Effect of EPEG with Different Molecular Weight on Early Strength of Polycarboxylic Acid Superplasticizer

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Abstract. The aim of this study was to investigate the effect of EPEG with different molecular weight on the early strength of polycarboxylic acid superplasticizer. Through experimental testing and analysis, it was found that the early strength of polycarboxylic acid superplasticizer could be improved by appropriately increasing the molecular weight of EPEG, and the influence of EPEG molecular weight on the 1-day early strength of the synthesized polycarboxylic acid superplasticizer was more obvious at 20℃ than at 5℃, but the water reducing and dispersion performance of the high molecular weight EPEG synthesized polycarboxylic acid superplasticizer would be decreased.

Keywords: Polycarboxylic acid superplasticizers; EPEG; Molecular weight; Early strength performance

1 Introduction

Polycarboxylic acid superplasticizer is a key component of concrete admixtures, which can adjust the fluidity and improve the working performance of concrete by adsorbing on concrete particles and cement colloid surface. Due to its strong designability, polycarboxylic acid superplasticizer has become a research focus of concrete admixtures in recent years [1].

The early strength development of concrete is an important index in the design and construction of concrete engineering, which plays an important role in rapid construction, accelerated strength development and shortened construction period. Therefore, polycarboxylic acid superplasticizers with early strength properties are also an important research direction of functional polycarboxylic acid superplasticizers. Many scholars [2-6] have prepared early-strength polycarboxylic acid superplasticizers through different synthesis methods, and studied their effects on concrete properties. A large number of studies have shown that increasing the chain length of polyether monomers used in the synthesis of polycarboxylic acid superplasticizers can not only promote cement hydration, but also affect the morphology of hydration products, thus improving the early strength of concrete. However, the longer the chain length of polyether macromonomer used for synthesis of polycarboxylic acid superplasticizer is not the better. The increase in the number of chain segments will lead to the decrease of

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polymerization activity of polyether macromonomer and the decrease of conversion rate during polymerization. In addition, the unreacted polyether macromonomer in polymerization system will introduce a large number of bubbles in the use of concrete, which will seriously affect the later strength of concrete and easily cause the strength to shrink. Therefore, more stringent requirements were put forward for polymerization conditions [7-10].

Due to its special structure, the new polyether macromonomer of EPEG has high double bond activity [11]. Using EPEG, a long-side chain polycarboxylic acid superplasticizer with higher conversion rate may be synthesized. In order to fill the research gap, the effect of EPEG with different molecular weight on the early strength of polycarboxylic acid superplasticizer at low temperature and room temperature was studied in this article.

2 Experimental

2.1 Experimental raw materials

Cement (C): Chunchi P.O 42.5 cement, specific performance indicators are shown in Table 1, cement chemical composition is shown in Table 2.

Table 1. Cement performance indicators

Stability	Setting time /min		Compressive strength /MPa		Flexural strength /MPa	
	Initial setting	Final setting	3 d	3 d	3 d	28d
qualified	181	262	29.6	49.8	6.6	9.4

Table 2. Chemical composition of cement

Chemical composition	CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	SO_3	Na_2O	K_2O	Firing loss	Insoluble matter	Free calcium oxide
content /%	52.52	0.73	27.92	3.98	6.1	2.39	0.23	0.59	3.16	0.92	0.43

Sand (S): ISO standard sand.

Water (W): Tap water.

Water reducing agent (A): polycarboxylic acid water reducing agents PCE-3000, PCE-4000, PCE-5000 and PCE-6000 are synthesized using EPEG with Mw 3000, 4000, 5000 and 6000, respectively. The gel permeation chromatograms of PCE-3000, PCE-4000, PCE-5000 and PCE-6000 are shown in Figure 1 to Figure 4, and the molecular weight distribution data are shown in Table 3.

