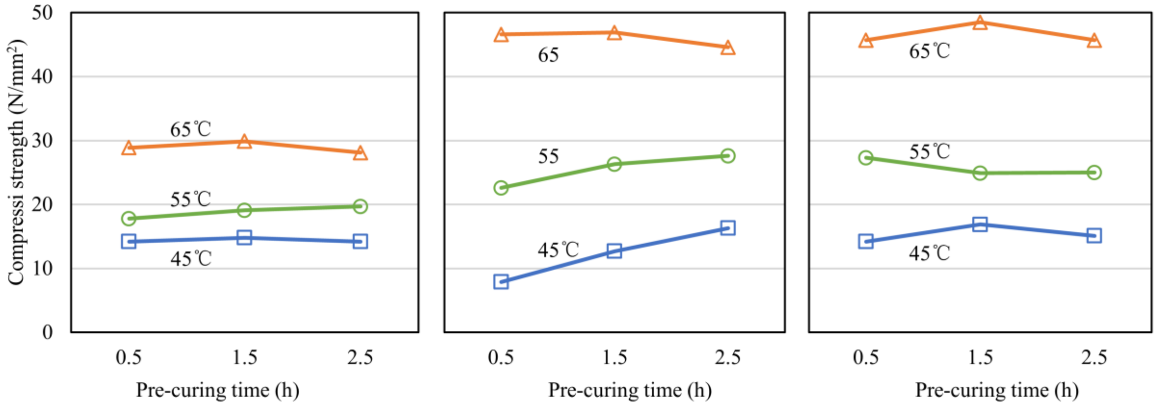
A length change test result with a maximum temperature of 55 °C is shown Fig.5. From this result, the expansion reaction due to the expansion material in all cases occurs earlier than the ettringite type (Et) with the lime type (CaO) expansion material and peaks over several hours. The timing was the same for both ettringite and lime, and this tendency was the same even in the case where the maximum temperature was different. In comparison with the maximum expansion strain, the lime type expansion agent is generated about twice for the ettringite type expansion agent, and these have also been confirmed in the past research of the authors. Next, the relationship between the preliminary time at the time of demolding (material age 20 h) and the constraint expansion strain is shown in Fig.6. From this figure, it can be confirmed that the constraint expansion strain tends to be larger in the case where the preliminary time is longer in all the cases. For this reason, it is understood that it is necessary to secure sufficient preliminary time to sufficiently exert the expansion effect of the expansion material irrespective of the curing temperature.

Fig.7. shows the relationship between compressive strength and restraint expansion strain at the time of demolding (material age 20 h). In all cases, the compressive strength of the ettringite (Et) expansion material tends to increase, that is, the restraint expansion strain tends to increase as the maximum temperature of steam curing increases. On the other hand, in the case of the lime type (CaO) expansion material, the constraint expansion strain tended to decrease as the maximum temperature of the steam curing increased. Therefore, in the figure, a broken line is written at a position intermediate between the ettringite type expansion material and the lime type expansion material. As described above, the constraint expansion strain of the both expansion materials of the ettringite-based expansion material and the lime type expansion material is increased as the preliminary time becomes longer. Furthermore, it can also be confirmed that the convergence tends to occur as the compressive strength increases. Compressive strength levels are all equal to the range of 10 to 50 N / mm2. From this, it is also expected that the Young's modulus and the linear expansion coefficient will be different, noting the timing at which the expansion amount appears due to the different preliminary time.



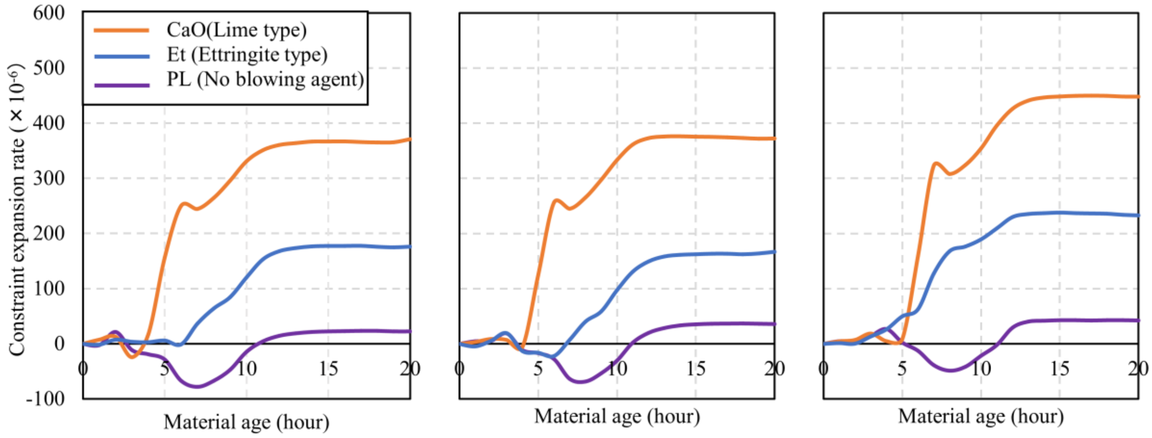
a) Max temparature 45℃ b) Max temparature 55℃ c) Max temparature 65℃

Fig.3. Compressive strength test result.



