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論 文

[1116] The Influence of Medium and High Temperature Environments (20～50°C) on the Physical Properties of High-Strength Concrete

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1. INTRODUCTION.

Long-term high temperatures such as those found in power plants and chemical plants can increase the temperature on the surface of concrete member up to 50℃.In hot weather, where the temperature is almost around 35℃, the strength maintenance for outer layer of high-strength or high quality concrete is important both for theoretical and practical reasons. Firstly, the corrosion of steel reinforcement in concrete structures due to the carbonation is considered greater when the outer layer concrete cannot provide enough protection for early cracks after being exposed to those temperatures for certain time.Therefore,the effective means of protecting the steel reinforcement is to prepare an adequate cover and maintain the strength of that cover (outer layer concrete). Secondly,it will provide useful informations in maintaining the quality of high-strength concrete under medium and high temperature environments.This preliminary study deals with the influence of medium and high temperature,within the range of 20℃ to 50℃, on the properties of high-strength concrete made with four types of concrete mixes.

2. EXPERIMENTAL PLANS.

2.1) MATERIALS.

(1) Cement

Ordinary portland cement was used in this study.

(2) Mineral admixture

Three types of mineral admixture, blast-furnace slag, fly ash-fume and silica fume (Elkem Microsilica grade 940-U) were used in this study. Blast-furnace slag (hereinafter called 'slag') were used on the basic weight of 50% replacement of cement while fly ash-fume and silica fume were used on the basic weight of 10% replacement of cement. The specific

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gravity of slag was 2.89, fly ash-fume was 2.47 and silica fume was 2.24.
(3) Aggregate

Crushed stone was used for the coarse aggregate whereas for the fine aggregate, the river sand was used.

(4) Air entraining and water reducing agent

Type ‘ SP-8N ’ was used with the fluidizing admixture to act as air content adjustment.

2.2) MIX PROPORTION.

The details of mix proportions are listed in Table 1. The control mixtures were proportioned to have a slump of 18 ~ 24cm, and air content of 2 ± 1% by using AE admixtures and a high-range water reducer. In the temperature control room, the mixtures were mixed for 8 minutes, using pan type revolving paddle mixer 0.05m^3. The mix proportions of concrete with mineral admixtures were similar to those concrete without mineral admixtures.

Table 1 - Detail of Mix Proportions

Type of mix	W/C (%)	S/a (%)	Unit weight (kg/m^3)							SP-8N	Fluidizing admixture (xC%)
			Water	Cement	B/F slag	Silica fume	Fly ash-fume	Fine agg.	Coarse agg.	(xC%)	
NPC	25	39	160	640	-	-	-	627	993	1.35	0.40
Sg	25	39	160	320	320	-	-	616	977	1.10	0.30
SF	25	39	160	576	-	64	-	616	979	1.80	0.48
FF	25	39	160	576	-	-	64	619	985	3.0	0.80

2.3) SCOPE OF TESTS.

After the properties of fresh concrete such as temperature, slump, slump flow, air content and unit weight had been measured, (see Table 2) all cylindrical concrete specimens (φ7.5cm x h15cm) were cast in cast iron molds. The specimens were compacted in two layers by rodding each layer ten times. Then, these concrete specimens were left in the curing room at 20℃ for 24 hours. The concrete specimens were demolded on the following day and marked before subjected to temperature curing of 20℃, 35℃, and 50℃. Three types of curing method were adopted in this study, namely water curing, wet-wrapped curing and dry air curing. In order to determine the properties of high-strength concrete between inner and outer portion of a concrete member, concrete specimens under wet-wrapped curing and dry air curing were assumed as an inner concrete and outer layer concrete respectively.

Compressive strength test were conducted at the ages of 7, 28, 56, and 91 days. Three concrete specimens were tested at each age. Dynamic modulus of elasticity were measured on the concrete specimens for compressive strength test at the same age. Static modulus of elasticity were measured at the age of 28 days.

Table 2. The Properties of Fresh Concrete

Type of mix	Slump (cm)	Flow (cm)	Air Content (%)	Density (kg/m^3)	Concrete temperature (℃)
NPC	23.0	40.5	1.5	2463	22.0
Sg	25.0	50.5	2.2	2412	20.0
SF	23.0	38.0	1.9	2432	22.0
FF	21.0	27.5	1.8	2437	22.0

3. TEST RESULTS AND DISCUSSION

3.1) PROPERTIES OF FRESH CONCRETE

The properties of fresh concrete are given in Table 2. From this point, concrete incorporating slag, fly ash-fume, and silica fume were called as Sg concrete, FF concrete and SF concrete respectively. Normal portland cement concrete was called as NPC concrete.

