- Technical Paper -

RESEARCH ON THE IMPROVEMENT OF EARLY STRENGTH DEVELOPMENT FOR ORDINARY PORTLAND CEMENT

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ABSTRACT

In order to improve early strength development performance of ordinary Portland cement with economically feasible compared to early strength Portland cement, the influence of Blaine surface area, types and content of gypsum in regard to cement were examined. An increase of Blaine surface area of cement leads increase of early strength of concrete but decrease of flowability. The influence of Anhydrite is to improve flowability and early strength but excessive content leads delay of setting time of cement.

Keywords: apartment, early strength concrete, reduction of construction period

1. INTRODUCTION

Recently it is generalized the effort to reduce construction period through introducing prefabrication of rebar and system form at the apartment construction in Korea. Also it is trying to reduce removal time of the form through development of early strength concrete.

It is restricted compressive strength of concrete to remove the form of structure at Korean standard specification of building construction as shown in Table 1.

Table 1 Recommended concrete strength to remove form

	Vertical	Horizontal
Location	Side of Column, Wall and etc.	Bottom of Slab and Girder
Strength	5 N/mm^2	12 N/mm^2

Technology of early strength development for concrete has been rich concrete with Ordinary Portland Cement(Type I according to KS F5201) in the aspect of mix design and early strength Portland Cement (Type III) in the aspect of material so far. However, there are problems that it is limited to secure required early strength and it is economically infeasible because of high cost. [1]

In this research, early strength development performance of early strength type Ordinary Portland Cement(Type I') which is economically feasible compared to early strength Portland Cement(Type III), which was improved early strength from Ordinary Portland Cement(Type I), was estimated to derive minimum curing temperature and proper water to cement ratio according to cement types for early strength development through examination of fresh concrete properties and compressive strength according to water to cement ratio, curing temperature 10℃, 15℃ and 20℃ to suggest appropriate mix proportion.

2. EXPERIMENTAL PROGRAMS

2.1 Experimental Scheme

Experiment was divided into series1 and series2 as shown Table 2. In regard to series1, to improve early strength of Ordinary Portland Cement, setting time and compressive strength of cement were measured and slump, air content and compressive strength as physical properties of concrete were measured according to Blaine surface area, gypsum types and content of

Table 2 Experimental Scheme

	Factor	Variable	Measuring Item
Series1	Blaine	4000, 4300, 4500	Cement : Setting Time Compressive Strength(15, 18, 24 hours) Concrete : Slump, Air Content(Elapsed Time) Compressive Strength(15, 18, 24 hours)
	Gypsum	Normal, Anhydrite	
	Contents of Gypsum	2.6, 2.8, 3.0, 3.2	
Series2	Cement	Type I, Type I', Type III	Compressive Strength(15, 18, 24, 39, 42 hours)
	W/C	40, 45, 50	
	Curing Temperature	10, 15, 20	

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gypsum at 15℃ curing temperature with 45% water to cement ratio. Every measured data was compared with Ordinary Portland Cement.

In regard to series2, slump, air content and compressive strength as physical properties of concrete were estimated according to cement types, water to cement ratio and curing temperature.

2.2 Materials

(1) Cement

The physical properties of Portland cement are shown in Table 3.

Table 3 Physical Properties of Portland Cement

Type	Density (g/cm^3)	Blaine Surface Area(cm^2/g)	Ignition Loss(%)
Type I	3.15	3,330	1.2
Type I’	3.13	4,290	0.5
Type III	3.12	4,550	0.8

(2) Aggregate

Physical properties of aggregates are shown in Table 4.

Table 4 Physical properties of aggregates

		Fineness Modulus (%)	Density (g/cm^3)
Fine Aggregate	S1	2.8	2.60
	S2	3.1	2.62
Coarse Aggregate	G	7.03	2.64

2.3 Mix Proportion

The standard mix proportion of concrete for experiment is shown in Table 5.

3. RESULTS AND DISCUSSIONS

3.1 Series 1

(1) Blaine Surface Area

The results of series 1 are shown in Table 6. Increase of Blaine surface area of cement had effect on shorter setting time of cement and increase of compressive strength of concrete as shown in Fig. 1.

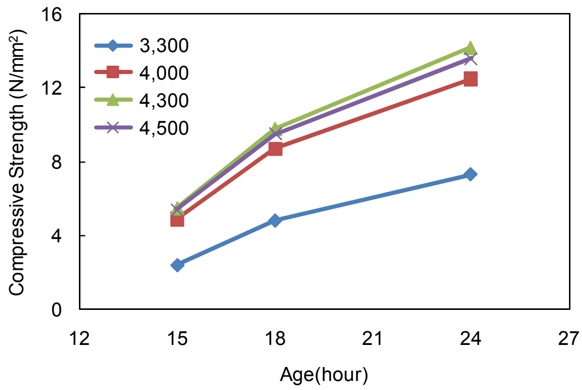

Fig. 1 Compressive strength of concrete with Blaine surface area of cement

However, it also had effect on decrease of flowability of concrete according to elapsed time as shown in Fig. 2.