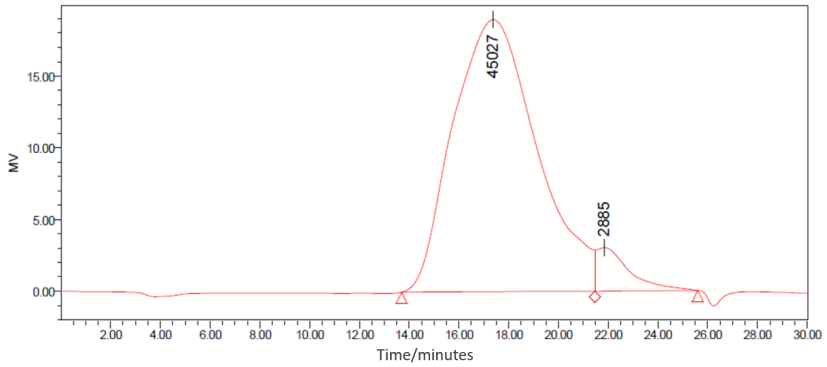

Fig. 1. Gel permeation chromatogram of PCE-3000

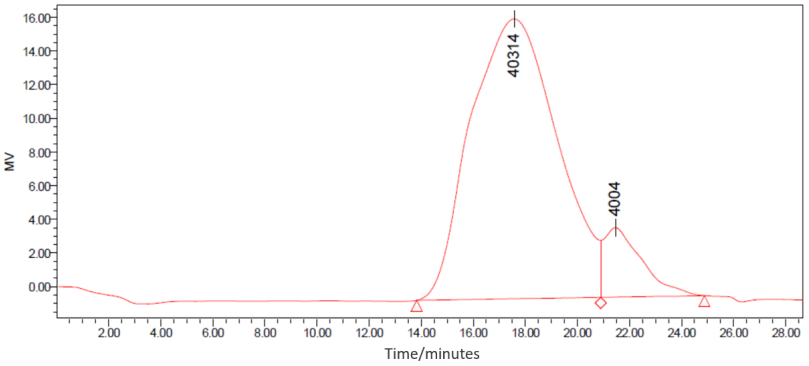

Fig. 2. Gel permeation chromatogram of PCE-4000

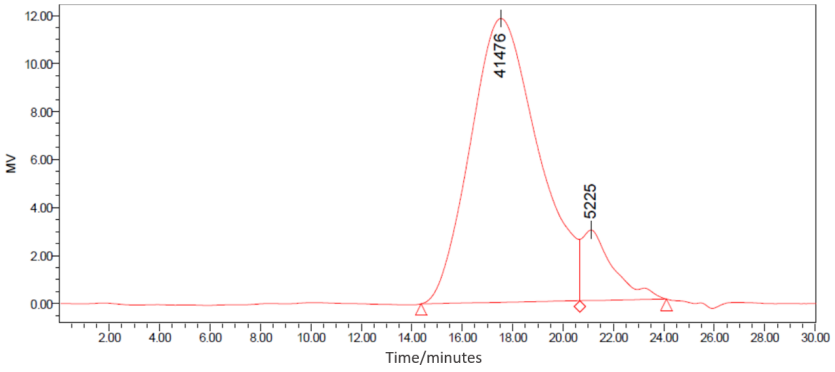

Fig. 3. Gel permeation chromatogram of PCE-5000

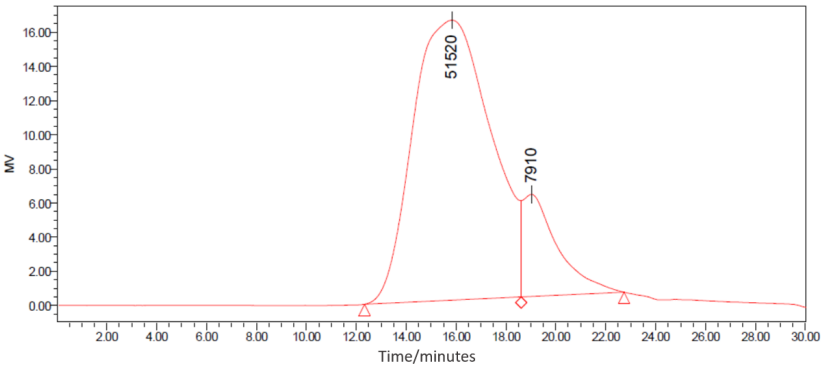

Fig. 4. Gel permeation chromatogram of PCE-6000

Table 3. Molecular weight distribution of polycarboxylic acid superplasticizer

Sample type	MP	Mw	Mn	Conversion rate /%
PCE-3000	45027	63752	27636	94.03
PCE-4000	40314	58820	29216	90.12
PCE-5000	41476	47899	28916	89.72
PCE-6000	51520	54384	34878	85.92

2.2 Performance testing methods

The performance of cement mortar shall be tested in accordance with the standards of GB/T 2419-2005 "Method for Determining the Fluidity of Cement Mortar" and GB/T 17671-2021 "Method for Testing the Strength of Cement Mortar (ISO Method)".

3 Experimental Results and Discussion

Evaluate the performance of polycarboxylic acid superplasticizer PCE-3000, PCE-4000, PCE-5000, and PCE-6000 synthesized using different molecular weights of EPEG. The experimental mix is shown in Table 4. By adjusting the dosage of polycarboxylic acid superplasticizer, the fluidity of the mortar is within the range of 180 ± 5mm, forming 40mm × 40mm × 160mm mortar specimens were cured at 5 ℃± 1 ℃ and 20 ℃± 1 ℃ for one day, and then transferred to standard curing conditions (temperature within the range of 20 ℃± 1 ℃, relative humidity not less than 90%) for curing. The test results are shown in Figures 5 to 8.

