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Effect of Curing Temperature on Expansion of Expansive Concrete

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EFFECT OF CURING TEMPERATURE ON EXPANSION OF EXPANSIVE CONCRETE

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ABSTRACT

This paper describes the relations between temperature and expansion characteristics of uniaxially restrained expansive concrete and mortar varying the type and quantity of expansive admixture, the type of cement used, mix proportion of concrete or mortar, and curing temperature in a range from 5°C to 50°C or storage conditions of the specimens. It has been clarified that the effect of temperature on the expansion characteristics of expansive concrete differs greatly not only with the curing temperature from the time of placing, but also with subsequent temperature variation, the type and quantity of expansive admixture, and the type of cement, and that reverse results are produced depending on the combination of these factors. Especially, the effect of high temperature at early age is most prominent.

INTRODUCTION

When alleviating so-called temperature cracking by using expansive concrete for massive concrete, for hot-weather concrete, or cold-weather concrete, it is extremely important to have thorough knowledge of the relation between temperature and expansion characteristics of the concrete. It is conceivable that the relation depends on the type and quantity of expansive admixture and the type of cement used in combination, but it has not yet been clarified.

This study was carried out on uniaxially restrained specimens varying the type and quantity of expansive admixture, the type of cement used in combination, and mix proportions of concrete or mortar, varying curing temperature in a range from 5°C to 50°C, and also varying the storage conditions until transferring to the specified temperature. The expansion characteristics in such cases were measured, and the results were summarized in an effort to experimentally clarify the effect of temperature on expansion characteristics.

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OUTLINES OF EXPERIMENTS

The experiments of three series (see Table 1) were performed. Series 1 was on mortars containing 4 varieties of expansive admixture presently being sold commercially in Japan. The effects of placing temperature (20°C and 35°C) and curing temperature after the age of 1 day (5°C, 20°C, 35°C and 50°C) on expansion characteristics were determined. Series 2 in which the quantity of expansive admixture was varied at two levels, had high-early-strength portland cement as the cement to be used in combination, while Series 3 used restrained expansion specimens of concrete to determine the influence of curing temperature on expansion characteristics.

The expansive admixtures used were those furnished by the Expansive Admixture Association in 1977. Expansive admixtures A and B are classified as ettringite type, and C and D as lime type. The cements used were ordinary and high-early-strength portland cements manufactured by Mitsubishi Mining and Cement Co., Ltd. The sand used for mortar was Toyoura standard sand, while the aggregates used for concrete were river sand and river gravel from the Fuji River with the specific gravities of 2.60 and 2.66, fineness moduli of 2.87 and 6.92 (maximum size 25 mm), and the rate of water absorptions of 2.5% and 0.99%, respectively.

Mix proportion of 468 g of cement, 52 g of expansive admixture, 1040 g of Toyoura standard sand and 312 g of water for mortar as indicated in Proposed Method of Testing Expansion Properties of Expansive Admixtures in Standard Methods of Testing (1) was employed. In other words, using expansive admixture at the ratio of 10% of the total quantity of cement and expansive admixture is the standard. In the present study, experiments were made further for the case of using two thirds of the standard quantity of admixture. Mix proportion of concrete with water content of 172 kg/m^3 and cementitious material, totalling cement and expansive admixture, of 382 kg/m^3 were held constant with the expansive admixture content of 30 kg/m^3 and 50 kg/m^3. Slumps were approximately 8 cm.

Table 1 Outlines of experiments

Series	Type of expan.	Amount of expan.	Placing temp.	Curing temp.	Type of cement
1	A B C D	Standard Standard ×⅔	20℃	5℃ 20℃ 35℃ 50℃	Type I
			35℃	35℃ 50℃	
2	A C	Standard	20℃	5℃ 20℃ 35℃ 50℃	Type III
3	A C	30kg/m^3 50kg/m^3	20℃	5℃ 20℃ 35℃ 50℃	Type I

The shapes and dimensions of the specimens used were prisms with cross section of 4 × 4 cm and length of 13.5 cm for mortar and cross section of 10 × 10 cm and length of 36 cm for concrete. The mortar specimens of Series 1 and Series 2 were uniaxially restrained specimens with restraining steel ratio approximately 0.63% as specified in the abovementioned Proposed Standard Methods of Testing. The concrete specimens in Series 3 were uniaxially restrained specimens with restraining steel ratio approximately 0.94% following Proposed Method of Testing Restrained Expansion of Expansive Concrete also of the Standard Methods of Testing. Manufacturing specimens followed the Proposed Standard Methods of Testing except for placing temperature of 35°C.