(2) Gypsum Types and Content

In order to improve decrease of flowability with increase of surface area, anhydrite was used instead of normal gypsum. The effect of anhydrite had increase of compressive strength of cement. As shown in Fig. 3 to 4, anhydrite had effect on flowability and early strength development of concrete.

Table 5 Standard mix proportion of concrete

	W/C (%)	S/a (%)	Unit Weight (kg/m^3) W	C	S1	S2	G	AD
Series 1	45	48.5	165	367	598	254	911	5.51
Series 2	40	47.5	165	413	573	244	908	6.61
	45	48.5	165	367	598	254	911	5.51
	50	49.5	165	330	621	264	909	4.62

Table 6 Results of Series 1

Series1		Cement: Setting Time Init. (min)	Final (h:m)	Compressive Strength (N/mm^2) 15h	18h	24h	Concrete: Slump (mm) Init.	60m	Air Content(%) Init.	60m	Compressive Strength(N/mm^2) 15h	18h	24h
Type I Blaine (cm^2/g)	3,300	250	6:00	2.2	3.9	7.8	210	195	5.5	4.7	2.4	4.8	7.3
	4,000	250	5:35	4.5	8.6	11.3	210	180	4.4	3.9	4.9	8.7	12.5
	4,300	240	5:20	6.7	10.5	15.4	205	170	4.1	3.3	5.5	9.8	14.2
	4,500	230	5:10	7.6	11.7	17.2	210	155	3.8	3.4	5.4	9.5	13.6
Gypsum Types	Normal	240	5:20	6.7	10.5	15.4	205	170	4.1	3.3	5.5	9.8	14.2
	Anhydrite	250	5:10	7.7	11.9	16.7	205	200	4.3	3.4	6.3	11.9	17.4
Content of Anhydrite (%)	2.6	-	-	-	-	-	210	180	4.1	3.3	5.9	-	-
	2.8	-	-	-	-	-	205	200	4.3	3.4	6.3	-	-
	3.0	-	-	-	-	-	210	210	4.5	3.5	6.5	-	-
	3.2	-	-	-	-	-	215	215	4.6	3.4	6.1	-	-

