Effect of Functional Monomer on Strength and Shrinkage Properties of Concrete

Yanmei Lin*, Mingzi Gong, Yifan Su

Kezhijie New Material Group Co., Ltd., Fujian, Xiamen, 361101；CCCC Xiamen Engineering Co., LTD., Fujian, Xiamen, 361000, China

Corresponding author: Yanmei Lin, female, 15759281170, 15759281170@163.com

Abstract. In this paper, the molecular structure of polycarboxylic acid water reduction agent was designed, and five different functional monomers were introduced to prepare early-strength polycarboxylic acid water reducer. Study the effects of different functional monomers on the macro properties and heat of hydration of the early-strength polycarboxylate water-reducer; adding functional monomers can improve the dispersion performance and early stage strength of the polycarboxylate water-reducer; Gel permeation chromatography are used to characterize the structure of the synthetic early-strength polycarboxylate water reducer. The structure of the product is consistent with the originally designed water reducer; the hydration calorimeter was used to study the effect of early-strength functional monomer on the heat of hydration of cement, and it was found that DAC had the best promotion effect on early cement hydration.

Keywords: functional monomers; early strength; shrinkage; heat of hydration

1 Introduction

Precast concrete is one of the most important development directions of the concrete and cement products industry. With the continuous development of its application and promotion, there are more and more types of precast concrete products. In order to improve production efficiency and speed up formwork turnover, precast concrete is required not only to have good workability, but also to have high early strength. The molecular structure of polycarboxylic acid water reducing agent is mostly comb-shaped or worm-like, which has strong design. In the development of polycarboxylic acid water reducing agent, the method of designing synthesis parameters and adjusting molecular structure parameters is usually adopted to improve its early strength performance and dispersion performance, but China's current production has not realized the preparation of early strength polycarboxylic acid water reducing agent from the polymer molecular structure design, and most of the traditional early strength composite water reducing agent is combined with early strength agent, the dosage of which is large, the early strength water reducing agent prepared has poor early strength

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performance. Therefore, through molecular structure cutting technology, the development of high-early strength, high dispersion, green environmental protection early strength polycarboxylic acid high-performance water reducing agent will promote the development of precast concrete technology in China[1-5].

China started late in the research and development of early strength polycarboxylic acid water reducing agent. There are two main types of methods for preparing early strength polycarboxylic acid water reducing agents in China, first, early strength polycarboxylic acid water reducing agents are prepared by compounding water reducing agents and early strength agents, and second, early functional monomers are added to the synthesis of polycarboxylic acid water reducing agents, thereby introducing functional groups with early strength functions on the molecule[6-9]. In this paper, five kinds of functional monomerss were introduced to synthesize polycarboxylic acid water reducing agents with early strength functions by molecular design means, and the macroscopic properties, dispersion properties and concrete strength properties of the synthesized early strength polycarboxylic acid water reducing agents were tested, and the hydration of cement slurry with early strength polycarboxylic acid water reducing agent was studied and analyzed by combining cement hydration heat meter and gel permeation chromatography, and the mechanism of functional monomerss on the early strength of polycarboxylic acid water reducing agent was revealed.

2 Experiment

2.1 Main raw materials

Synthetic raw materials: polyether monomer (TPEG), molecular weight of 3000, industrial grade; Ammonium persulfate, industrial grade; Acrylic, industrial grade; Sodium hypophosphite, industrial grade; mercaptoacetic acid, industrial grade; Sodium hydroxide solution, industrial grade;Acryloyloxyethyltrimethylammonium chloride(DAC), industrial grade; 2-Acrylamide-2-methylpropanesulfonic acid(AMPS), industrial grade; Acrylamide (AM), industrial grade; N-Hydroxymethylacrylamide (N-MAM), industrial grade; N,N-Dimethacrylamide (DMAA), industrial grade.

Test raw materials: cement, Min Fu P. O52.5, stone, particle size 10~20mm; Sand, fineness modulus 2.7~2.9; water, tap water.

2.2 Preparation method of polycarboxylic acid water reducing agent

Polyether monomer TPEG was added to the four-mouth bottle, and the method of free radical copolymerization in aqueous solution was used to add ammonium persulfate, acrylic acid, sodium hypophosphite, thioacetic acid, and aqueous solution of functional monomers to the four-mouth flask dropwise, copolymerized for 3h at 60°C, and then kept warm for about 1h after the reaction, and the reaction product was cooled and neutralized with sodium hydroxide solution to pH 7.0, that is, polycarboxylic acid water reducing agent was obtained. The water reducing agent synthesized without functional monomers is PCE-0, the water reducing agent synthesized by DAC is PCE-DAC, the water reducing agent synthesized by AMPS is PCE-AMPS, the water reducing agent synthesized by AM is PCE-AM, the water reducing agent synthesized by N-MAM is PCE-N-MAM, and the water reducing agent synthesized by DMAA is PCE-DMAA.

