Research and application of polycarboxylate water reducer for precast components

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Abstract. Aiming at the ever-developing precast structural system, this paper developed a new type of polycarboxylic acid mother liquor, and compared it with other polycarboxylic acid mother liquors combined with various early strength agents and defoamers to study and analyze the impact on precast concrete components and engineering applications effect. The test results show that this type of water reducing agent can increase the softness of high-grade concrete and improve the workability of concrete. It can be widely used in pipe piles, subway segments and prefabricated construction projects.

1. Introduction

With the continuous advancement of urbanization, the number of reconstruction and expansion projects in towns and cities has gradually increased, the large-scale construction of affordable housing, and the steady development of the construction industry have made its status in our country's economic development not to be underestimated. However, the traditional construction industry is facing problems such as waste of resources, environmental pollution, shortage of labor, and unsatisfactory engineering quality at the construction site, making the construction industry have to seek changes. Therefore, the industrialization of construction has once again attracted the attention of the industry. The central government and governments across the country have issued relevant documents to clearly promote the industrialization of construction—accelerating the pilot promotion and application of prefabricated structural systems.

In response to the continuous development of the construction industry, Wang Jun [1] and others proposed to focus on the development of factory processing, reduce the manual workload of the construction site, improve production efficiency and engineering quality, and reduce environmental pollution at the construction site to meet the requirements of the development of construction industrialization, realize the purpose of industrial transformation and technological upgrading of the construction industry. Lin Yanmei [2] improved the synthesis process of polycarboxylate water-reducing agent and developed a polycarboxylate product suitable for prefabricated components such as shield subway segments. Huang Zhenxing [3] conducted a comparative study on the mix ratio of precast components and found that by reducing the water-binder ratio, selecting early-strength cement and early-strength water reducing agent, and optimizing the combination of cement slag, the early demoulding strength of precast components can be improved. Li Chongzhi [4] used a normal temperature process to introduce sulfonic acid groups, amide groups and other groups to synthesize an early-strength polycarboxylic acid-based water-reducing agent to improve the strength of precast concrete. Li Bing [5] studied the effects of different types of polycarboxylic acid mother liquor,
retarding components and viscosity-increasing components on the working performance and mechanical properties of prefabricated concrete, and obtained the best admixture ratio.

2. Experimental

2.1. Materials

2400 molecular weight isopentenol polyoxyethylene ether (TPEG); Initiator: Acrylic acid (AA); 2-acrylamide-2-methylpropanesulfonic acid (AMPS); Acryloyloxyethyl trimethyl ammonium chloride (DAC); catalyst and chain transfer agents, etc.. Cement: Mengdian P•O42.5 grade cement, the main physical and mechanical technical indicators are shown in Table 1; Stone: Use 5mm~10mm and 10mm~20mm continuous graded gravel; River sand: fineness modulus is 2.6, mud content is less than 1%; fly ash: grade II fly ash, the main physical and mechanical technical indicators are shown in Table 2. Water: drinking water. The mother liquor of polycarboxylic acid and early Strength Agent are all derived from Kezhijie new material, Its types and characteristics are shown in Table 3.

2.2. synthesis technology

Put a certain amount of TPEG and deionized water into a 2L four-neck flask equipped with a stirrer, and raise the temperature to 45°C, after the monomer is completely dissolved and stirred uniformly, add the initiator, and simultaneously add the A (A mixed solution of AA, DAC, AMPS, etc. and water) and B (Mixed solution of catalyst, chain transfer agent and water) into the four-neck flask at a uniform rate. Material A and material B were controlled at 2.5h and 3.0h, respectively, after the dripping was completed, and then kept at 45°C for 1h. After the reaction is over, adjust its pH value with liquid sodium hydroxide and add water to dilute it to 50% water reducer PCE-5.

2.3 Mix ratio used in performance test

The performance test coordination is shown in Table 4:
The admixture compound scheme is shown in Table 5:

| Tab.5 Additive compounding scheme |
|----------------------------------|
| PCE-1  | PCE-2  | PCE-3  | PCE-4  | PCE-5  | W     |
| 2000   | 2000   | 2000   | 2000   | 2000   | 8000  |
| 8000   | 8000   | 8000   | 8000   | 8000   | 8000  |

### 2.4 Performance test method
The performance of concrete is implemented in accordance with the provisions of GB 8076-2008 "Concrete Admixtures", and related performance indicators are tested. The degree of expansion is implemented in accordance with GB/T 50080-2016 "Standard for Test Methods for Performance of Ordinary Concrete Mixtures". The homogeneity test of the admixture is carried out in accordance with GB/T 8077-2012 "Test Method for the Homogeneity of Concrete Admixture". The production and maintenance of concrete specimens and the test of compressive strength refer to GB/T 50081-2019 "Standard for Test Methods of Physical and Mechanical Properties of Concrete".

### 3 Test results and discussion

#### 3.1 Dosage sensitivity
The quotient obtained by dividing the first admixture value of concrete expansion greater than 550mm by the admixture value of concrete expansion (300±10) mm. The quotient represents the sensitivity of concrete content, and the larger the quotient, the lower the sensitivity of concrete content. The experimental results are shown in Figure 1.