For cases of placing temperature of 35°C, sand was warmed to 50°C, water was 25 to 35°C, and mixing and placing were done in a room of temperature of 20°C ± 2°C and humidity of not less than 80% RH. After placing, molds were placed in vinyl bags and immersed in a tank of 35°C in a manner that the surface of the water and the tops of the molds would coincide. Three to four hours later, the top surfaces were scraped, the specimens were again put in the vinyl bags and cured in the tank. Molds were stripped at the age of 24 hours, and after measuring the expansive strain curing was performed in a tank of the specified temperature.

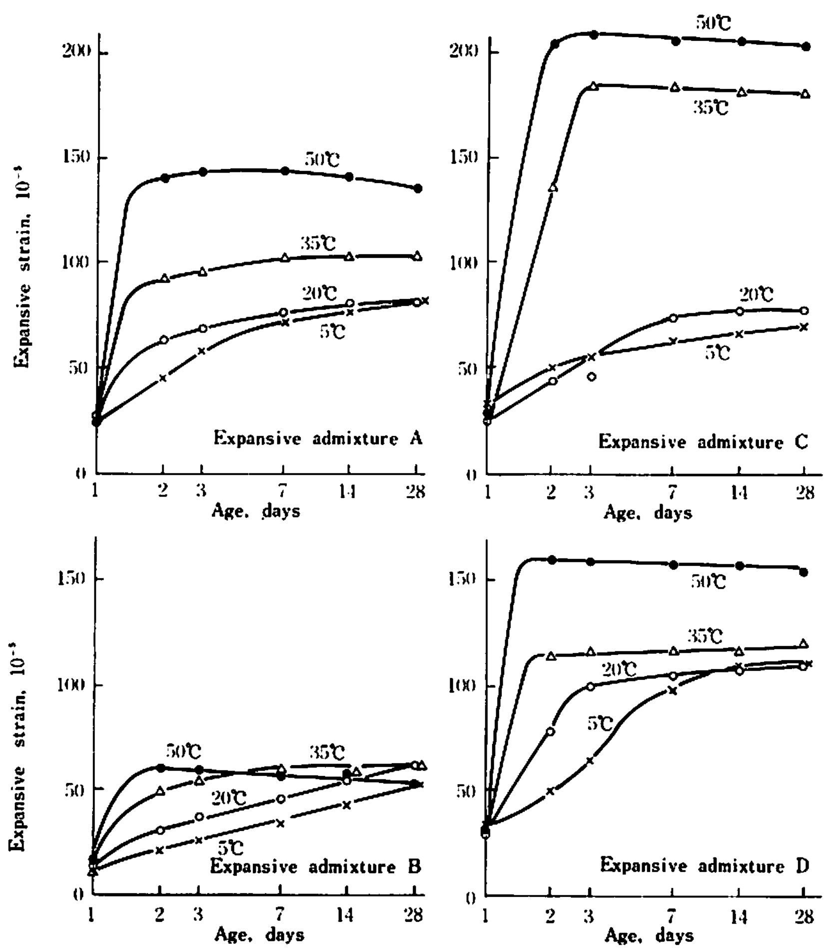

Fig. 1 Effect of temperature change at the age of 1 day on expansion characteristics

All curing temperatures were controlled within ±2°C. Placing temperatures were controlled within ±1°C. In order to correct temperature strains caused by differences in curing temperatures, the coefficients of thermal expansion of ordinary mortar and concrete at the age of 1 day were determined, the results of which were 1.12×10^{-5}/°C and 1.02×10^{-5}/°C, respectively. These values were used to make corrections of measurements to a unified curing temperature of 20°C. The test results were examined by using the corrected expansive strains.

