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Effect of early strength agents on specified density concrete

Shuaishuai Yan[1,2] and Ming Zhang[1,2]

[1] State Key Laboratory of Green Building Materials, Beijing, China
[2]College of Civil Science and Engineering, Yangzhou University, Yangzhou, China
E-mail: zhangmingjob@sina.com

Abstract. Early strength agents are beneficial to improving early strength of concrete, thereby shorting curing time as well as production efficiency of concrete products, and consequently saving production costs. This study investigated the influence of triethanolamine, potassium carbonate, Calcium formate and Potassium aluminum sulfate on properties of specified density concrete, based on orthogonal experiment, composite early strength agent is determined.

1. Introduction

Specified density concrete is the concrete that apparent density is 1950 kg/m^3 ~ 2300 kg/m^3 by in addition of moderate amount of lightweight aggregate into ordinary aggregate. Specified density concrete has many good qualities such as high strength, light weight and long durability, which results in the concrete has broad prospect of application on high rise building, bridge and marine engineering. Like other concrete materials, mechanical properties is one of typical properties. Main effect factors of mechanical properties include strength and water absorption of ceramisite, water to binder (W/B), and sand ratio, et al.

When specified density concrete is damaged by compressing, generally the damage begins from ceramsite, then the crack gradually runs through the whole concrete matrix [1], and the higher cylinder compressive strength of ceramsite, the higher strength of specified density concrete. Replacement rate of ceramsite has important effect on strength of concrete too, with the rise of replacement rate of ceramsite the mechanical properties of concrete decreases [2].

More Higher water absorption of ceramsite, more beneficial to late mechanical properties, which because high water absorption means high water storage, and consequently more beneficial to improving interfacial transition zone as well as mechanical properties.

There is inverse relationship between W/B and mechanical properties of specified density concrete, with the increase of W/B, the mechanical properties decrease, and the ratio of compressive strength to flexural is between 10 and 19 [3].

Within certain scope, increase of sand ratio is good to improve the compatibility of specified density concrete as well as mechanical properties [4], however, if sand ratio too high, the density difference between mortar and ceramsite increases, and the homogeneity of concrete becomes worse similarly to mechanical properties.

Within certain scope of content, the common mineral admixtures such as fly ash and slag can decrease the density of cement mortar, thereby relieve the layering trend of between ceramsite and mortar, which lead to the improving of mechanical properties.

2. Materials and methods

2.1. Materials and mix design

Cement was P·O 42.5 ordinary Portland cement. river sand was medium sand. crushed strong size was 5 mm~10 mm. grade I fly ash was obtained from thermal power plant. spherical calcined clay Ceramsite was 5 mm ~ 10 mm diameter, mixing water was tap water. the early strength agents were Triethanolamine, potassium carbonate, Calcium formate and Potassium aluminum sulfate, all of them were chemical regents. The mix proportion of specified density concrete as shown in Table 1.

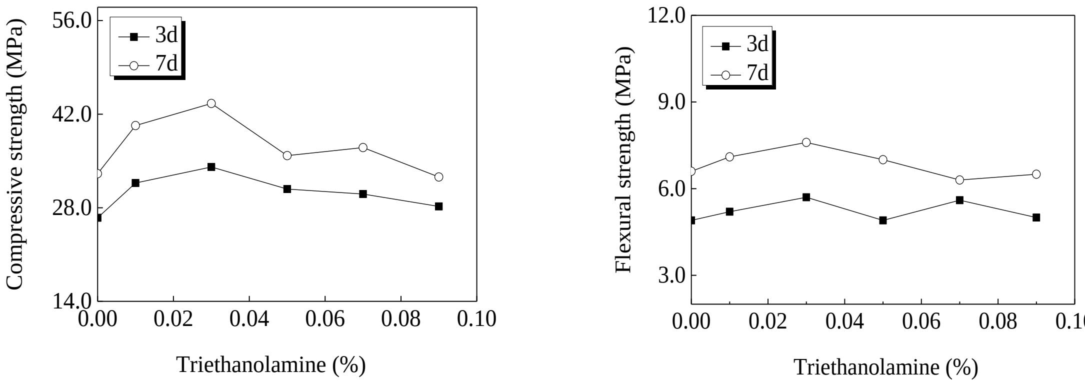
Table 1. Mix proportion of specified density concrete (kg)

Cement	Fly ash	sand	Crushed stone	ceramsite	water
320	80	730	834	104	112

2.2. Methods
According to specified density concrete mix proportion in Table 1, and GB/T 50082-2009 [5], concrete cubes with the dimensions of 100 × 100 × 100 mm^3 were prepared and demoulded right after 1 d, the samples were cured in concrete standard curing room (more than 95%RH and 20 ± 2 ℃) until the compressive strength measurements were carried out at 3 d and 7 d.