3.2) COMPRESSIVE STRENGTH

In order to study the properties of high-strength concrete between inner and outer portion of concrete member under medium and high temperature environments, the compressive strength have been calculated and plotted in Figure 1 ~ 4. These serve as a basis for analysis.

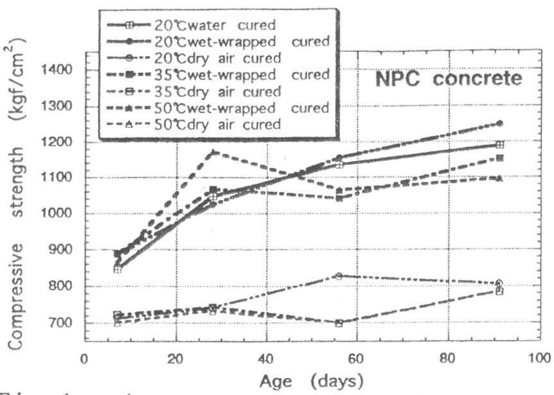

Fig.1 - Age versus strength

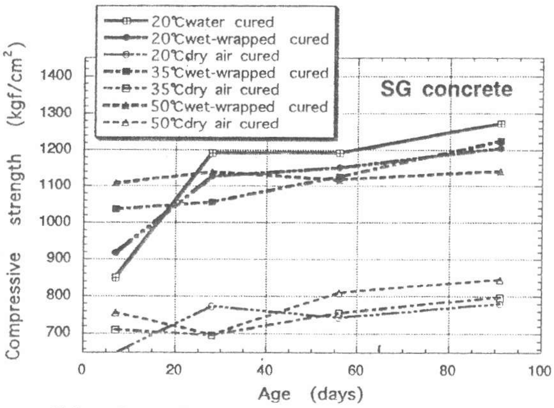

Fig.2 - Age versus strength

The highest compressive strengths of all concrete specimens were produced at any age by water curing and wet-wrapped curing. Dry air curing which has been assumed as outer layer concrete provided lower strength at all ages. The compressive strength were practically increased from the age of 7 and 28 days for all types of concrete specimens except for Sg concrete (Fig:2) under 35℃ and 50℃ of dry air curing at the age of 28 days. There are two possible reasons for the strength losses of Sg concrete at this point. Firstly, the rate and degree of hydration is affected by the loss of moisture at an early age, with a decrease in strength gain. Secondly, may be the heat of generation were decreased in Sg concrete after being exposed to these temperatures for 10 days.[1]

The compressive strength of wet-wrapped curing which has been assumed as inner concrete increased from age 7 to 28 days, especially for SF concrete that produced highest level of strength at the age of 28 days under 35℃. However, the strength were slighly decreased at the age of 91 days under 50℃. It might be due to the insufficient water for full hydration. Furthermore, from the age of 7 days, the strength of Sg, SF and FF concrete practically reached above 1000kgf/cm^2. This indicated that the enhanced bonding strength between the paste and aggregate of those concrete to be resulted from the signficantly accelarated pozzolanic reaction of mineral admixture at high temperatures.