EFFECT OF CURING TEMPERATURE CHANGE AT THE AGE OF 1 DAY

Fig. 1 shows the relations between restrained expansive strain and age of mortars placed at 20°C and maintained at that temperature for 24 hours after which they were cured in water at 5°C, 20°C, 35°C or 50°C, where expansive admixtures were used in standard amounts. Expansive strains were generally seen to change suddenly immediately after temperature had been changed with the rate increased the higher the temperature and completion of expansion also promoted. This had already been recognized by Nakahara et al. in experiments using the expansive admixture A(2), and as shown in this figure it is seen in common regardless of the variety of expansive admixture. Such a phenomenon was seen in every specimen when expansive admixtures of two thirds of the standard quantity was used, and in the specimens for which expansive admixtures A and C and high-early-strength portland cement were used and in concretes with expansive admixture contents of 30 kg/m^3 and 50 kg/m^3.

Fig. 2 based on Fig. 1 , shows the expansive strains for the various temperatures at the age of 2 days (in effect, 1 day after temperature change)

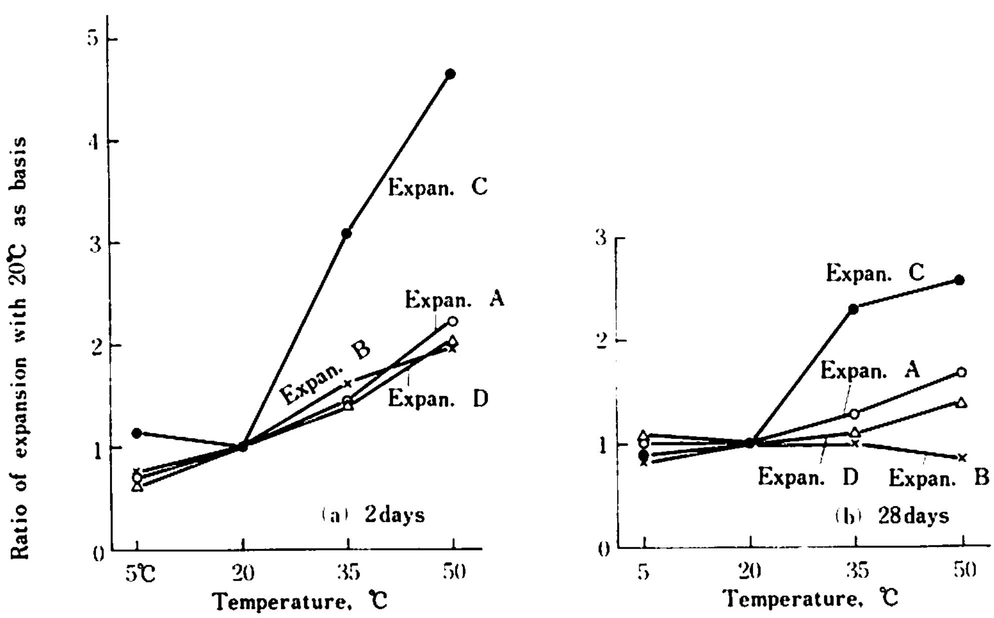

Fig. 2 Ratios of expansive strains at various curing temperatures to those cured at 20°C as basis (ordinary portland cement).

and at the age of 28 days as ratios to the expansive strain of specimens cured at 20°C. It may be recognized the expansive strains at the age of 2 days is greatly affected by temperature, compared with those at the age of 28 days. Also, it is clear that the influence of curing temperature on expansion characteristics differ according to the type of expansive admixture, when cured under a constant temperature from the time of placing, as shown in Fig. 3.

Expansive admixture C is especially sensitive to high temperature, and not only immediately after changed to high temperature, but also ultimately, showed extremely great expansion. Expansive admixtures A and D are influenced roughly same degrees by temperature, although expansive admixture A is somewhot more sensitive. Expansive admixture B appears to be the least susceptible to the effect of temperature, and especially at the age of 28 days, and unlike the other expansive admixtures, there was a tendency for expansive strain to be decreased as temperature was increased showing an opposite characteristic to that at the age of 2 days.

A similar tendency to the above was seen when expansive admixtures were used in dosages of two thirds of the standard amount, and with the exception of the case of expansive admixture C at curing temperature of 50°C, there was less sensitivity to temperature at both at the age of 2 days and 28 days compared with the cases of using standard amounts.

