BASIC PERFORMANCE OF CONCRETE USING ALKALI-FREE C-S-H BASED ACCELERATOR

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1. INTRODUCTION

Setting time and early-age strength in concrete determine the finishing time and formwork removal time. Accelerated hardening of fresh concrete shortens setting time, enhances early age strength, reduces construction time, and improves manufacturing efficiency of pre-cast concrete products by realizing good surface finish and early formwork removal. Hardening accelerators help hydration occur at an elevated pace and increase the rate of set and strength gain. The purpose of this study is to review the performance of the newly developed alkaline free and conventional C-S-H based accelerators in Ordinary Portland Cement (OPC) concrete in terms of fresh properties, setting time, and compressive strength development.

2. EXPERIMENTAL PROCEDURE

Table 1 and Table 2 show the raw materials used for the experiment with their physical characteristics and the concrete mix design. The water-to-cement ratio (W/C) is set to 45%. The target fresh properties of concrete are slump of 18.0 ± 1.5 cm. and air content of 1.5 ± 0.5 %. The dosage of the superplasticizer (SP) is adjusted to meet the prescribed slump and air content when using the alkali-free hardening accelerator (AC1) or conventional hardening accelerator (AC2)(Koyama 2019), or no accelerator. The experiment was conducted at room temperature (20°C). Slump and air content were measured in fresh concrete while casting specimens to measure setting time, compressive strength. Table 3 shows respective JIS standard test methods used to take the measurements. Fig. 1 shows the curing conditions of specimens cast to measure compressive strength.

3. RESULTS AND DISCUSSION

Table 4 shows the fresh properties of OPC concrete with and without hardening accelerators. To produce concretes with identical fresh properties, the SP amount to be added is significantly lower when using AC2 than without any accelerator. In contrast, when

Table 1 – Raw materials used and their physical properties

Raw material	Symbol	Physical properties
Water	W	Tap water
Cement	C	Ordinary Portland Cement Density = 3.16 g/cm^3 Specific Surface Area = 3,240 cm^2/g
Fine aggregate	S	Land Sand from Oi River water system Surface dry density = 2.59 g/cm^3 Fineness Modulus = 2.57
Coarse aggregate	G	Crushed sandstone from Ome Surface dry density = 2.67 g/cm^3 Water absorption = 0.62%, Maximum dimension = 20 mm.
Superplasticizer	SP	Polycarboxylate ether-based component
Hardening accelerator	AC1	Alkali free C-S-H based hardened accelerator Density = 1.15 g/cm^3, Na_2O eq. = 0.1%
	AC2	Conventional C-S-H based hardened accelerator Density = 1.07 g/cm^3, Na_2O eq. = 1.4%

Table 2 – Mix design of concrete

Batch name	Slump (cm.)	Air cont. (%)	W/C (%)	s/a (%)	W (kg/m^3)	Accelerator	
						Type	(C × %)
C45-0	18.0 ± 1.5	1.5 ± 0.5	45.0	43.6	165	-	-
C45-AC1-2						AC1	2.0
C45-AC1-4							4.0
C45-AC2-4						AC2	4.0

Table 3 – List of concrete properties measured and their standards

Measurement	Standard for test method
Slump	JIS A 1101
Air content	JIS A 1128
Setting time	JIS A 1147
Compressive strength	JIS A 1106 Specimen dimensions: φ10 × 20 cm. Measured at: (Steam cured) 7h, 16h, 14d (Standard curing) 8h, 16h, 24h, 3d, 7d, 28d

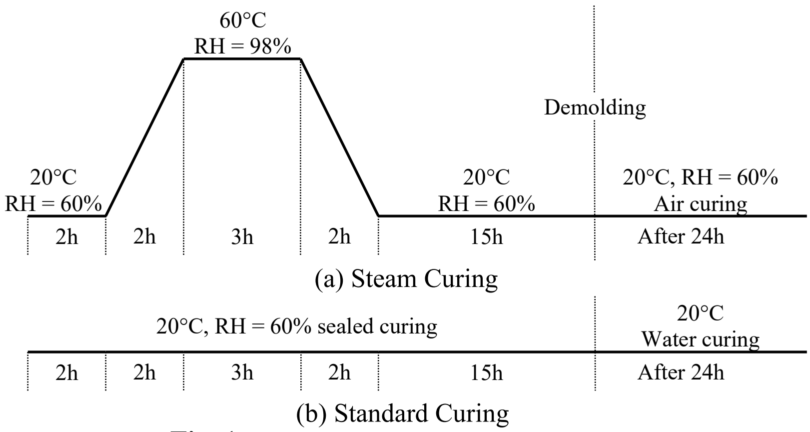

Fig. 1 – Curing conditions of concrete specimens

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using AC1, the SP to be added is only slightly lower compared to without any accelerator. The hardening accelerators AC1 and AC2 contain a necessary amount of dispersant to allow stable dispersion of the C-S-H nanoparticles. It might be because the newly developed alkali-free AC1 requires less dispersant for stabilization and thus has little effect on the SP amount required.

Fig. 2 shows the setting times of OPC concretes with and without hardening accelerator. The set time acceleration was identical when C × 2.0% of AC1, C × 4.0% of AC2 were used. Higher amounts of AC1 can further speed up the setting time.

