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Influence Study of the Combined Action of Shrinkage Reducing Agent and Water Reducing Agent on the Mechanical Characteristics of Cement-Based Composite Material

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This paper studied the compatibility of shrinkage reducing agent and water reducing agent in cement-based composite material and analyzed the change of dispersity, stability and mechanical characteristics of cement-based composite material at different ratios of shrinkage reducing agent and water reducing agent, which revealed the mechanism of action of these two chemical agents on cement-based composite material. The results showed that when cement admixture with water reducing agent was mixed with a small amount of shrinkage reducing agent, the initial fluidity of cement had little variation, but the thickening time of cement paste extended significantly. The effect of shrinkage reducing agent on ester water reducing agent was relatively larger compared with ether water reducing agent and the fluidity loss was about 10mm. Ether water reducing agent could significantly reduce the degree of shrinkage of the cement mortar test block. After the maintenance for 70d, the shrinkage value of cement mortar test block with shrinkage reducing agent and water reducing agent reduced by 21.4% compared with cement mortar test block with only shrinkage reducing agent. There is no reduce shrinkage effect when adding ester water reducing agent. However, the shrinkage value of cement mortar with ester shrinkage reducing agent and water reducing agent reduced by 17.4% compared with cement mortar with only shrinkage reducing agent. Water reducing agent could effectively inhibit the defoaming effect of shrinkage reducing agent on the cement-based composite material and the strength of cement-based composite material adding water-reducing agent and shrinkage reducing agent was greater than that with shrinkage reducing agent alone.

1. Introduction

Cement-based composite material (concrete, mortar, cement mortar, etc.) is the most widely used building materials in the constructional engineering and have typical high brittleness characteristics of high compressive strength, low tensile strength and flexural strength. The initial cracks, porosity and high brittleness of cement-based composite material during the initial casting stage are the important reasons for the decrease of mechanical properties, durability and whole life-span of cement-based composite material. (Bentz, 2008; Bentz et al., 2008; Bentz et al., 2009)

Aiming at the inherent defects such as high brittleness and initial crack of cement-based composite material, the traditional method is to add fiber materials, such as steel fiber and carbon fiber, into the material. The fiber material can increase the compressive strength and adhesive property of cement mortar and thus reduce initial cracks and pores to a certain extent (Bernard et al., 2003; Bella et al., 2016; Young et al., 2005; Akkaya et al., 2007). However, the adding of fiber material does not change the chemical composition of cement paste, the initial cracks cannot be effectively inhibited (Sheikh and Yau, 2002; Ozbakkaloglu and Saatcioglu, 2006; Binici and Mosalam, 2007).

Shrinkage reducing agent and water reducing agent are the main external chemical reagents to inhibit the shrinkage of cement-based composite material and reduce the surface tension of cement paste. Relevant studies have shown that the addition of shrinkage reducing agent and water reducing agent can effectively

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inhibit the pores and cracks of the material (Ma et al., 2005; Zhang et al., 2012; Rajabipour et al., 2008). In order to achieve better cement mortar work performance, shrinkage reducing agent and water reducing agent are generally added at the same time, so the compatibility of these two agents cannot be ignored. It is necessary to conduct in-depth research on the ratio of shrinkage reducing agent and water reducing agent and the impact on the strength of cement base (Sant et al., 2011; Dang et al., 2013; Bentz et al., 2001).
This paper studied the compatibility of shrinkage reducing agent and water reducing agent in cement-based composite material and analyzed the change of dispersity, stability and mechanical characteristics of cement-based composite material at different ratios of shrinkage reducing agent and water reducing agent, which revealed the mechanism of action of these two chemical agents on cement-based composite material.

2. Experimental materials and methods

Two types of water reducing agents were selected: ether water reducing agent (WR1) and ester water reducing agent (WR2). The added volume of WR1 and WR2 is 0.1% -0.3% of the total amount of cement. The statistics of surface tension of the aqueous solution are shown in Table 1.

Table 1: Statistics of Surface Tension of Two Types of Water Reducing Agents

W (WR)/%	Surface tension of solution/(Mn·m^{-1})	
	WR1	WR2
0	73.6	71.8
0.2	58.0	73.6
0.3	53.4	70.2
0.6	46.9	66.1

It can be seen from the table that the ether water reducing agent has a better effect of reducing the surface tension of the solution than that of ester water reducing agent. Meanwhile, two kinds of shrinkage reducing agents SR1 and SR2 were also chosen, whose added volume is1.5% and 3.5% of the total amount of cement respectively. The cement selected is PO42.5R Portland cement, and the modulus coefficient of the middle sand is 3.0.
Table 2 shows the chemical composition of the cement and coal ash.