2.3 Performance testing and characterization

Fluidity of cement slurry.
According to the water-to-adhesive ratio of 0.29, the solid content of water reducing agent is 0.1%, and the fluidity of cement slurry of synthetic water reducing agent is tested with reference to GB/T 8076-2008 "concrete admixture".

Concrete strength and shrinkage test.
The compressive strength properties of concrete is determined according to GB/T 8076-2008 "Concrete admixture".
The shrinkage properties of concrete is determined according to GB/T 50082-2009"Standard for long-term performance and durability performance test methods for ordinary concrete".

Gel permeation chromatographic analysis.
Difference detector: Waters 1515 Isocratic HPLP pump/Waters 2414, acquisition and analysis system: Breeze software. Column: UltrahydragelTM 250 in series with UltrahydragelTM 500, mobile phase: 0.1mol/L sodium nitrate aqueous, flow rate: 0.8mL/min.

Hydration thermal analysis.
The cement hydration calorimeter (PTS-12S, Wuhan Botaisi Technology Co., Ltd.) was used to determine the heat release performance of cement slurry doped with different water reducing agents during the hydration process. The water-cement ratio of the cement slurry used is 0.33, and the content of water reducing agent is 0.13% of the cement mass.

3 Results and discussion

3.1 Molecular weight and molecular weight distribution

Five functional monomers, DAC, AMPS, AM, N-MAM and DMAA, were introduced into the molecular structure of polycarboxylic acid water reducing agent, and the influence of functional monomers species on the structure of polycarboxylic acid water reducing agent was investigated, and the results are shown in Table 1.

Table 1. Molecular weight information of synthetic water reducer from different functional monomers

Water reducer	Mn	Mw/Mn	Side chain density	Conversion rate/%

PCE-0	49517	1.8115	0.1621	91.30
PCE-DAC	57693	1.7996	0.1885	88.70
PCE-AMPS	56145	1.8787	0.1782	90.75
PCE-AM	55752	1.7827	0.1789	91.22
PCE-N-MAM	53502	1.8279	0.1811	91.16
PCE-DMAA	52322	2.0157	0.1813	85.73

It can be seen from Table 1 that the introduction of functional monomers will reduce the conversion rate of polycarboxylic acid water reducing agent large monomer, increase its molecular weight and side chain density, which indicates that the addition of functional monomers can make the main chain of water reducing agent shorter and the side chain density larger, which is conducive to improving the early strength of concrete[10-12].

3.2 Effect of functional monomers on the dispersion performance of water reducing agent

Five functional monomerss, DAC, AMPS, AM, N-MA and DMAA, were introduced into the molecular structure of polycarboxylic acid water reducing agent, and the effect of functional monomers on the dispersion performance of polycarboxylic acid water reducing agent was investigated, and the results were shown in Figure 1.

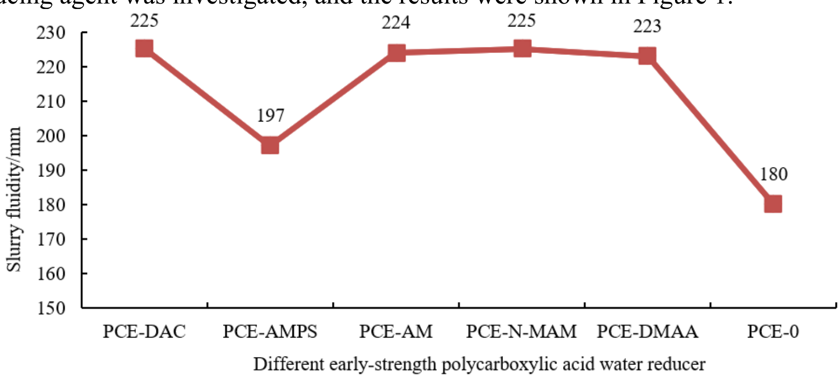

Fig. 1. The effect of different functional monomers on dispersion performance

It can be seen from Figure 1 that the functional monomers can significantly increase the flow degree of cement slurry of polycarboxylic acid water reducing agent and improve its dispersion performance. Among them, the net pulp fluidity of PCE-AMPS is the smallest, and the purifying pulp fluidity of DAC,AM, N-MAM and DMAA early strength polycarboxylic acid water reducing agent is similar. It can be seen that among the five functional monomers, AMPS has the worst effect on improving the dispersion performance of polycarboxylic acid water reducing agent. Because these five functional monomerss contain sulfonic acid or amide groups, these charged groups are introduced into the molecular structure of the water reducing agent, which can increase the electrostatic repulsion between the molecular chains, thereby promoting the dispersion of cement-based materials.