3. Results and discussion

3.1. Triethanolamine
As shown in figure 1, mechanical properties of concrete increase with the dosage of triethanolamine within the scope of 0.00% ~ 0.03%, but inverses within the scope of 0.03% ~ 0.09%. during hydration process of cement, triethanolamine forms complex ions with Fe^{3+} and Al^{3+}, the complex ions can accelerate the dissolution of C_3A and C_4AF and generate calcium sulphoaluminate, consequently reduce the concentration of Fe^{3+} and Al^{3+} in solution, which is conducive to the hydration of C_3S and early strength development of cement [6].



(a) Compressive strength (b) Flexural strength

Figure 1. Mechanical properties of specified density concrete mixed triethanolamine.

3.2. Potassium carbonate
Potassium carbonate reacts with calcium hydroxide in cement paste and generate calcium carbonate, which reduces the concentration of calcium hydroxide, and increases the solid ratio in the solution accordingly improves early strength [7]. However, with the increase dosage of potassium carbonate, mechanical properties of concrete decrease. as shown in figure 2, when the dosage of potassium is between 0.0% and 1.0%, both the compressive strength and flexural strength are improved, and reach to the peak value at the dosage of 1.0%, which means the optimal dosage of potassium carbonate is 1.0%. excessive addition will lead to negative effect on neither compressive or flexural strength of specified density concrete.

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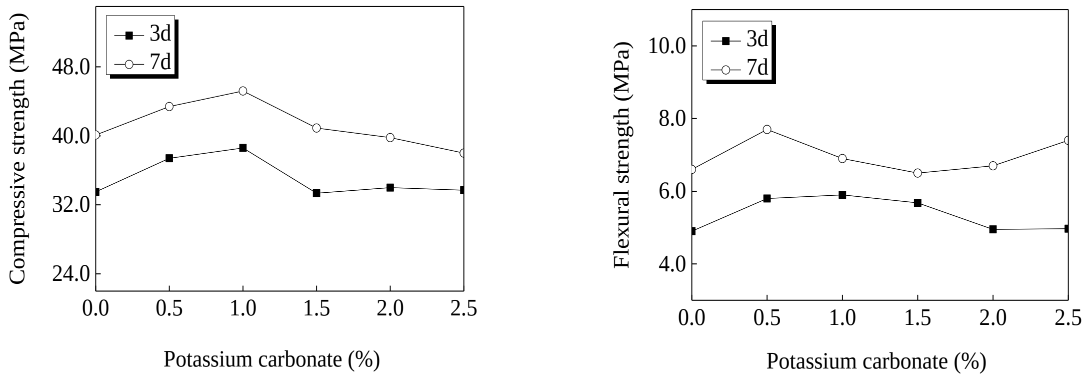
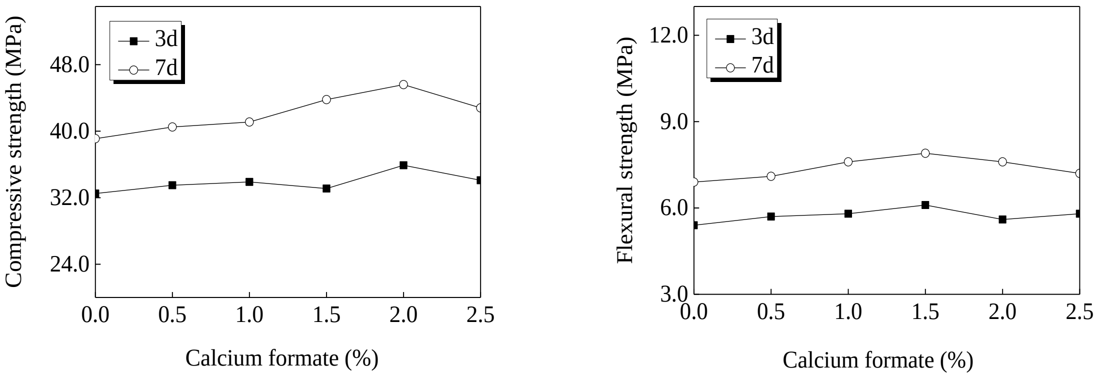


(a) Compressive strength (b) Flexural strength

Figure 2. Mechanical properties of specified density concrete mixed potassium carbonate

3.3. Calcium formate

According to figure 3, when the dosage of calcium formate is from 0.0% to 1.5%, the mechanical properties of specified density concrete show an upward trend, which is mainly due to the role of formate ions, it generates products limilar to AFt and AFm and penetrate into hydration layer of C_2S and C_3S, resulting in the hydration of C_2S and calcium hydroxide is accelerated, so as to improve the early strength. When dosage of calcium formate between 1.5% and 2.5%, mechanical properties of specified density concrete decreases.

