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The Effect of Curing Time on Compressive Strength of Composite Cement Concrete

Md. Alhaz Uddin[1, a], Mohammed Jameel[1, b], Habibur Rahman Sobuz[2, c], Noor Md. Sadiqul Hasan[3, d], Md. Shahinul Islam[4, e] and Khan Mahmud Amanat[4, f]

[1]Department of Civil Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia.

[2]School of Civil, Environmental and Mining Engineering, The University of Adelaide, South Australia 5005, Australia.

[3]School of Civil Engineering, Linton University College, Legenda Education Group, 71700 Mantin, Malaysia.

[4]Department of Civil Engineering, Bangladesh University of Engineering and Technology, Bangladesh.

[a]mauce52@siswa.um.edu.my, [b]jameel@um.edu.my, [c]mdhabibur.sobuz@adelaide.edu.au, [d]s_adiqul@yahoo.com, [e]shahinul02@gmail.com, [f]amanatbu@gmail.com

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Abstract. The effect of curing condition of five different composition of Portland composite cement (PCC) and ordinary Portland cement (OPC) were investigated in this study. Compressive strength development of five different concrete types has been investigated in terms of cement content and curing duration. From the experimental observation, it is found that the early age strength of concrete made with PCC is lower than that of concrete made with OPC due to the presence of fly ash in PCC which is responsible for the pozzolanic reaction. The continued pozzolanic activity of fly ash contributes to increase strength gain at later ages at continued curing condition. It is also found that drying ambient conditions reduction of the strength potential of concrete made with PCC because the secondary (pozzolanic) reaction fails to contribute to the development of strength.

Introduction

The strength of concrete is one of the most important engineering properties of construction materials. There are many factors that affecting strength development of concrete including curing. Curing of concrete is very important for its strength development and durability [1]. The main factors for appropriate curing are temperature of curing and moisture curing duration. Because, the rate of hydration is controlled by the quality and quantities of the cementitious materials present in mixture and the ambient temperature and the availability of moisture in the mixture [2]. The strength increase at the early stage due to higher temperature during placing and setting but undesirably affect the strength at later ages while they are continuously cured in water at 21°C [3]. At the early stage temperature increase performance of mortar but decrease at later age were investigated by the change of mechanical and physical properties of mortars [4; 5]. In view of, Saul [6] and Kim et al., [7] investigation the strength gain of concrete is subjected to combined effect of curing time and temperature during hardening process. They found that the concrete gain strength at early-age subjected to a high temperature in moisture. Sometimes dying ambient disorders significantly reduce the strength potential of concrete made with PCC for secondary (pozzolanic) reaction fails to contribute to gain of strength [8].

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The aim of this paper is to examine that the effect of curing of five different composition cement types was investigated. In the framework of experimental study during 365 days; mortars have been prepared with different composition cement such as clinker, fly ash, gypsum, slag and limestone which kept at two different curing conditions. It is found that PCC concrete has shown lower early age strength than OPC whereas, at later ages both of the concrete is providing quite distinct strength characteristics due to continuous curing conditions and well performed pozzolanic reaction activities.

Materials and Methods

This study represents a general scenario of the effect curing on compressive strength of concrete were made with PCC and OPC, both at earlier and later ages. All properties of concrete ingredients were kept constant and cement type was varying with different composition. The work was performed using locally available materials such as stone chips, sand (coarse sand) and cement (Portland composite and ordinary Portland). The concrete were cured in two different ways, one set of concrete specimens were cured continuously until testing while the other set of concrete specimens were cured only 14 days under water to know effect of continuous curing over 14 days curing.

Materials properties

Aggregate. Aggregate act as an inert filler in concrete providing improved volume stability [9]. Locally available coarse sand was used for this project as fine aggregate. The physical properties of fine and coarse aggregate are shown in Table 1.