Table 4. Mortar mix ratio

W(g)	C(g)	S(g)
190	450	1350

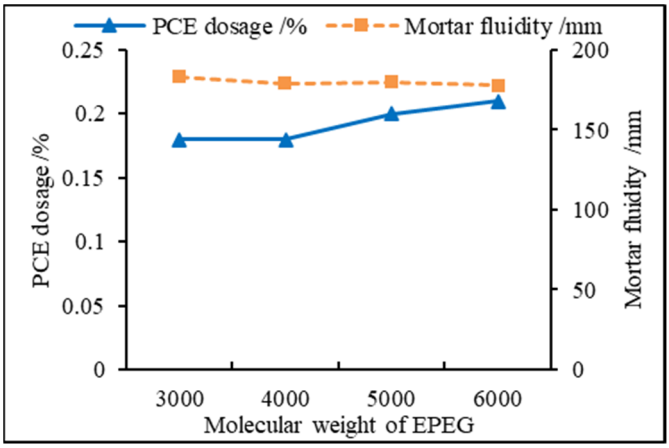

Fig. 5. The mortar fluidity of PCE synthesized with different molecular weight EPEG

As shown in Figure 5, when the mortar fluidity of PCE-3000, PCE-4000, PCE-5000, and PCE-6000 is within the range of 180 ± 5mm, the dosage of PCE gradually increases. This is mainly because the polymerization activity of EPEG decreases as the molecular weight of EPEG increases, which is also illustrated by the polymerization conversion rates of PCE-3000, PCE-4000, PCE-5000 and PCE-6000 in Table 3.

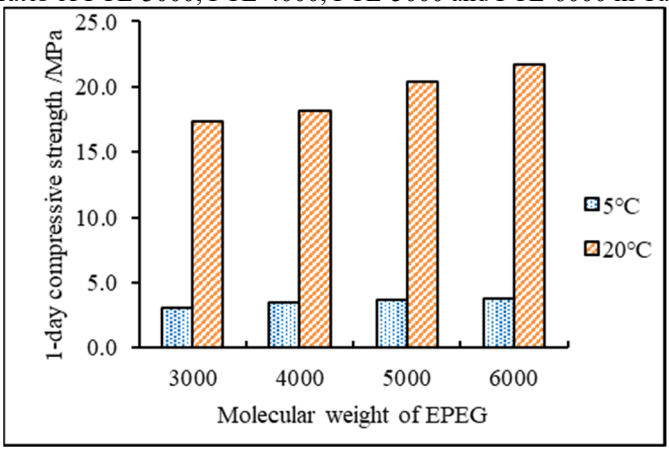

Fig. 6. The 1-day compressive strength of PCE synthesized with different molecular weight EPEG

As shown in Figure 6, the 1-day compressive strength of mortar specimens cured at 20 ℃ gradually increases with the increase of EPEG molecular weight, indicating that the polycarboxylic acid superplasticizer synthesized with high molecular weight EPEG has a certain early strength effect under 20 ℃ curing conditions. The 1-day compressive strength of mortar specimens cured at 5 ℃ is significantly lower than that of mortar specimens cured at 20 ℃, and the 1-day compressive strength of mortar specimens cured at 5 ℃ does not change significantly with the increase of EPEG molecular

weight. This indicates that under low temperature conditions at 5 ℃, due to the slow hydration reaction between water and cement, the strength of mortar specimens increases slowly, the early strength effect of polycarboxylic acid superplasticizer synthesized using high molecular weight EPEG is also not evident.

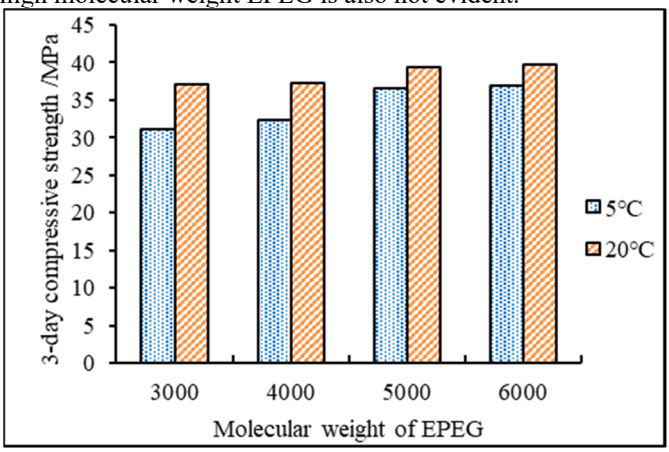

Fig. 7. The 3-day compressive strength of PCE synthesized with different molecular weight EPEG

As shown in Figure 7, the 3-day compressive strength of mortar specimens cured at 20 ℃ gradually increases with the increase of EPEG molecular weight, indicating that the polycarboxylic acid superplasticizer synthesized with high molecular weight EPEG has a certain strengthening effect when cured at 20 ℃ for 3 days.