3.3 Effect of functional monomers on concrete performance

Functional monomers, DAC, AMPS, AM, N-MAM and DMAA, were introduced into the molecular structure of polycarboxylic acid water reducing agent, and the effects of different functional monomerss on the strength and shrinkage performance of polycarboxylic acid water reducing agent were investigated, and the results are shown in Figure 2.

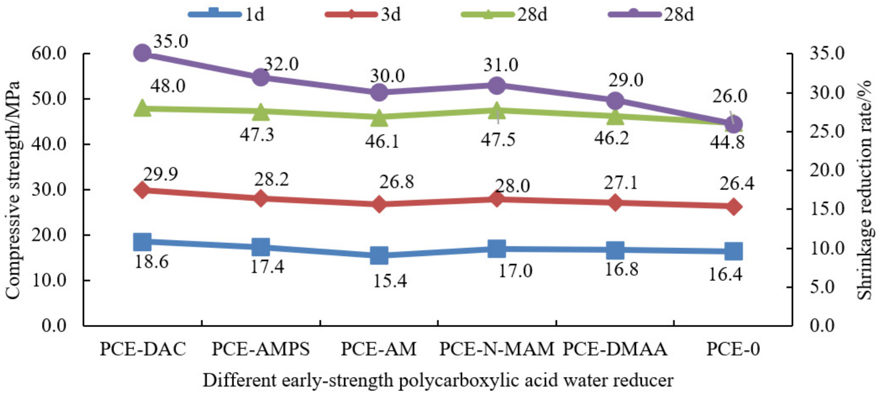

Fig. 2. The influence of different functional monomers on strength and shrinkage performance

As can be seen from Figure 2, the compressive strength and shrinkage reduction rate of concrete with the introduction of functional monomers synthetic water reducing agent is higher than that of PCE-0. Among them, PCE-DAC have the highest 1d,3d compressive strength and 28d shrinkage reduction rate of concrete, which is 13.4% and 13.3% higher than PCA-0, respectively. Followed by PCE-AMPS and PCE-N-MAM, both of which have similar concrete compressive strength improvement effects, while PCE-AM has the worst concrete compressive strength.

3.4 Effect of functional monomers on cement hydration heat

Five functional monomerss, DAC, AMPS, AM, N-MA and DMAA, were introduced into the molecular structure of polycarboxylic acid water reducing agent to investigate the effect of functional monomers on cement hydration, and the results are shown in Figure 3.

For the effect of functional monomers on cement hydration, it can be found from Figure 3 that the temperature-time curve of cement slurry mixed with different polycarboxylic acid water reducing agents has the same development trend, the initial hydration rate is slow, and the slurry temperature does not change significantly with time. Then, as the rate of hydration increases, the highest temperature peak is quickly reached, and finally the temperature gradually decreases. Moreover, the functional monomers will lead to an increase in hydration temperature, an increase in hydration heat peak, and an increase in the nucleation rate of hydration products, resulting in an increase in the number of nucleation [13].

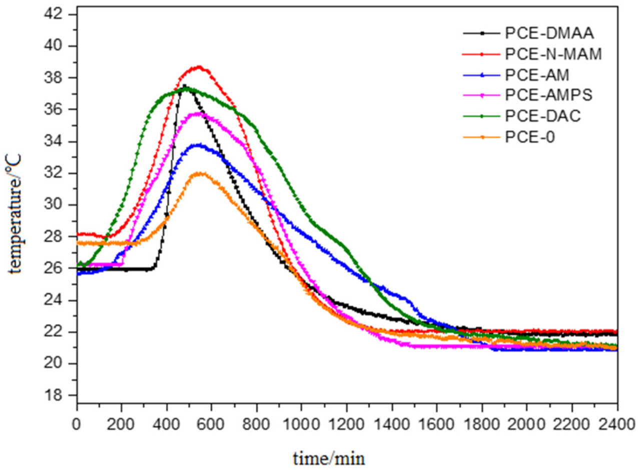

Fig. 3. The effect of different functional monomers on the heat of hydration of cement

The peak temperature of hydration heat release heat mixed with PCE-N-MA cement slurry was the highest, and the peak temperature of hydration heat mixed with PCE-DAC cement slurry was 37°C, but its exothermic peak area was the largest and the comprehensive heat release was the largest. Therefore, DAC has the best effect on cement hydration, and the other functional monomerss have the best promotion effect on cement hydration, and the other functional monomerss are DMAA, AMPS, and AM. The faster the hydration rate of early cement, the higher its early strength, which is consistent with the conclusion of the study on the influence of 2.3 section functional monomers on the early strength of concrete.