Table 1 Physical properties of fine and coarse aggregate

Properties	Local sand	Crushed stone
Maximum aggregate size, mm	2.36	19
Bulk Specific gravity	2.56	2.71
absorption capacity, %	1.21	0.45
Unit weight, kg/m^3	-	1556
Fineness modulus	2.73	6.74

Cement. Cement is a cementitious material in concrete mixture. In this project PCC of four different types and one ordinary (ASTM Type I) Portland cement (OPC) were used in making concrete. The chemical compositions and ingredient of different types of cement are shown in Table 2 and Table 3 respectively.

Table 2 Chemical composition of PCC and OPC

Constituent	PCC	OPC
SiO_2	20.60	19.24
Al_2O_3	4.74	4.78
Fe_2O_3	3.28	2.90
CaO	64.82	64.05
MgO	1.84	1.65
SO_3	2.4	3.36
Na_2O	0.21	0.25
K_2O	0.38	0.81
LOI	1.73	2.96

Table 3 Proportions of ingredients in cements

Ingredient	PCC				OPC
	Type-A (%)	Type-B (%)	Type-C (%)	Type-D (%)	Type-E (%)
Clinker	66.4	74.53	72.32	87.56	96.47
Gypsum	3.36	3.21	2.90	1.77	3.53
Slag, Fly Ash, Limestone	30.24	22.26	24.78	10.67	-

Mixture Compositions. According to ACI mix design method, the cement 41.86 kg, fine aggregate 65.07 kg and coarse aggregate 93.16 kg were mixed for target strength of 41.37 MPa. Concrete mixtures were proportioned using w/c ratios 0.41 in non-air entrained condition. Slump value of mixtures was 25-51 mm for this project.

Preparation of Test Specimens. The steel molds (cylindrical in shape with 100 mm diameter and 200 mm height) were used for casting of all specimens and then, compacted using a vibrating table. After that, leaving the molded concrete specimens in place of hardening for a period of 24 hrs, and then de-molded. The total 165 numbers of concrete specimens were prepared according to different curing condition (continuously curing and only 14 days curing). In this project PCC of four different compositions and one OPC were used in making concrete for target strength of 41.37 MPa.

Curing of Specimens. Concrete specimens were cured in two different ways, one set of concrete specimens were cured continuously until testing while the other set of concrete specimens were cured only 14 days under water in the laboratory. These 14 days cured specimens were kept in air until testing. A curing tank was constructed for curing the concrete specimens properly. The temperature of the curing water varies from 20 to 25° C.

Testing Procedure. The effect of curing on compressive strength with age of concrete is determined in accordance with ASTM C39 (1996). Compressive strength is one of the most important and useful properties of concrete [10]. It usually gives an overall picture of the quality of concrete because it is directly related to the structure of the hardened cement paste [11]. Compressive strength test of moist cured concrete specimens was carried out after removal from moist storage. The compressive strength of concrete cylinders was tested at 3, 7, 14, 28, 90, 180, 365 days of concrete.

Test Results and Discussion

Fig. 1 shows the compressive strength of concrete at early and later ages with different types of cement at continuous curing condition that were designed for target strengths of 41.37 MPa. As seen from Fig. 1, the compressive strength increases in all specimens with time. The percentage of target compressive strength gain at early ages (3 days, 7 days, and 14 days) of PCC concrete is lower than that of OPC concrete but at later ages (180 days and 365 days), PCC have gained only 5 percent less strength than of OPC concrete at continuous curing condition. It also shows that the strength gain curve fitting for all cement composition of target strength 41.37 MPa. The best cement composition is fc $(OPC)_E$ = 0.0383Ln(t) + 32.657 with R^2 = 0.5288 and worst cement composition is fc $(PCC)_B$ = 0.0573Ln(t) + 25.057 with R^2 = 0.6242; where fc is compressive strength in MPa, t is age of specimen in days, and R^2 is the coefficient of correlation.