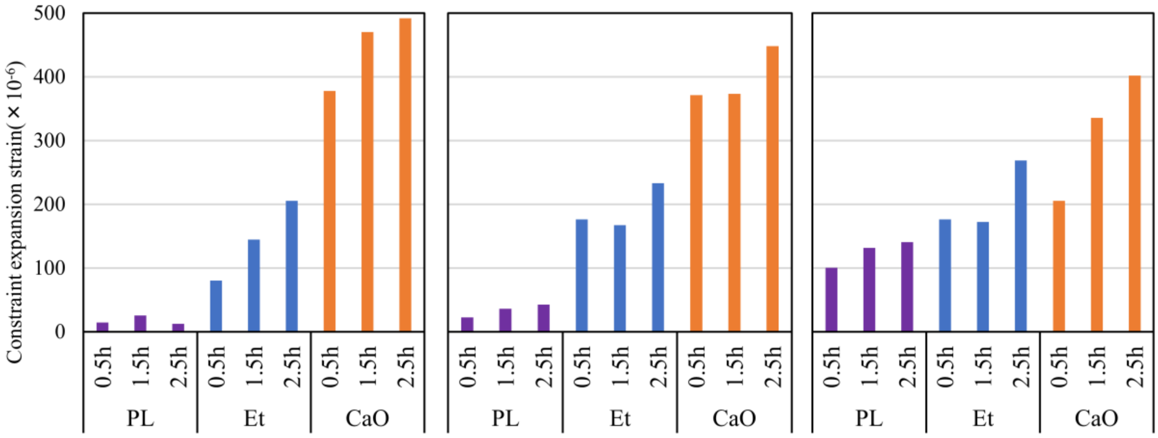
a) PL formulation (No blowing agent) b) Et formulation (Ettringite type) c) CaO formulation (Lime type)

Fig.4. Relationship between preliminary time and compressive strength
At demolding: Material age of 20 hour



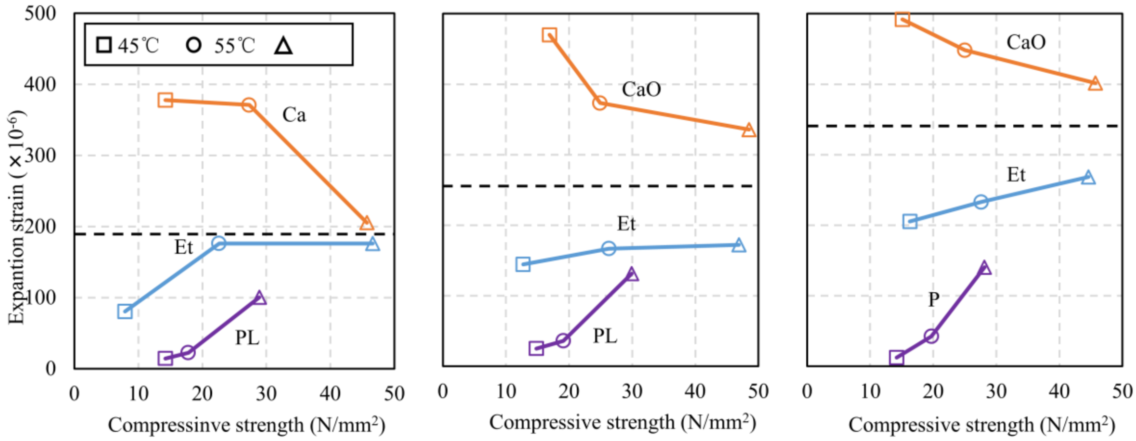
a) Pre-curing time 0.5h b) Pre-curing time 1.5h c) Pre-curing time 2.5h

Fig.5. Length change test result (Maximum temperature 55 ° C).



a) Max temparature 45℃ b) Max temparature 55℃ c) Max temparature 65℃

Fig.6. Relationship between Pre-curing time and constraint expansion strain
At demolding: Age of 20 hour.



a) Pre-curing time 0.5h b) Pre-curing time 1.5h c) Pre-curing time 2.5h

Fig.7. Relationship between compressive strength and constraint expansion strain
At demolding: material age 20 hour.

4. Experiment result and discussion

This experiment investigated the influence of steam curing temperature and pre-curing time on expanding agent for powdered high fluidity concrete blended with blast furnace slag fine powder. As a result, the conclusions of this study are as following.

(1) When expanding material is added for enhancing demolding strength, it was found that the maximum temperature of steam curing is required to be about 55 °C or more.

(2) The restraint expansion strain due to the addition of the expansion agent increases as the preliminary time increases. However, the effect of enhancing compressive strength was relatively small, and it was almost the same for both type of expansion agent.

(3) When the maximum temperature of steam curing is increased, constraint expansion strain due to the addition of the expansion material is increased in the ettringite-based expansion material, but it decreases in the lime type expansion material.

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