With expansive admixtures A and C, the expansive strains at the age of 2 days, when high-early-strength portland cement was used, indicated more or less the same trends (see Fig. 4). Expansion characteristics different from the cases where ordinary portland cement was used were indicated, and when high-early-strength portland cement was used, expansive

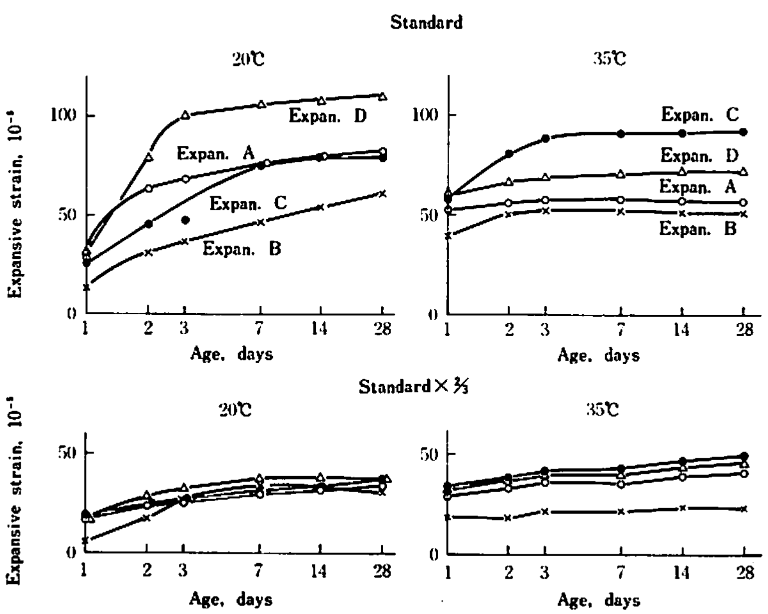

Fig. 3 Effect of curing temperature (kept constant all the time) on expansion characteristics

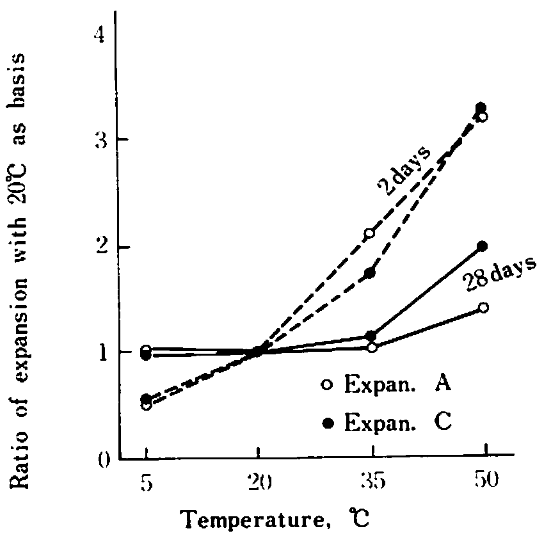

Fig. 4 Effect of curing temperature on expansion characteristics when high-early-strength portland cement was used.

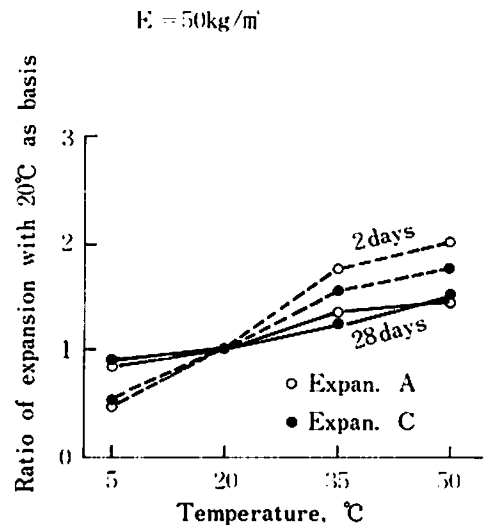

Fig. 5 Effect of curing temperature on expansion characteristics of expansive concrete.