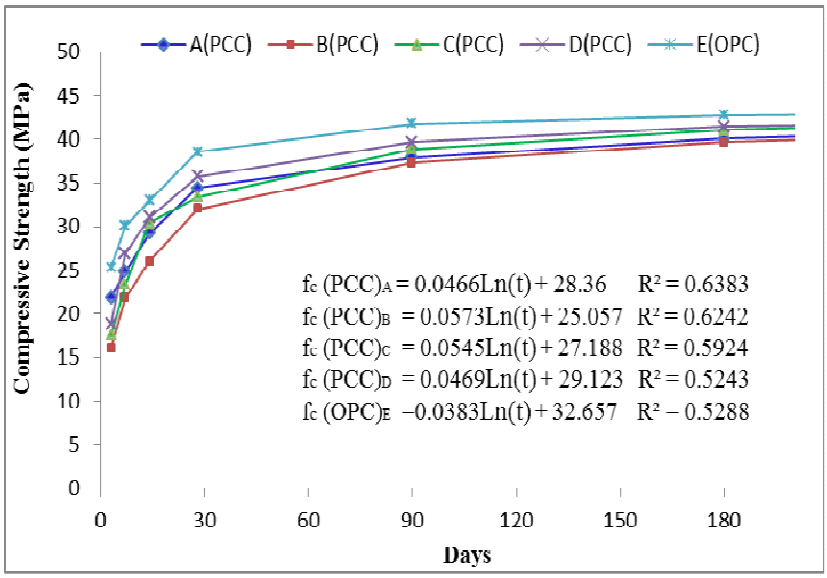

Fig. 1. Comparison of compressive strength gain with age of concrete made with various cement for 41.37 MPa.

Effect of Curing on Strength Development of Concrete. Concrete properties are significantly influenced by curing since it greatly effects the hydration of cement. A proper curing maintains a suitably warm and moist environment for the development of hydration products and thus reduces the porosity in hydrated cement paste and increases the density of microstructure in concrete.

Table 4 Compressive strength gain with age of concrete for 41.37 Mpa

Cement Type	Curing condition	% of Compressive strength			
		28 days	90 days	180 days	365 days
A(PCC)	14 days curing	82.37	88.58	90.63	89.75
	Continuous curing	83.20	91.63	96.93	101.87
B(PCC)	14 days curing	75.12	85.02	89.08	90.87
	Continuous curing	77.37	90.22	95.92	101.05
C(PCC)	14 days curing	80.27	90.48	92.88	94.35
	Continuous curing	80.78	93.97	99.17	104.30
D(PCC)	14 days curing	85.48	92.02	94.05	95.20
	Continuous curing	86.42	95.83	100.13	102.62
E(OPC)	14 days curing	91.00	94.43	97.10	97.92
	Continuous curing	93.23	100.97	103.38	104.92

Table 4 shows that PCC concrete specimens were failed to gain full target strength (41.37 MPa) within 365 days at 14 days curing condition. Concrete specimens were gained 100 percent and 90 percent of target strength after 365 days at continuous curing and 14 days curing condition respectively. OPC concrete was gained 105 percent and 95 percent of target strength at continuous curing and 14 days curing condition respectively after 365 days. It is suggested that adequate curing at early ages as well as later ages is essential to continue the pozzolanic reaction in concrete which contribute to the development of strength of concrete made with PCC.

Conclusions

This study was investigated the effect of curing on compressive strength of five different composition cement types in terms of different curing conditions. The compressive strength gain at early ages of PCC concrete is lower than that of OPC concrete. Lack of proper Pozzolanic reaction in the presence of fly ash in PCC concrete strength is lower at early age. The pozzolanic activity of fly ash also contributes to the strength gain at later stages of continuous curing. At continuous curing condition, PCC concrete for the target strengths of 41.37 MPa requires 180 to 200 days to gain full target strength. But it fails to gain the target strength of 41.37 MPa in 365 days at 14 days curing condition. The compressive strength of five different compositions cement increased with increasing curing time. Adequate curing at early ages as well as at later ages is essential in the strength development of PCC concrete. It can be concluded that drying ambient conditions reduce the strength potential of PCC concrete as the secondary (pozzolanic) reaction fails to contribute to the development of strength.

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