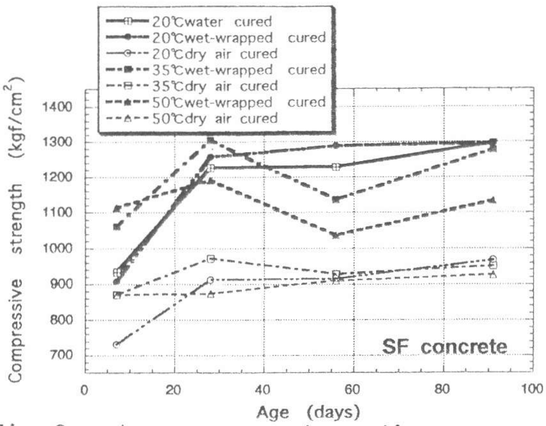

Fig.3 - Age versus strength

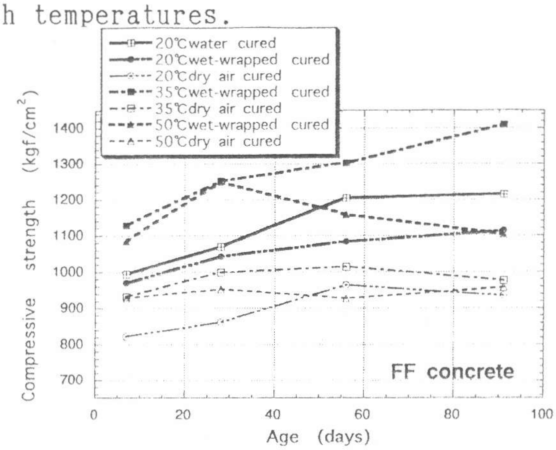

Fig.4 - Age versus strength

3.3) MODULUS OF ELASTICITY

The results of the correlation between compressive strength and static modulus of elasticity of all concrete mixes are shown in Figure 5 ~ 8. For normal concrete, the static modulus of elasticity at the strength of 200kgf/cm^2 is about 2.1 x 10^5kgf/cm^2. As observed in this study, the static modulus of elasticity of high-strength concrete under medium and high temperature environments are between 3.2 to 4.8 x 10^5 kgf/cm^2. By using least-squares procedure, the differences of curing condition for all concrete mixes cannot be recognized easily because the static modulus of elasticity seemed to be approximately same.

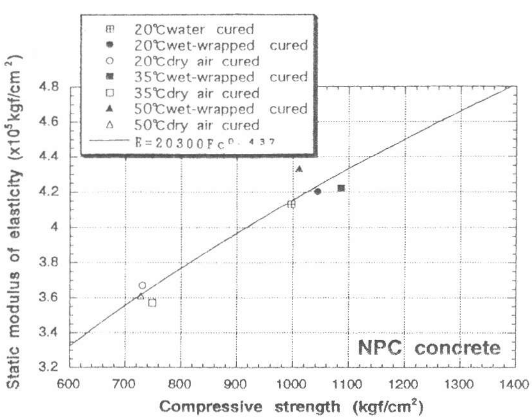

Fig.5 - Strength vs static modulus

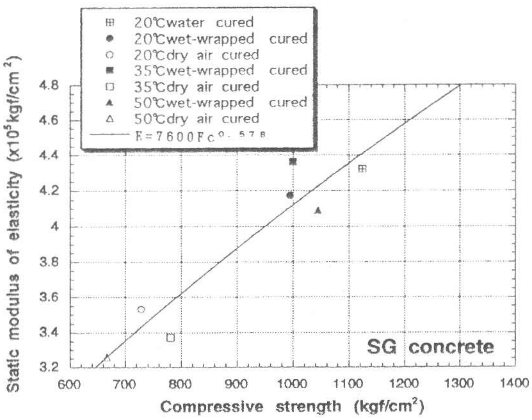

Fig.6 - Strength vs static modulus

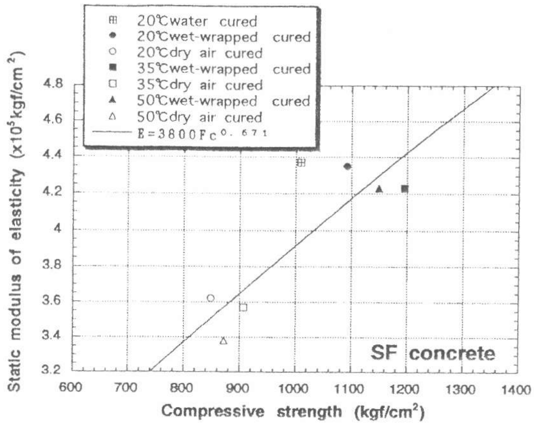

Fig.7 - Strength vs static modulus

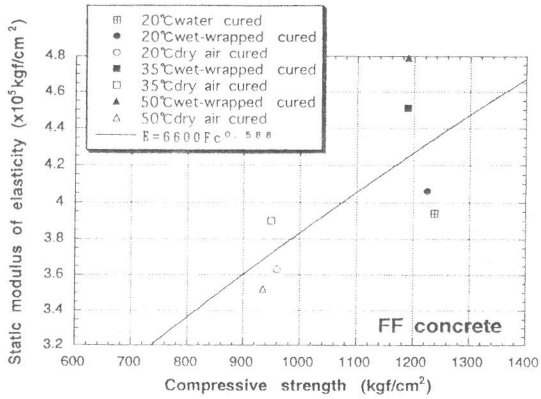

Fig.8 - Strength vs static modulus

The dynamic modulus of elasticity of all concrete mixes are plotted in Figure 9 ~ 12. The figures show that the dynamic modulus of elasticity increased continously with the age under 20℃ of water and wet-wrapped curing but decreased from the age of 28 days under dry air curing. However, under 50℃ of dry air and wet-wrapped curing,the dynamic modulus of elasticity of all concrete mixes decreased continously with age. Similarly, it is also due to the insufficient of water for full hydration.