Table 2: Chemical Composition of Cement and Coal Ash

Material	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	TiO_2	SO_3	IL
Cement	21.34	5.56	3.52	62.77	0.88		3.03	1.19
Fly ash	48.13	25.45	13.97	3.36	1.09	2.48	2.35	3.87

The size of the test block for the material strength test is 40×40×40mm, and is put in water for maintenance; the size of the test block for material drying shrinkage test 25 25×200mm. at maintenance, the indoor relative humidity is 55 and the room temperature is 25°C; the potential analyzer is used to test the potential variation at the cement surface with the presence of these two chemicals.

3. Experiment results and analysis

3.1 Impact of shrinkage reducing agent on the plasticization of water reducing agent

Figure 1 shows situation that the cement mortar with water reducing agent is mixed with different ratios of shrinkage reducing agent to examine the impact of shrinkage reducing agent on the plasticization of water reducing agent. Figure 1 (a) shows the situation of using the ether shrinkage reducing agent, and Figure 1 (b) shows the situation of using the ester shrinkage reducing agent. It can be seen from Figure 1 (a) that when the mixing amount of shrinkage reducing agent is small, the initial fluidity of cement had little variation, but the thickening time of cement paste extended significantly. It can also be seen from Figure 1 (a) that the impact of shrinkage reducing agent on ester water reducing agent is greater than that on ether water reducing agent and the fluidity loss was about 10mm. It can be found from the comparison of Figure 1 (a) and Figure 1 (b) that the coexistence of water reducing agent and shrinkage reducing agent nearly exerts no impact on the fluidity of cement.

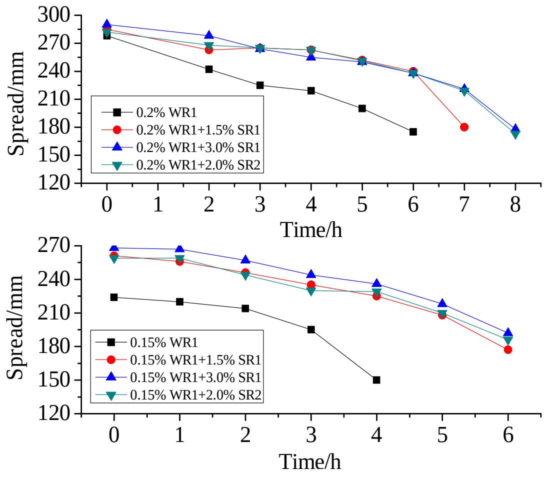


Figure 1: Impact of Different Ratio of Water Reducing Agent and Shrinkage Reducing Agent on Cement Fluidity

Figure 2 shows the potential variation of the cement when adding water reducing agent alone into the cement mortar and adding water reducing agent and shrinkage reducing agent together. It can be seen from the figure that when the cement mortar is mixed with shrinkage reducing agent only, the potential on the cement surface will reduce significantly. When the concentration of WR1 is 1g / L, the potential on the cement surface when adding two types of chemical reagents is higher than that adding water reducing agent only. In general, the existence of these two types of agents exerts no negative impact on the potential and electrostatic repulsion on the cement surface.
Figure 2 Simultaneous incorporation of shrinkage inhibitors and ether superplasticizer on the cement surface potential

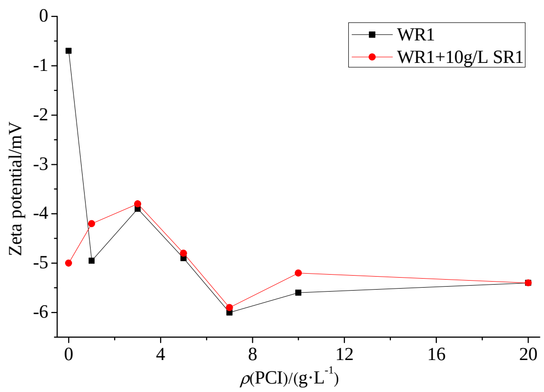


Figure 2: Impact of Adding Shrinkage Reducing Agent and Ether Water Reducing Agent on the Potential on Cement Surface

Table 3: Impact of Different Content of Water Reducing Agent and Shrinkage Reducing Agent on the Emission Spectrum