4 Conclusion

In this paper, the effect of functional monomers on the hydration heat and microstructure of cement is studied, and the following conclusions are obtained:

(1) The addition of functional monomers can improve the dispersion performance of polycarboxylic acid water reducing agent and the early strength performance of concrete. The dispersion performance improvement effect of different functional monomerss on water reducing agent was N-MAM>DMAA>AM>DAC>AMPS, and the improvement effect of early strength performance of concrete was DAC>AMPS>N-MAM>DMAA> AM, and the improvement effect of shrinkage reduction rate of concrete was DAC>AMPS>N-MAM>AM>DMAA.

(2) The addition of functional monomers can increase the molecular weight of polycarboxylic acid water reducing agent, make the main chain shorter, and the side chain density become larger, thereby greatly improving its dispersion performance and improving the early strength of concrete.

(3) The addition of functional monomers can increase the peak temperature of cement hydration exothermic and advance the start time of the acceleration period of

cement hydration. The promotion effects of different functional monomerss on early cement hydration were DAC>DMAA>AMPS>AM>N-MAM.

References

1. Y.H. Fang, Z.J. Lin, D.M. Yan, X.F. Zhang, X.X. Ma, J.Y. Lai, Y. Liu, Z.H. Chen, Z.P. Wang. Study on the Effect of Polycarboxylate Ether Molecular Structure on Slurry Dispersion, Adsorption, and Microstructure[J]. Polymers, 2023, 15, 2496.
2. Y.H. Fang, X.F. Xiao, D.M. Yan, Z.J. Lin, X.X. Ma, J.Y. Lai, Y. Liu, Y.L. Ke, Z.H. Chen, Z.P. Wang. Study on Dispersion, Adsorption, and Hydration Effects of Polycarboxylate Superplasticizers with Different Side Chain Structures in Reference Cement and Belite Cement[J]. Materials, 2023, 16, 4168.
3. Y.H. Fang, Z.H. Chen, D.M. Yan, Y.L. Ke, X.X. Ma, J.Y. Lai, G.L. Ge, X.F. Zhang, Z.J. Lin, Z.P. Wang. Study on the Effect of Main Chain Molecular Structure on Adsorption, Dispersion, and Hydration of Polycarboxylate Superplasticizers[J]. Materilas, 2023, 16, 4823.
4. GAO Yue, LI Peng. Research status and problems of early strength polycarboxylic acid water reducing agent[J]. Liaoning Chemical Industry, 2023,52(6): 911-913.
5. HUANG Wei, ZHOU Jiamin, ZHEN Conghao. Effect of early strength polycarboxylic acid water reducing agent on early hydration of benchmark cement[J]. Bulletin of the Chinese ceramic society, 2022, 41(4): 1211-1221.
6. SUN Deyong. Super Early Strength Polycarboxylate Superplasticizer and its Application in Precast Concrete[D]. Yantai:Yantai University, 2022.
7. W. Jurg. Multipurpose cement dispersing polymers for high flow and high strength concrete. US6, 376-387.
8. P. Pepi. Admixture for producing cementitious compositions having good fluidity and high early compressive strength. US6, 767-799.
9. P. Pepi. Admixture for producing cementitious compositions having good fluidity and high early compressive strength. US6, 767-799.
10. A. A. Jeknovarian. High early-sterength-enhancing admixture for precast hydraulic cement and compositions containing same. US5, 840-852.
11. W. Jury. Multipurpose cement dispersing polymers for high flow and high strength concrete. US 6, 387, 176.
12. Du Chin. Early strength properties and mechanism of polycarboxylic acid water reducing agent[D]. Wuhan: Wuhan University of Technology, 2012.
13. HE Xiaofang, ZHANG Yashuang, LI Xiaoqing, et al. Research progress on thermal analysis of cement hydration products[J]. Bulletin of the Chinese Ceramic Society, 2012, 31(5): 1170-1174.