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Fine aggregate and curing temperature effect on concrete maturity

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Abstract

Removal of formwork can be made in a short time by early-strength gain of concrete with heat treatment. The effects of accelerated curing temperature and fine aggregate on early strength as well as the relationships between early strength–28-day strength and strength maturity have been examined. Cube concrete specimens produced with a 10-cm constant slump value, 0.59 w/c ratio, and with two different types of fine aggregate were subjected to three-phase cure processes. These cure processes include a 1-h preheating process after having replaced concrete in the mould, the cure application process, and finally the last waiting period for 2 h that is aimed at minimizing the effects of thermal stresses. Each of the specimen groups was cured at different temperatures for different periods (6 or 18 h). At the end of curing and on the 28th day, cube compressive strengths were determined. Therefore, it was seen that it is possible to estimate 28-day strength beforehand with reasonable accuracy.

Keywords: Concrete; Heat treatment; Early strength; Maturity

1. Introduction

With the aim of satisfying increasing accommodation demands economically and in a short period of time, various methods have been developed to accelerate the strength gain of concrete. Factors such as material properties, concrete composition, concrete replacement and compaction factor, and geometric dimensions of building element, cure cycle, and curing conditions affect early-strength gain along with the heat-treatment applications [1]. Various types of fine aggregate are being used in concrete mixtures. The type of fine aggregate used changes the geometric properties of cement paste, and affects not only the shell formation during heat treatments but also the properties of concrete. The quality of poured concrete must be determined to control the production quality during the time required to remove the formwork. Compressive strength is parallel with all the other properties of concrete; therefore, it is an important criterion that must be followed while removing the formwork from the concrete [2]. In fact, the concrete strength is determined with the help of coring from the buildings. However, taking coring specimens is very difficult when the concrete is of early age. Therefore, to determine the removal time of the formwork, some ideas about concrete strength can be obtained by using various methods, such as ultrasound velocity or Schmidt rebound hummer [3,4].

The maturity method, which can determine the strength of concrete, replaced in-place relating with heat and time, and the accelerated cure methods, which are based on the determination of 28-day strength by finding the relationship between the early strength that is gained by the concrete generally through heating in order to accelerate the hardening of the concrete, and 28-day strength, are alternative methods.

In this study, early strength has been provided for specimens by the curing method in cabinet, and the effects of the curing temperature and the fine aggregate type on early strength has been investigated. It is aimed that the concrete subjected to the heat treatment will be tested by the accelerated cure and the maturity methods with the early strength–28-day strength relationships provided by regression analysis of the experimental results.

2. Estimation of concrete strength with the maturity method

The maturity method is a method in which time and temperature effects must be taken into consideration in

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Table 1
Properties of cement used in experiments

Chemical composition (%)	
CaO	63.97
Al_2O_3	5.58
Fe_2O_3	3.69
SiO_2	20.96
MgO	1.69
Fe_2O_5	–
K_2O	–
Na_2O	–
SO_3	2.84
Cl	0.008
TiO_2	–
Excess heating loss	1.15
Unassigned	0.05
Physical properties	
Blain fineness (cm^2/g)	3345
Specific gravity	3.15
Initial setting	2 h 5 min
Final setting	3 h
Lechatalier soundness (mm)	3
Compressive strength (MPa)	
2-day	21.9
7-day	38.3
28-day	45.1

Table 2
Sieve analysis of aggregates used in experiments

Aggregate	Sieve size	31.5	16	8	4	2	1	0.5	0.25
RS	Passing	100	100	100	98.6	76.8	57.0	42.2	16.2
CS	(%)	100	100	100	98.0	71.0	56.0	42.0	26.0
CS I		100	96.6	0	0	0	0	0	0
CS II		100	12.0	0	0	0	0	0	0

Table 3
Material contents used in concrete production of 1 m^3

MC	RS			CS		
	δ_u (g/cm^3)	V (dm^3)	W (kg)	δ_u (g/cm^3)	V (dm^3)	W (kg)
C	3.150	111	350	3.150	122	384
S	2.630	287	756	2.700	274	741
CS I (8–16)	2.690	201	540	2.690	192	515
CS II (16–32)	2.700	181	488	2.700	172	465
Water	1.000	205	205	1.000	225	225
Air	0.000	15.0	0.00	0.000	15.0	0.00
Mixture	2.339	1000	2339	2.330	1000	2330

strength development. If the same specimens are kept under various cured conditions, strength estimations can be done with strength–maturity relationships about the temperature history of concrete and specimens. It is necessary to know the relationships of the concretes that are to be used in buildings in which the maturity method will be used.

The temperature history of the concrete in place is observed continuously, and maturity is defined with this information. By observing strength–maturity relationship in place, the strength of a building can be estimated. The Nurse–Saul maturity function, which is frequently used in the determination of the maturity index, is given below as [5]:

$$M = \sum_{0}^{t} (T - T_0)\Delta t \quad (1)$$

In this function, M is the maturity index (°C-h or °C-day), T is the average concrete temperature at time interval Δt (°C), T_0 is the datum temperature (− 10 °C), t is the time (days or hours), and Δt is the time interval (days or hours).

One of the most common equations about the strength–maturity relationship is the logarithmic equation below suggested by Plowman [6].

$$f_c = a + b\log(M) \quad (2)$$

In this equation, M is the maturity index (°C-h or °C-day), and a and b are coefficients peculiar to the concrete mixture.

Volz et al. [7] show the importance of cure conditions in the first 7 h (early age) following concrete moulding in the relationship of maturity and strength in their studies. They conclude that Eq. (1) becomes inefficient because it ignores the first hours. Then, they try to determine the concept of early age regarding the Nurse–Saul equation. Therefore, concrete specimens produced from the same mixture were kept at − 1 °C (30 °F), 21 °C (70 °F), and 43 °C (100 °F). Some of the specimens were kept in temperatures as above, and the others were kept at 21 °C (70 °F) after 6, 18, 30, and 48 h, respectively, and were tested in compression on the 1st, 3rd, 5th, 7th, and 28th days.

From the results obtained, it was observed that the maturity–strength relationship, which was acquired after keeping the specimens at a normal temperature after 6, 18, 30, and 40 h, or at the first temperature, did not change

Table 4
Experimental results of cube compressive strength (MPa) made on specimens

Specimen	AC											
	6-h						18-h					
	20 °C	40 °C	60 °C	20 °C	40 °C	60 °C	20 °C	40 °C	60 °C	20 °C	40 °C	60 °C
	9-h			28-day			21-h			28-day		
RS	3.7	10.1	13.6	48.2	42.4	35.3	8.4	21.1	23.3	46.9	36.7	32.5
CS	5.5	11.7	14.3	42.2	37.2	33.2	10.7	22.6	23.9	41.5	34.8	28.6