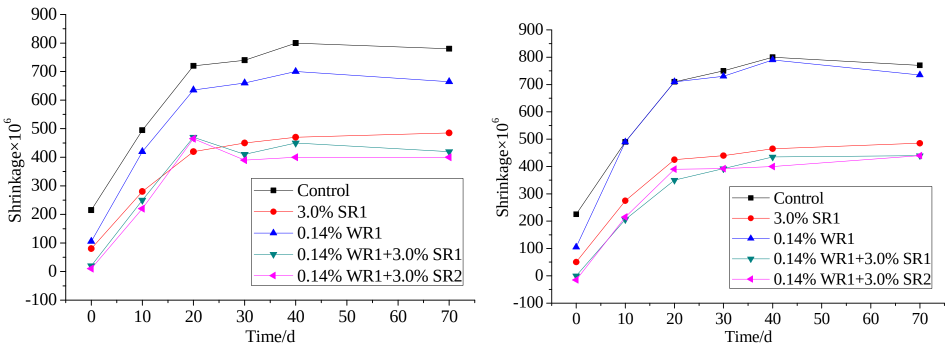
Type	I_{373}	I_{379}	I_{384}	I_{390}	I_{394}	I_{373}/ I_{384}
1g/L WR1	242.59	144.73	139.22	177.80	178.25	1.72
15g/L SR1	313.32	175.04	179.32	223.18	232.49	1.79
1g/L WR1+15g/L SR1	560.23	294.29	315.89	370.40	389.46	1.75

Table 3 shows the emission spectrum variation of water reducing agent and shrinkage reducing agent. Emission spectrum is a test of the microstructure change of water-soluble molecule under different conditions. Water reducing agent belongs to surface-active molecules. The emission spectrum can be used to test the microstructural change of water reducing agent under random conditions. It can be seen from the Table that the intensity of the emission spectrum of the cement mortar mixed with shrinkage reducing agent and the ether water reducing agent is lower than the sum of the intensity of the emission spectrum mixed with WR1 and SR1 respectively, indicating that there is molecular diffusion phenomenon in the ether water reducing agent after the addition of shrinkage reducing agent. The polarity in the solution increased and the molecular branches can expand outward better, thus increasing the space potential of the ether water reducing agent.

3.2 Impact of water reducing agent on the reduce shrinkage effect of shrinkage reducing agent

When Shrinkage reducing agent is added in the cement mortar alone, the pore-surface tension of cement can be reduced and the dispersion effect of water reducing agent can accelerate the pore-hardening of cement paste and the escape of pore water. It is an important part in the study of the compatibility of two types of chemical reagents that whether the addition water reducing agent in the cement mortar with shrinkage reducing agent will influence the performance of shrinkage reducing agent.

Figure 3 shows the shrinkage of cement test blocks after adding ether water reducing agent and ester water reducing agent respectively into the cement mortar with shrinkage reducing agent. It can be seen from Figure 3 that ether water reducing agent can significantly reduce the degree of shrinkage of the cement mortar test blocks. After 70 days of maintenance, the shrinkage value of cement mortar test block with shrinkage reducing agent and water reducing agent reduced by 21.4% compared with cement mortar test block with only shrinkage reducing agent. There is no reduce shrinkage effect when adding ester water reducing agent. However, the shrinkage value of cement mortar with ester shrinkage reducing agent and water reducing agent reduced by 17.4% compared with cement mortar with only shrinkage reducing agent.



(a) Ether water reducing agent (b) Ester water reducing agent

Figure 3: Impact of Two Types of Water Reducing Agent on the Effect of Shrinkage Reducing Agent

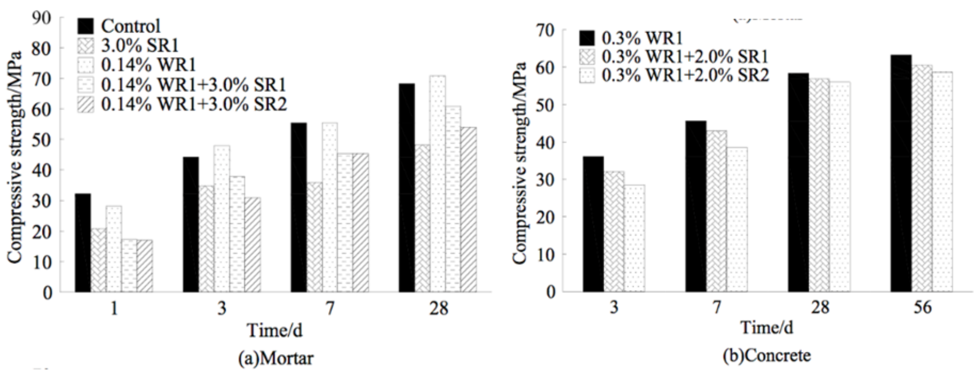


Figure 4: Impact of Addition of ether Water Reducing Agent and Shrinkage Reducing Agent on the Strength of Cement Mortar and Concrete