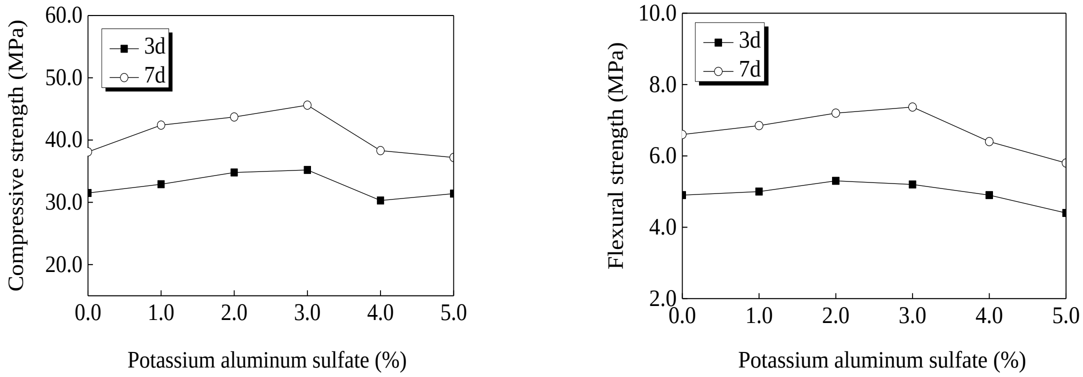


(a) Compressive strength (b) Flexural strength

Figure 3. Mechanical properties of specified density concrete mixed calcium formate

3.4. Potassium aluminum sulfate

Figure 4 is mechanical properties of specified density concrete mixed different dosage of potassium



(a) Compressive strength (b) Flexural strength

Figure 4. Mechanical properties of specified density concrete mixed potassium aluminium sulfate

aluminum sulfate, as shown in the figure, under dosage of 3.0%, the mechanical properties of specified density concrete increase with the dosage of potassium aluminum sulfate, however the mechanical properties decrease when the dosage of potassium aluminum sulfate beyond 3.0%, which means the optimal dosage of potassium aluminum sulfate is 3.0%.

3.5. Orthogonal experiment
Table 2 is orthogonal experiment and results of early strength, according to the range analysis (R value), the order of influence factors on 3 d compressive strength are $R_b > R_d > R_c > R_a$, namely potassium carbonate > potassium aluminum sulfate > calcium formate > triethanolamine, and the best composite is $A_3B_1C_1D_2$ based on R value. Similarly the order of influence factors on 7 d compressive strength are $R_b > R_d > R_c > R_a$, namely potassium carbonate > potassium aluminum sulfate > calcium formate > triethanolamine, $A_2B_1C_1D_2$ is the best composite based on R value.

Table 2. Orthogonal experiment and results

No.	(A) Triethanolamine (%)	(B) Potassium carbonate (%)	(C) Calcium formate (%)	(D) Potassium aluminum sulfate (%)	Compressive strength (MPa)	
					3d	7d
1	1(0.01)	1(0.50)	1(1.50)	1(1.00)	40.91	52.62
2	1	2(1.00)	2(2.00)	2(2.00)	41.43	42.42
3	1	3(1.50)	3(2.50)	3(3.00)	30.20	43.16
4	2(0.03)	1	2	3	40.95	49.19
5	2	2	3	1	36.55	47.06
6	2	3	1	2	37.61	45.45
7	3(0.05)	1	3	2	42.22	55.03
8	3	2	1	3	38.55	44.82
9	3	3	2	1	34.44	38.98
$\overline{K}_1$	37.51	41.34	39.01	37.28		
$\overline{K}_2$	38.37	38.84	38.91	40.42		
$\overline{K}_3$	38.74	34.08	36.32	36.55		
R	1.23	7.26	2.69	3.87		

Table 3 and table 4 are gest group of composite agent and optimal dosage of single early strength agent and the compressive strength of specified density concrete mixed those agents.

Table 3. Best group of composite agent and optimal dosage of single early strength agent

Best group	(A) Triethanolamine (%)	(B) potassium carbonate (%)	(C) Calcium formate (%)	(D) Potassium aluminum sulfate (%)
$A_2B_1C_1D_2$	0.01	0.50	1.50	2.00

As shown in table 4, the specified density concrete mixed composite early strength agent ($A_2B_1C_1D_2$) than that of whichever single early strength agent no matter at 3 d or 7 d.

Table 4. Compressive strength of specified density concrete mixed composite and single agent (MPa)

Curing age	$A_2B_1C_1D_2$	Single early strength agent			
		Triethanolamine	potassium carbonate	Calcium formate	Potassium aluminum sulfate
3d	39.42	32.21	36.63	35.42	34.16
7d	48.33	39.65	43.27	42.41	41.65

4. Conclusions

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(1) to the addition single early strength agent, mechanical properties of specified density concrete increase with the dosage of early strength agent within certain scope, however the rule inverse if the dosage of early strength agent over certain value.
(2) the composite early strength agent is more effective than whichever single agent, and the best composite is Triethanolamine : potassium carbonate : Calcium formate : Potassium aluminum sulfate =0.01%：0.50%：1.50%：2.00%.

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