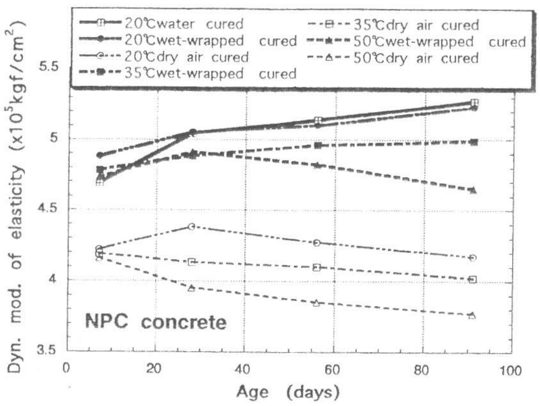

Fig.9 - Age vs dynamic modulus

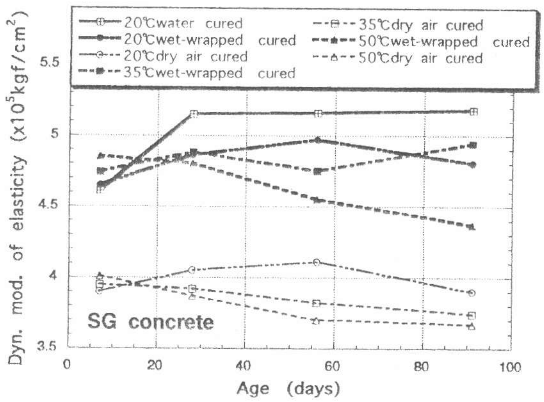

Fig.10 - Age vs dynamic modulus

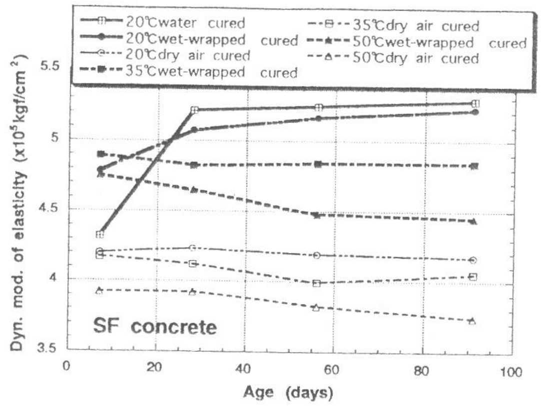

Fig.11 - Age vs dynamic modulus

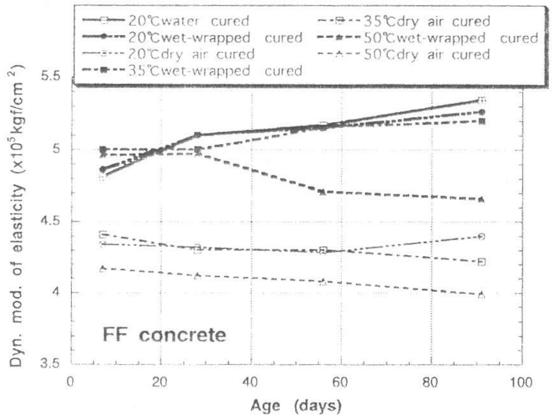

Fig.12 - Age vs dynamic modulus

4. CONCLUSION

The following preliminary conclusions seem reasonable based on the results of this study concerning the influence of medium and high temperature environments on the physical properties of high-strength concrete.

① The compressive strength of wet-wrapped curing which has been assumed as inner concrete were usually greater than dry air curing (outer layer concrete). Comparing to the inner concrete, the loss of strength of the outer layer concrete from age of the 7 days, was around 70%. This may suggest that, in order to maintain the strength of outer layer concrete, sufficient curing method such as spraying with water or covering with wet sheet on the concrete member is necessary.

② The concrete specimens incorporated with mineral admixtures produced greater strength from the age of 7 days. This indicated that the significant accelaration pozzolanic reaction of those admixtures at medium and high temperatures will increase the strength.

③ For normal concrete, the static modulus of elasticity at compressive strength of 200kgf/cm^2 was about 2.1 x 10^{5}kgf/cm^2. However, as observed in this study, the static modulus of elasticity of high-strength concrete was between 3.2 to 4.8 x 10^{5}kgf/cm^2.

④ The dynamic modulus of elasticity of all concrete mixes increased continuously with age under 20℃ of water and wet-wrapped curing but decreased from the age of 28 days under dry air curing. The ratios of dynamic modulus of elasticity from the age of 7 days were between 5.04 to 5.34 x 10^{5}kgf/cm^2.

REFERENCES

1. Bamforth,P.B. 1980, "In-situ Measurement of the Effect of Partial portland cement replacement using either Fly Ash or Ground Granulated Blastfurnace slag on the performance of mass concrete." Proceeding, Institution of Civil Engineers (London), Part 2, V.69, 1980.