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The effect of $Al_2(SO_4)_3$ + Li_2CO_3 + $C_6H_{15}O_3N$ compound early strength agent on the early mechanical properties of concrete

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Abstract. The effect of $Al_2(SO_4)_3$ + Li_2CO_3 + $C_6H_{15}O_3N$ compound early strength agent on the early mechanical properties of concrete is studied in this paper, the microanalysis was carried out by SEM scanning electron microscope. The results showed that $Al_2(SO_4)_3$ + Li_2CO_3 + $C_6H_{15}O_3N$ composite early strength agent had very significant enhancement effect. The flexural strength of concrete reaches 7.9MPa for 8 hours, and the compressive strength is 43.06MPa, which is increased by 648% and 259% respectively, compared with those without the early strength agent.

1. Introduction

As a traditional admixture, early strength agent can significantly improve the early setting and hardening of concrete, and then rapidly enhance the early mechanical properties of concrete, so as to meet the needs of practical engineering. There are some defects in both organic or inorganic early strength agent separately mixed into concrete, such as the commonly used organic triethanolamine. Because of its small amount of mixing, the early strong agent triethanolamine is not easy to control and has different effect on different kinds of cement systems, so it is generally not added alone[1-2]; Sodium sulfate, as a commonly used inorganic salt early strength agent and mixed with concrete, is prone to salting out, which not only affects appearance, but also has potential threat to alkali aggregate reaction of sodium ions in solution[3]. The compound early strength agent can reduce the adverse effect of various substances to concrete as much as possible while giving full play to the advantages of various early strength agents, and fully display the superposition effect of all early strength agents[4]. The compound early strength agent is one of the main directions of the development of the early strong agent industry, and it is also the main subject of the research of early strong agent. Therefore, the effect of compound early strength agent on the early mechanical properties of concrete is studied by combining inorganic and organic early strength agents.

2. Experimental materials and experimental methods

2.1. main material of test

- Cement: the cement used in the experiment is the P▪O42.5 cement produced by Yatai group in Jilin province.

Table 1. Physical mechanical properties of cement

Type of cement	Standard consistency%	Densityg /cm^3	Specific surface area m^2/kg	Setting time/min		Flexural strength/MPa		Compressive strength/MPa	
				The initial setting	End condensing	3d	28d	3d	28d
P▪O42.5	27.0	3.15	350	240	320	5.2	8.4	26.1	47.0

- Silica fume: the chemical composition of silica fume (SF) is shown in table 2, and the physical properties of silica fume are shown in table 3.

Table 2. Chemical composition of silica fume

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SiO_3	Na_2O	K_2O	MnO	ZnO
90.35	1.04	2.16	0.92	0.76	0.25	0.58	0.58	0.24	0.32

Table 3. The physical properties of silica fume

Density (g/cm^3)	Active index（%）	Specific surface area（m^2/g）
2.35	86	17.8275

- Quartz sand: the quartz sand used in this experiment is different in size distribution. The particle size of coarse sand is mainly between 2.36 and 4.75mm. The size of middle sand is mainly between 1.18 and 2.36mm, and the diameter of fine sand is mainly between 0.6 and 1.18mm. The distribution of the quartz sand is shown in table 4, and the physical performance parameters are shown in table 5.

Table 4. Grading distribution of quartz sand

Particle size（mm）	Accumulative sieve residue（%）		
	Coarse sand	Medium sand	Fine sand
4.75	0.0%	0%	0.0%
2.36~4.75	87.6%	14.8%	0.0%
1.18~2.36	97.6%	96.0%	11.9%
0.6~1.18	98.0%	97.3%	99.8%
0.3~0.6	99.3%	98.6%	99.9%
0.15~0.3	99.5%	99.8%	99.9%
Screen bottom	100.0%	100.0%	100.0%

Table 5. Physical properties of quartz sand

Aggregate type	Stacking density（kg/m^3）	Apparent density（kg/m^3）	Voidage（%）
Coarse aggregate	1573.5	2564.1	38.6
Medium aggregate	1477.7	2604.2	43.3
Fine aggregate	1416.6	2673.8	47.0

- Admixture: polycarboxylic superplasticizer is provided by Shenyang Huayin environmental protection material Co., Ltd., the water reducing efficiency is 20%. Compound early strength agent : $Al_2(SO_4)_3$,Li_2CO_3 ,$C_6H_{15}O_3N$.

2.2. experimental method

2.2.1 concrete mix ratio parameters

In this experiment, the water cement ratio is 0.28, silica fume content was 10%, cement sand ratio is 0.5 (coarse sand, medium sand, fine sand mixing ratio is 1.2:1.01:0.9), the water reducing agent is a cementitious material quality of 3 per thousand, compound early strength agent dosage: $C_6H_{15}O_3N$ (0.04%) + $Al_2(SO_4)_3$ (2%) + Li_2CO_3 (1.6%). Concrete mix ratio is shown in table 6.

Table 6. Concrete mix ratio

Water (g)	Cement (g)	Silica fume (g)	Quartz sand			Water reducing agent (g)
			Coarse sand (g)	Medium sand (g)	Fine sand (g)	
196	630	70	540	455	405	4.2

2.2.2 the procedure and process of experimental operation

Firstly the powder of compound early strength agent is added into concrete mixing material, and the powder is well stirred, which is beneficial to the powder of early strength agent to be more evenly dispersed in concrete, and then $C_6H_{15}O_3N$ liquid in the compound early strength agent is added into the mixing water and stirred in the concrete mix together with the mixing water. Then the mixed mixture is loaded into the 40 x 40 x 160mm triad die, and the mold is put into the concrete curing box. The curing condition is used for the standard maintenance. After 4-5 hours of maintenance, the mold is removed and the specimen is maintained for 8 hours.