Fig. 3 and 4 show the early age and long-term compressive strength. The early age strength with AC1 or AC2 is higher than without accelerator in both curing methods. The rate of strength gain was identical when using C × 2.0% of AC1, C × 4.0% of AC2 in both curing methods, same as the trends of setting time. Generally, compressive strength of 12 MPa is required for concrete to hold its weight. When no accelerator is used, it takes longer than 7h of steam curing. When used C × 4.0% of AC1, it takes less than 7h of steam curing. The same strength can be gained through standard curing as well, in just over than 16h of time. By further optimizing the mix-design of concrete, AC1 could provide the same strength of steam cured OPC without an accelerator, through standard curing instead. There is almost no change in 3d, 7d, 28d standard cured compressive strength, which indicates that adding AC1 or AC2 to develop higher early age strength doesn't compromise long-term compressive strength gain. From the trends of 14d steam cured compressive strength, adding either of the two C-S-H based accelerators increases the compressive strength when using steam curing.

Table 4 – Properties of Fresh concrete

Batch Name	Accelerator type	(C × %)	SP dosage (C × %)	Slump (cm)	Air (%)	Concrete Temperature (°C)
C45-0	-	-	0.70	18.0	1.5	20
C45-AC1-2	AC1	2.0	0.65	17.5	1.3	20
C45-AC1-4		4.0	0.60	17.5	1.1	20
C45-AC2-4	AC2	4.0	0.25	19.5	1.5	20

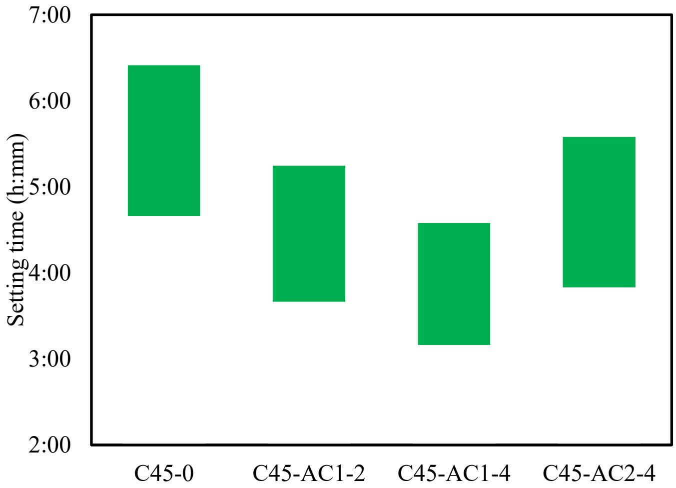

Fig. 2 – Setting time

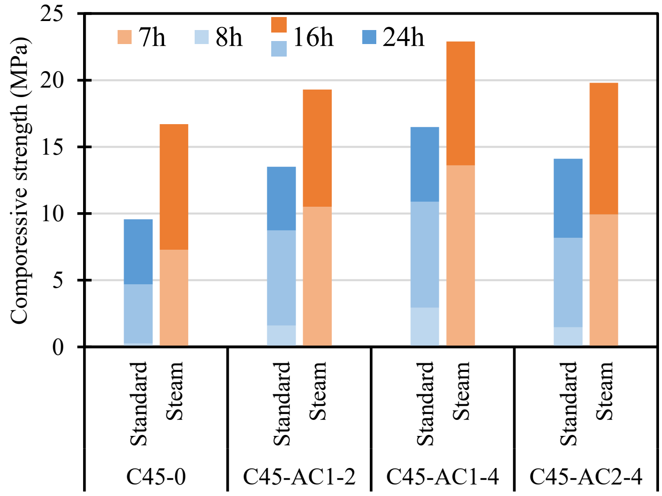

Fig. 3 – Early age compressive strength

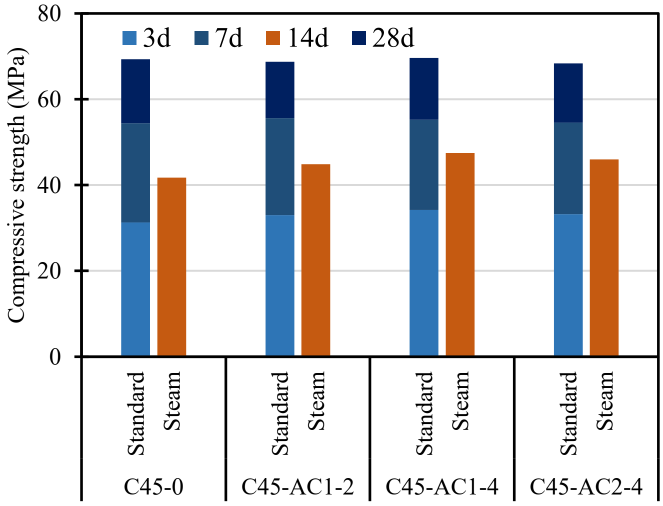

Fig. 4 – Long-term compressive strength

4. CONCLUSIONS

1. The amount of SP to be added is affected by the type of accelerator. Newly developed AC1 can be used with little change in SP amount than without any accelerator. But, when adding AC2, the amount of SP should be reduced to obtain identical properties of fresh concrete.
2. AC1 can provide similar acceleration in setting time and early age compressive strength to AC2, with half the dosage.
3. Using a C-S-H based accelerator doesn't affect long-term compressive strength gain under standard curing but improves strength if steam curing is used.

REFERENCES

Koyama, H. and Imoto, H: Action Mechanism and Application Example of C-S-H type Accelerator, Concrete Journal, Vol.57, No.1, pp.20-23, Jan 2019 (Japanese)