According to the above analysis, it can be found that the combined action of water reducing agent and shrinkage reducing agent can effectively reduce the shrinkage effect of cement mortar, which is due to the fact the root structure of the water reducing agent enhances the dispersion degree of cement particles and improves the hydration rate is improved, thus inhibiting the tension of capillary pore and crack. Meanwhile, water reducing agent also has air-entraining effect, which can reduce the shrinkage stress of cement mortar in the drying process.

Fig. 4 and Fig. 5 show the strength variation of cement mortar and concrete when adding water reducing agent and shrinkage reducing agent respectively into cement mortar and concrete. The material strength of cement mortar after the maintenance of 1d, 3d, 7d and 28d is monitored and the material strength of concrete after the maintenance of 3d, 7d, 28d and 56d is monitored. It can be seen from the figure that the material strength of cement mortar adding WR1 and SR1 is higher than that of the combination of WR2 and SR1, which shows that the compatibility between WR1 and SR1 is better. WR1 has a stronger air-entraining effect and SR1 has defoaming effect, so the internal of mortar mixed with WR1 and SR1 is denser. There is no obvious difference between the material compressive strength of concrete mixed with shrinkage reducing agent and water reducing agent and cement mortar.

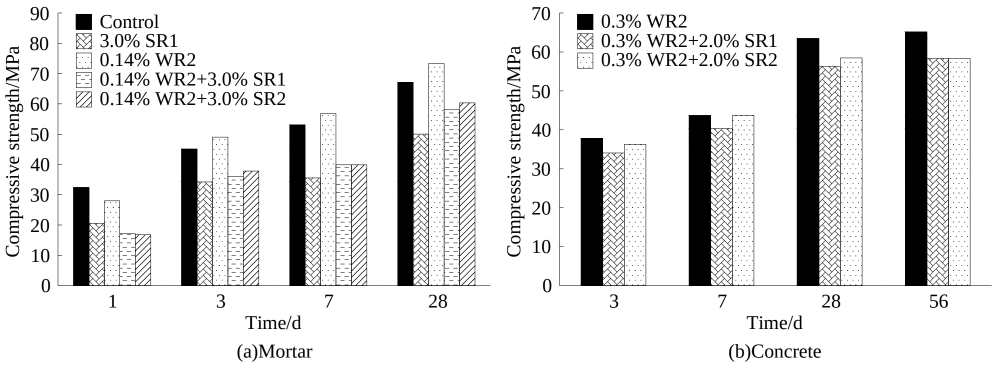


Figure 5: Impact of the Adding Water Reducing Agent and Shrinkage Reducing Agent on the Strength of Cement Mortar and Concrete

4. Conclusion

This paper studied the compatibility of shrinkage reducing agent and water reducing agent in cement-based composite material and analyzed the change of dispersity, stability and mechanical characteristics of cement-based composite material at different ratios of shrinkage reducing agent and water reducing agent, which revealed the mechanism of action of these two chemical agents on cement-based composite material. The research conclusions were as follow:

(1) When cement mortar with water reducing agent was mixed with a small amount of shrinkage reducing agent, the initial fluidity of cement had little variation, but the thickening time of cement paste extended significantly. The impact of shrinkage reducing agent on ester water reducing agent is greater than that on ether water reducing agent and the fluidity loss was about 10mm.

(2) Ether water reducing agent could significantly reduce the degree of shrinkage of the cement mortar test block. After the maintenance for 70d, the shrinkage value of cement mortar test block with shrinkage reducing agent and water reducing agent reduced by 21.4% compared with cement mortar test block with only shrinkage reducing agent. There is no reduce shrinkage effect when adding ester water reducing agent. However, the shrinkage value of cement mortar with ester shrinkage reducing agent and water reducing agent reduced by 17.4% compared with cement mortar with only shrinkage reducing agent.

(3) Water reducing agent could effectively inhibit the defoaming effect of shrinkage reducing agent on the cement-based composite material and the strength of cement-based composite material adding water-reducing agent and shrinkage reducing agent was greater than that with shrinkage reducing agent alone.

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