![Fig.1 Test results of different concrete content](image)

The following conclusions can be drawn from the Fig.1: PCE-5 has a wide range of expansion from 300mm to 550mm, with the largest quotient. That is, PCE-5 has the lowest sensitivity to dosage among the 5 types of water reducing agents.

#### 3.2 Viscosity analysis
The viscosity of concrete is a concern in construction. Control the initial expansion of concrete at 500±10mm, and test the emptying time at the beginning and one hour later to reflect the viscosity of the concrete. The experimental results are shown in Figure 2.
The initial emptying time from short to long is as follows: PCE-5=PCE-4<PCE-3<PCE-1<PCE-2. After one hour, the emptying time from short to long is: PCE-5<PCE-3<PCE-1<PCE-4<PCE-2. Comparative analysis shows that PCE-5 has the lowest viscosity.

3.3 Slump retention performance analysis
The slump retention performance affects the construction time and state of concrete. The initial expansion of concrete was controlled at 500±10mm, and the expansion after one hour was tested to compare the slump retention performance of the mother liquor. The experimental results are shown in Figure 3.

1h expansion degree from large to small: PCE-1>PCE-5>PCE-3=PCE-2>PCE-4. It shows that PCE-5 is in the upper middle level in terms of slump protection.

3.4 Strength analysis
The strength of concrete is its construction lifeline. Control the initial expansion of concrete to 500±10mm, and test and compare the strength development.
Fig. 4 Concrete strength development curve

1d intensity from high to low: PCE-2 > PCE-5 > PCE-4 > PCE-1 > PCE-3.

Comprehensive analysis shows that the early strength performance of PCE-5 is in the middle and upper class, second only to PCE-2.

In summary, the comprehensive performance of the PCE-5 mother liquor has great advantages in the process of use.

3.5 Gel chromatographic analysis

The molecular weight and molecular weight distribution of the polycarboxylic acid water reducer with high water holding capacity synthesized in this paper are tested, the results are shown in figure 5, the Mn value is 46542, the Mw value is 156816, the Mp value is 150872, the molecular weight distribution width is 3.43657, and the conversion rate is as high as 90.66%. The product conversion rate is high and the molecular weight distribution is uniform, which is consistent with the expected assumption, indicating that the process effectively controls the molecular weight distribution of high water-holding polycarboxylic acid water reducer.

Fig. 5 Gel chromatogram

4. Engineering Applications

4.1 Shield segment

4.1.1 Concrete mix ratio

The concrete mixing ratio of a segment factory in Henan is shown in Table 6, and the concrete technical indicators are shown in Table 7.

Tab. 6 Concrete mix ratio (kg/m³)

| Cement | Fly Ash | Fine Aggregate 1 | Fine Aggregate 2 | Coarse Aggregate | Admixture | Water |
|--------|---------|------------------|------------------|------------------|-----------|-------|
| 410    | 60      | 818              | 260              | 940              | 4.7       | 150   |
4.1.2 Site construction performance
The slump is controlled at 60-80mm during on-site pouring, and the pouring operability is good during the pouring process, the concrete has good cohesion, and there is no segregation and bleeding. The concrete is soft and easy to be collected when the workers are closing the surface. The rewinding time is 120-150min, the steam curing temperature is not more than 55°C, and the demolding strength is not less than 40% of the design strength. After demoulding, the concrete surface is bright and dense, with few bubbles. The 28d strength of the tested segment concrete is more than 115% of the design strength requirement, which meets the construction requirements. On-site construction status and demoulding effect are shown in Figure 6 and Figure 7.

4.2 Prefabricated building

4.2.1 Concrete mix ratio
A prefabricated construction company in Henan Province uses concrete for on-site construction as shown in Table 8 and its technical indicators are shown in Table 9.

| Index | 1d compressive strength /MPa | Slump /mm | Air content /% | Slump time /min |
|-------|------------------------------|-----------|----------------|-----------------|
| limit | ≥18                          | 180≤TL≤200| ≤4.0           | ≥30             |

| Index | Collection time /min | Slump /mm | Air content /% | Slump time /min |
|-------|----------------------|-----------|----------------|-----------------|
| limit | T≤150                | 70≤TL≤90  | ≤3.0           | ≥20             |

4.2.2 Site construction performance
When pouring on site, the slump is controlled at 180-200mm. During the pouring process, the pouring operability is good, the concrete has good cohesion, low viscosity, and no segregation bleeding. After demoulding, the concrete surface is bright and dense, with less bubbles. The 28d strength of the tested concrete is above 115% of the design strength requirement, which meets the construction requirements. On-site construction status and are shown in Fig. 8.
5 Conclusions

(1) In this paper, the study of different types of water-reducing agents shows that compared with the other four types of water-reducing agents, the newly synthesized water-reducing agent has better effects on dosage sensitivity, slump retention performance, early strength and viscosity. The overall performance is the best.

(2) For prefabricated components such as shield tunnel segments and prefabricated buildings, this type of water reducing agent has a good application effect, low viscosity, and high early strength, which solves some problems of prefabricated components.

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