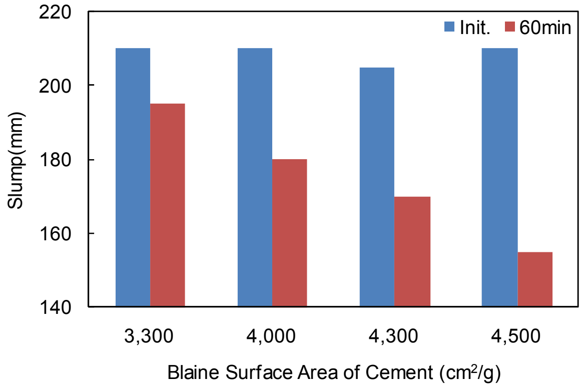

Fig. 2 Slump with Blaine surface area of cement

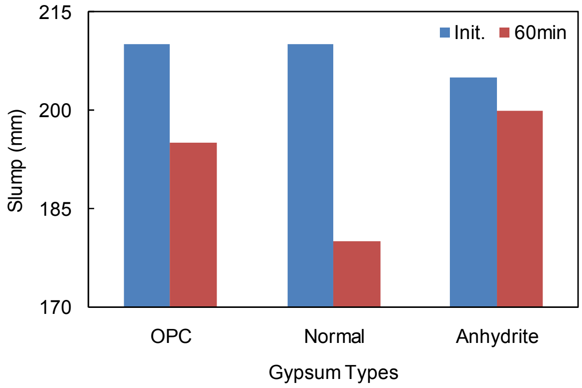

Fig. 3 Slump with gypsum types

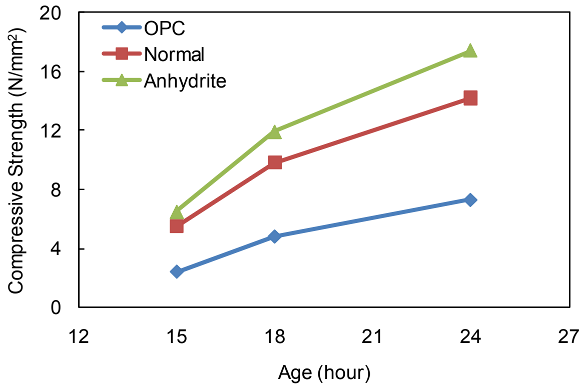

Fig. 4 Compressive strength of concrete with gypsum types

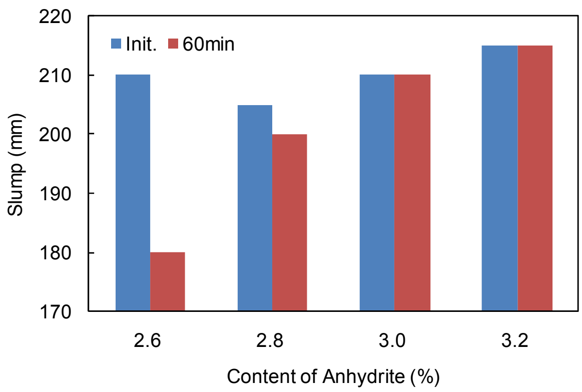

Fig. 5 Slump with content of anhydrite

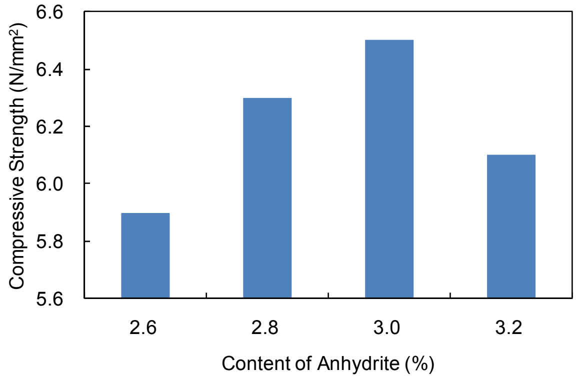

Fig. 6 Compressive strength of concrete with content of anhydrite at age 15 hour

The mechanical properties of concrete with content of anhydrite are shown in Fig. 5 to 6.

Flowability and early strength of concrete increased with an increase in the content of anhydrite by certain level. However, excessive content of anhydrite decreased compressive strength of concrete. The excessive content of anhydrite seems to lead delay of setting time.

3.2 Series 2

(1) Curing Temperature and Water to Cement Ratio

Compressive strength of concrete with cement types in regard to water to cement ratio curing at 10℃ is shown Fig. 7. Compressive strength of concrete decreased with an increase of water to cement ratio. Any type of cement didn't exceed 5N/mm^2 at age 15hour.

Fig. 8 shows Compressive strength of concrete with cement types in regard to water to cement ratio curing at 15℃. It seemed to be impossible that Type I could exceed 5N/mm^2 at age 15hour in every case. Type I' and Type III exceeded 5N/mm^2 at age 15hour with every water to cement ratio. Type I' showed similar performance of early strength development or more than Type III.

Compressive strength of concrete with cement types in regard to water to cement ratio curing at 20℃ is shown Fig. 9. Every cement type at the curing temperature of 20℃ exceeded 5N/mm^2 at age 15hour except in the case of Type I with water to cement ratio of 50%.

(2) Appropriate Water to Cement Ratio and Minimum Curing Temperature

Fig. 10 shows compressive strength with cement to water ratio in regard to curing temperature. In order to calculate appropriate water to cement ratio with each curing temperature as for early strength of 5N/mm^2 at age of 15 hour, it was analyzed through linear regression with high coefficient of determination. Table 7 shows calculated water to cement ratio in regard to curing temperature and cement types from the results of linear regression.

Compressive strength with curing temperature in regard to water to cement ratio is shown in Fig. 11.