After 1 day of curing at 5 ℃ and continuing to maintain under standard curing conditions for 2 days, the 3-day compressive strength of the mortar obtained is slightly lower than that of the mortar specimens that has been maintained at 20 ℃. This is mainly because under low temperature conditions of 5 ℃, the hydration of cement is slow, and the strength of mortar specimens increases very slowly. After being cured at 20 ℃, the hydration of cement accelerates, and the strength growth accelerates. The 3-day compressive strength of mortar specimens mainly increases during curing at 20 ℃. The setting period of mortar specimens cured at 5 ℃ for 1 day is equivalent to one day less than that of mortar specimens cured at 20 ℃.

The 3-day compressive strength of mortar specimens cured for 1 day at 5 ℃ gradually increases with the increase of EPEG molecular weight, and the increase is greater than that cured at 20 ℃. This is mainly due to the use of high molecular weight EPEG synthesized polycarboxylic acid superplasticizer, which only has a certain effect on accelerating early cement hydration and has no significant impact on the degree of later cement hydration. The setting period of mortar specimens cured for 1 day at 5 ℃ is equivalent to one day less than that of mortar specimens cured at 20 ℃, so the early strength effect is more obvious.

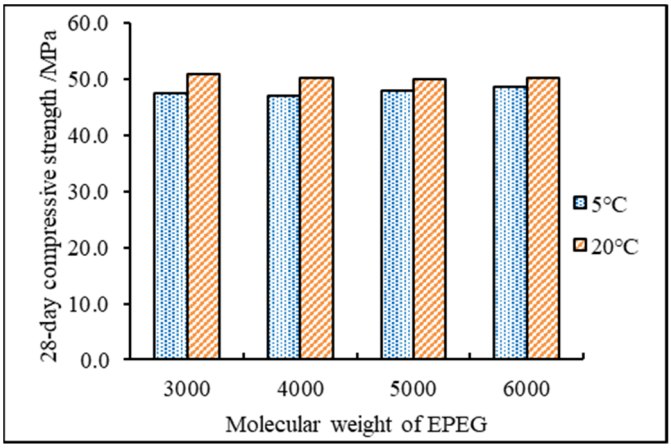

Fig. 8. The 28-day compressive strength of PCE synthesized with different molecular weight EPEG

As shown in Figure 8, the 28-day compressive strength of the mortar cured at 5 ℃ for 1 day and continued under standard curing conditions for 27 days was slightly lower than that of the mortar specimens cured at 20 ℃. However, the 28-day strength of the mortar specimens cured under both curing conditions with different molecular weight EPEG synthesized polycarboxylic acid superplasticizer did not change significantly. This further indicates that the use of high molecular weight EPEG synthesized polycarboxylic acid superplasticizer can only accelerate the early hydration of cement, there is no significant impact on the degree of cement hydration in the later stage.

4 Conclusions

(1) The increase in molecular weight of EPEG has a certain impact on the water reducing and dispersing effect of the synthesized polycarboxylic acid superplasticizer. The polycarboxylic acid superplasticizer synthesized with 6000 molecular weight EPEG has the worst water reducing and dispersing effect. This is mainly because the larger the molecular weight of EPEG, the lower its polymerization activity.

(2) The polycarboxylic acid superplasticizer synthesized using high molecular weight EPEG has a certain early strength effect, but the 1-day early strength effect is not significant under 5 ℃ curing conditions. This is mainly because under the condition of 5 ℃, the cement hydration is too slow, the mortar strength growth is too slow, and the early strength effect of polycarboxylic acid superplasticizer cannot be reflected. Therefore, simply increasing the molecular weight of EPEG can not solve the problem of insufficient early strength of concrete at 5℃ low temperature.

(3) The difference in 28-day compressive strength of polycarboxylic acid superplasticizers synthesized with different molecular weights of EPEG is not significant, indicating that the molecular weight of EPEG has little effect on the later compressive strength of the synthesized polycarboxylic acid superplasticizers.

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