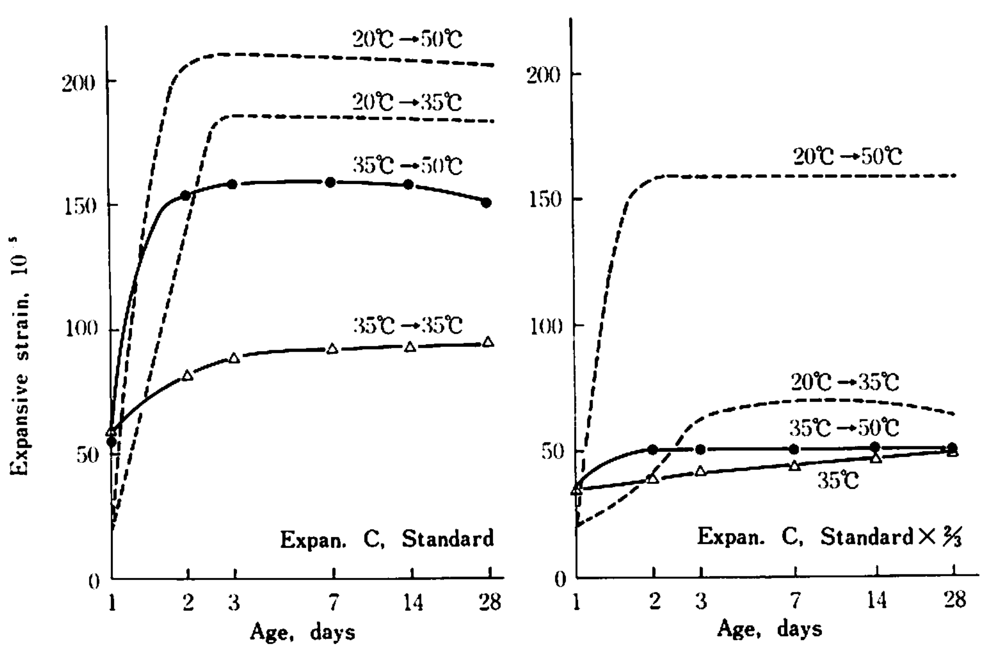

Fig. 6 Effect of temperature up to the age of 1 day on expansion characteristics.

admixture A was sensitive to temperature, whereas expansive admixture C was insensitive. However, at the age of 28 days, hardly any influence of temperature was seen from 5°C to 35°C, but at 50°C the expansion was 1.4 times that at 20°C with expansive admixture A and 2.0 times with expansive admixture C, for somewhat more insensitivity to temperature than when ordinary portland cement was used, but the trends were the same.

Regarding concrete, it seems that the influence of temperature according to the kind of expansive admixture is not as much as on mortars (see Fig. 5). Especially, it may be said that the extreme expansion shown at high temperature in case of mortar is hardly seen in the case of concrete with expansive admixture C.

EFFECT OF TEMPERATURE UP TO THE AGE OF 1 DAY

The results of mortars for which expansive admixture C was used placed at 35°C, maintained at the same temperature for 24 hours and then raised to 50°C, and mortars cured at the original temperature are shown in Fig. 6 , which also shows the cases shown in Fig. 1 for comparison.

When this expansive admixture of the standard amount is used and after cured at 35°C up to the age of 1 day and the temperature is raised to 50°C, it may be recognized that the expansive strain increases rapidly, but even then is lower than in the case of raising temperature from 20°C, while the expansive strain itself is also lower. This phenomenon appeared when expansive admixture D, also of lime type, was used, but did not appear when expansive admixture A of ettringite type was used, which showed this when raising temperature from 20°C. Further, compared with the cases of raising temperature from 20°C to 35°C, and the case when cured at 35°C from the time of placement, the expansive strains were low for all expansive admixtures.

When expansive admixtures were used at dosages of two thirds of the standard amount, sudden increases in expansive strains immediately after raising from 35°C to 50°C could hardly be seen, and the expansive strains at the age of 28 days were equal or even smaller than in the case of maintaining at 35°C.

Based on the above, the influence of high temperature is most prominent when raising to high temperature at early age. The influence of high temperature is greater in the case when temperature is raised after elapse of a day after placing than in the case when temperature is kept constantly high from the time of placing. And there is a tendency for expansive strain to be generally higher at higher temperatures. However, it appears that the influence of high temperature conversely becomes smaller if raised to high temperature is delayed.

CLOSURE

It has been clarified through experiments that the effect of temperature on the expansion characteristics of expansive concrete varies greatly not only with the curing temperature from the time of placing, but also with subsequent temperature variation, kind and dosage of expansive admixture, and the type of cement, and also clarified that reverse results are produced depending on the combination of these factors.

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