3. Experimental results and analysis

In this experiment, the effect of composite early strength agent on the early mechanical properties of concrete was investigated. Therefore, the experiment was based on 8 hours of compressive strength and flexural strength. The results obtained by the test are shown in table 7.

Table 7. Test results

Experimental groups	Compressive strength (MPa)	Flexural strength (MPa)
Without early strength agent	12.00	0.12
Adding early strength agent	43.06	7.90

It is not difficult to find out from table 7 that the effect of $C_6H_{15}O_3N$ + $Al_2(SO_4)_3$ + Li_2CO_3 early strength agent on the early mechanical properties of concrete is very significant. The curing time of this experiment is much shorter than the general maintenance time, the degree of hydration of cementitious materials in ordinary concrete is lower in such a short curing time, basically no cementation effect. It is difficult to establish the internal structure of concrete and therefore, the flexural strength of concrete is only 0.12MPa after 8 hours of maintenance. While adding $C_6H_{15}O_3N$ + $Al_2(SO_4)_3$ + Li_2CO_3 combined with early strength agent, the strength of concrete is greatly improved, the flexural strength of 8h reaches 7.9MPa, and the compressive strength is 43.06MPa.

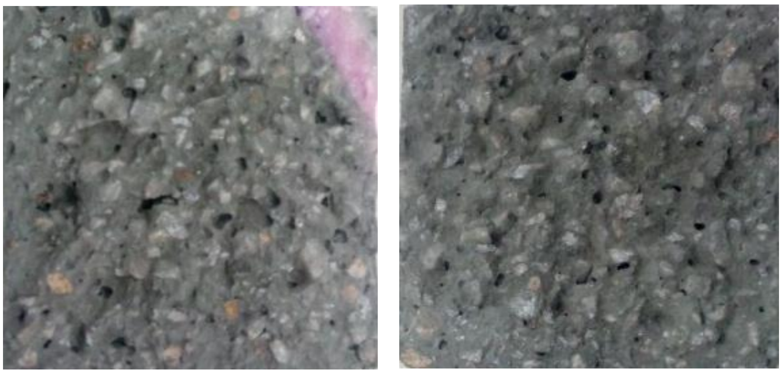

Figure 1. Section map of test block

By observing the internal section of the test block, as shown in fig. 1, the concrete block mixed with compound early strength agent is denser than the unfilled ones, and the internal porosity is smaller, and the pore radius is smaller. Lithium carbonate is a strong base and weak acid salt, and aluminum sulfate belongs to strong acid and weak base salt, therefore, when they are added to water at the same time, they will produce mutually promoted hydration reaction and produce lots of bubbles. These bubbles play the role of air entraining agent to some extent, making the bubbles larger in the concrete mixture less, reducing porosity and pore radius, and improving the compactness of the mixture.

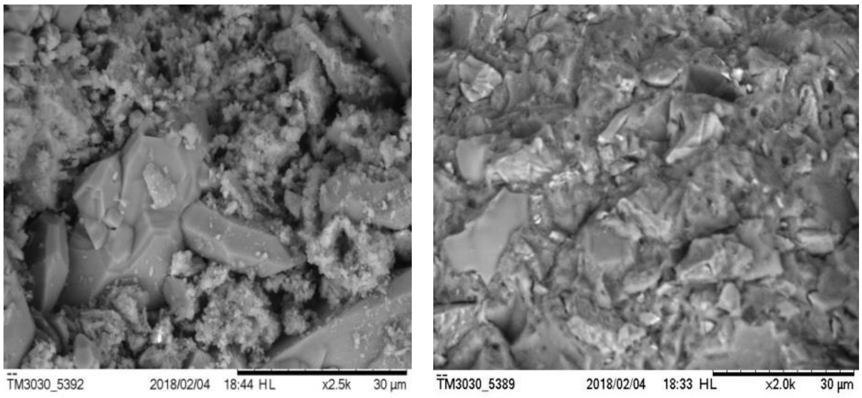

Figure 2. Microcosmic image of the test blocks

Through SEM scanning electron microscope, specimens in the experimental group were observed. We can see from fig. 2, in 8 hours short maintenance time, the inner structure of concrete blank in the experimental group is littered with a lot of unhydrated cement particles and voids filled unhydrated cement particles is relatively loose, causing the concrete flexural strength is low. It is clearly observed from fig. 2 that the hydration degree of the inner matrix of concrete mixed with compound early strength agent is relatively high, and the internal structure is more dense. Because lithium ion has a smaller radius and strong polarization effect, it shortens the hydration induction period, accelerates the formation of calcium sulphoaluminate crystal and accelerates the condensation speed significantly. Therefore, the early strength agent of $C_6H_{15}O_3N$ + $Al_2(SO_4)_3$ + Li_2CO_3 can greatly accelerate the hydration process of the matrix in a short time. The compound early strength agent has a certain air entraining effect, which makes the internal porosity decrease, the compactness increases, and the early mechanical properties have a remarkable strengthening effect.

4. Conclusion

- The early strength agent of $C_6H_{15}O_3N$ + $Al_2(SO_4)_3$ + Li_2CO_3 has enhanced the mechanical properties of concrete, especially the increase of flexural strength;
- The early strength agent of $C_6H_{15}O_3N$ + $Al_2(SO_4)_3$ + Li_2CO_3 can not only accelerate the setting and hardening process of cementitious materials, but also have a certain air entraining effect and improve the density of concrete.

Acknowledgments

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