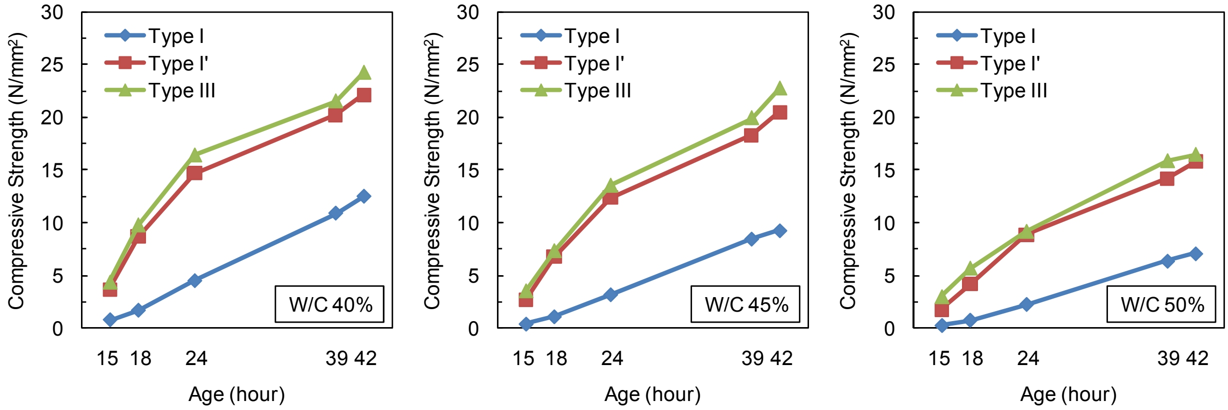

Fig. 7 Compressive strength with water to cement ratio at 10℃ curing temperature

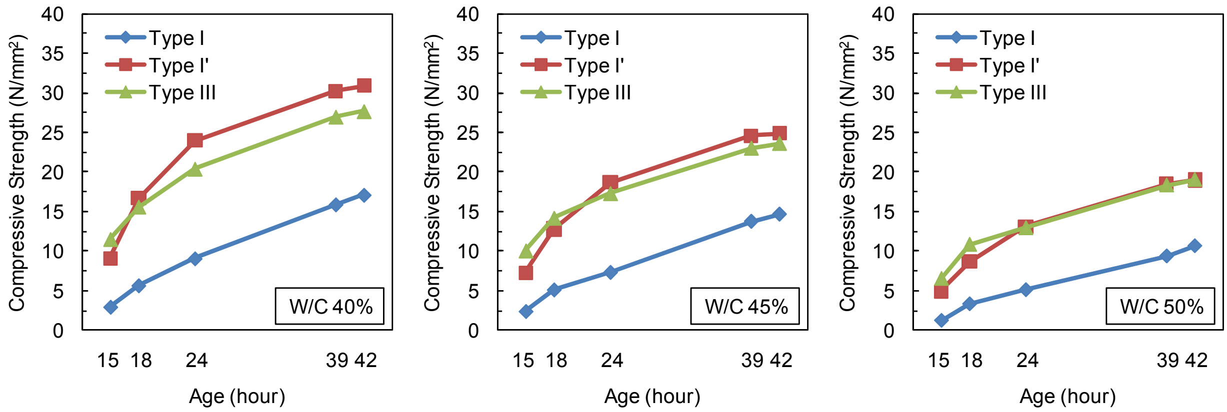

Fig. 8 Compressive strength with water to cement ratio at 15℃ curing temperature

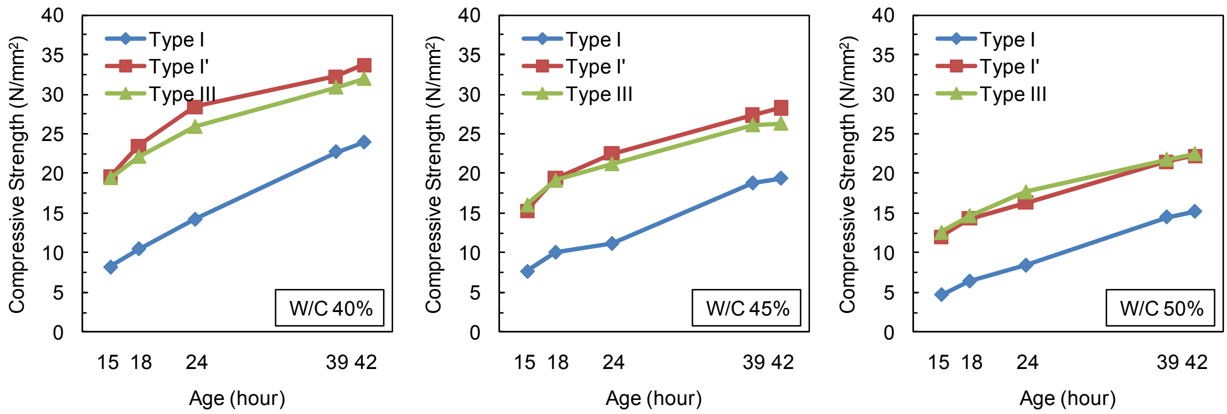

Fig. 9 Compressive strength with water to cement ratio at 20℃ curing temperature

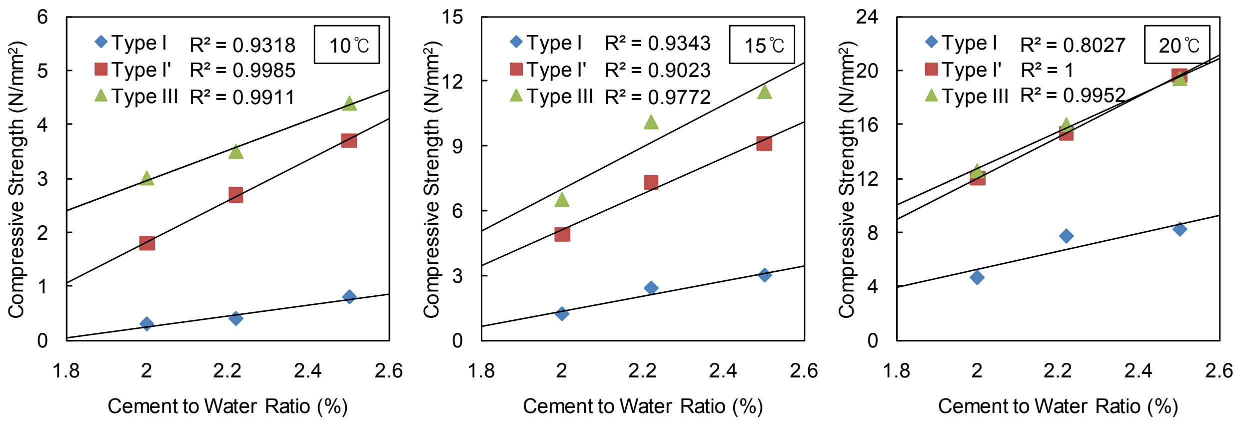

Fig. 10 Compressive strength with cement to water ratio in regard to curing temperature

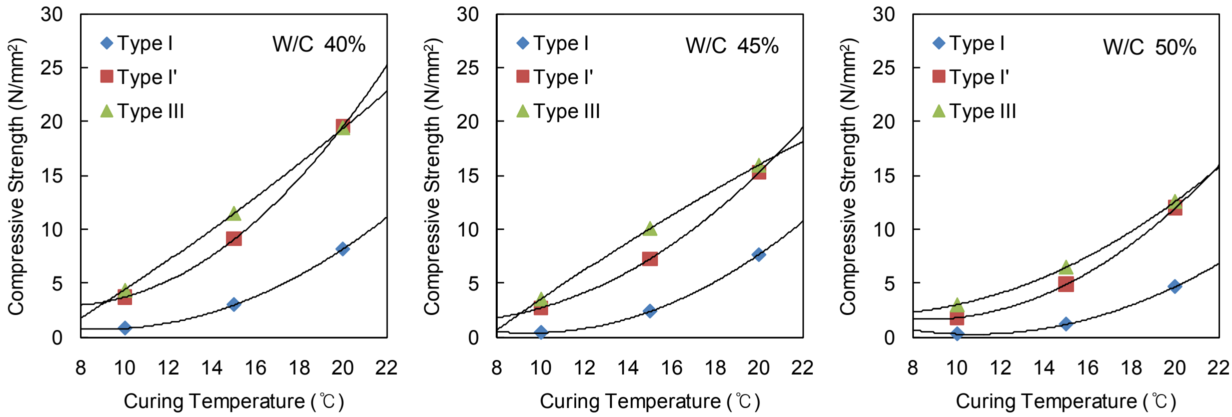

Fig. 11 Compressive strength with curing temperature in regard to water to cement ratio

Table 7 Calculated water to cement ratio

	Appropriate Water to Cement Ratio (%)		
	10℃	15℃	20℃
Type I	26.1	36.0	49.5
Type I'	36.6	49.8	74.5
Type III	37.0	56.8	81.3

Table 8 Minimum curing temperature

	Curing Temperature (℃)		
	40%	45%	50%
Type I	17.28	17.83	20.31
Type I'	11.74	14.26	15.09
Type III	10.44	11.09	14.46

From the correlation between compressive strength and curing temperature, it was calculated minimum curing temperature to secure 5N/mm^2 at age of 15hour in regard to water to cement ratio as shown in Table 8.

4. CONCLUSIONS

(1) An increase of Blaine surface area leads increase of early strength of concrete as same tendency of result by Price. [2]

(2) Anhydrite is effective to improve problem of flowability decrease.

(3) Type I' cement which is improved early strength development performance from ordinary Portland cement shows similar performance compared to early strength Portland cement.

(4) It is necessary to secure 5N/mm^2 within 15 hour that curing temperature should be more than 11℃ and water to cement ratio should be below 40% using type I' cement.

(5) These days, since there is a tendency to reduce standard construction period as 6-days cycle to 4 days cycle for apartment construction in Korea, Type I' could be economically feasible with commercial production.

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