Effect of cement particle size distribution on properties of cement mixed with polycarboxylate superplasticizer

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Abstract. The particle size distribution of cement under different milling time was studied, and the effects of different particle size distributions on the polycarboxylate superplasticizer dosage of the paste and the bleeding property of the paste were researched, and the early hydration exothermic rule of cement was investigated with the hydration heat meter. The results show that with the increase of ball milling time, the particle size distribution of cement is close to the direction of small particle size. With the same paste fluidity, the dosage of polycarboxylate superplasticizer increased and the bleeding rate of cement paste decreased with the increase of cement fine particle components. Under the same condition, with the increase of cement fine particle content, the hydration reaction speed is accelerated and the degree of hydration is relatively high.

1. Introduction
As a kind of powdery cementitious material, cement is widely used in various construction projects. Its powder characteristics (chemical composition, structural composition) are the core factors affecting the engineering properties of cement. From a physical point of view, it is necessary to consider the characteristics of cement particles as a powder. A very important aspect of describing particle characteristics is the particle size distribution. A large number of studies and experiments [1-5] have shown that the effect of particle size distribution on cement performance is significant. In this paper, in view of the adaptability problems in the application of cement and polycarboxylate superplasticizer, the project team changed the particle size distribution parameters of cement by controlling the ball grinding time and systematically explored the influence of particle size distribution on the dosage of polycarboxylate superplasticizer in the paste, the paste bleeding rate and cement hydration. It can supplement the application research of cement materials and provide theoretical basis for the practical application of cement.

2. Experimental
2.1. Materials
Cement: Wannianqing P. O42.5 cement, the main chemical composition is shown in table 1; Standard sand: Provided by Xiamen ISOSAND Co., Ltd.; Polycarboxylate superplasticizer: Point-TS8, solid content is 50%, Provided by KZJ New Materials Group Co., Ltd.
2.2. Performance test method

2.2.1. Chemical composition analysis method. Refer to GB/T176-2008 "Cement Chemistry Analysis Method" for testing.

2.2.2. Cement particle size distribution test. The cement particle size distribution test was performed by the Winner 3003 laser particle size analyzer.

2.2.3. Cement paste fluidity test. The fluidity of cement paste is tested according to GB/T 8077-2012 "Test method for homogeneity of concrete admixture". The fluidity of the paste reaches 220±10mm by adjusting the dosage of polycarboxylate superplasticizer.

2.2.4. Cement paste bleeding rate test. Fixed cement dosage 300g, water dosage 120g. The fluidity of the paste reaches 230±10mm by adjusting the dosage of polycarboxylate superplasticizer, and the amount of bleeding is tested after standing for 3h to calculate the bleeding of the paste.

2.2.5. Hydration heat determination. The hydration heat determination of cement slurry mixed with polycarboxylate superplasticizer is conducted in accordance with GB/T 12959-2008 "Determination Method for Cement Hydration Heat".

3. Experimental results and discussion

3.1. Different particle size distribution cement preparation
In order to investigate the effect of cement with different particle size distribution on the performance of cement mixed with polycarboxylate superplasticizer, the cement was milled with DELIXI JS11S ball mill at 0 min, 5 min, 10 min, 15 min, and 20 min, and the cement samples were numbered C0, C5, C10, C15 and C20, respectively.

3.2. Cement particle size test
The results of cement particle size distribution prepared under different ball milling time are shown in table 2.

Table 2. The results of cement particle size distribution prepared by different ball milling time

| Cement number | ball milling time/min | <3μm(%) | 3-32μm(%) | 32-65μm(%) | >65μm(%) | ≥80 μm(%) |
|---------------|----------------------|---------|-----------|------------|-----------|-----------|
| C0            | 0                    | 14.847  | 55.659    | 25.286     | 4.208     | 1.847     |
| C5            | 5                    | 14.343  | 56.736    | 25.137     | 3.784     | 1.636     |
| C10           | 10                   | 15.149  | 59.704    | 22.88      | 2.267     | 0.806     |
| C15           | 15                   | 15.527  | 61.007    | 21.938     | 1.528     | 0.463     |
| C20           | 20                   | 16.818  | 62.486    | 19.298     | 1.498     | 0.399     |

It can be seen from table 2 that as the cement ball milling time increases, the dosage of polycarboxylate superplasticizer increases. When the content of coarse particles (≥32μm) in cement is low and the content of fine particles (<32μm) is high, the dosage of polycarboxylate superplasticizer is higher. This is because the finer the cement particles, the higher the specific surface area, and the
higher the water requirements. In order to achieve the same fluidity in the case of a certain water-to-binder ratio, only increase the dosage of polycarboxylate superplasticizer.

3.3. Paste dosage test

In order to investigate the effect of cement particle size distribution on the dosage of polycarboxylate superplasticizer added to the paste, the cement with different particle size distribution is mixed with polycarboxylate superplasticizer. By adjusting the dosage of polycarboxylate superplasticizer, the fluidity of the paste is 220±10mm, and the dosage point is recorded for research. The data on the polycarboxylate superplasticizer dosage points of different cements are shown in table 3.

Table 3. Dosage data of polycarboxylate superplasticizer in different cements

| Cement number | ball milling time /min | < 3μm(%) | 3-32μm(%) | 32-65μm(%) | > 65μm(%) | ≥80 m(%) | PCs dosage/% |
|---------------|-----------------------|----------|-----------|------------|-----------|----------|--------------|
| C0            | 0                     | 14.847   | 55.659    | 25.286     | 4.208     | 1.847    | 3.16         |
| C5            | 5                     | 14.343   | 56.736    | 25.137     | 3.784     | 1.636    | 5.59         |
| C10           | 10                    | 15.149   | 59.704    | 22.88      | 2.267     | 0.806    | 6.32         |
| C15           | 15                    | 15.527   | 61.007    | 21.938     | 1.528     | 0.463    | 7.16         |
| C20           | 20                    | 16.818   | 62.486    | 19.298     | 1.498     | 0.399    | 7.54         |

It can be seen from table 3 that as the cement ball milling time increases, the dosage of polycarboxylate superplasticizer increases. When the content of coarse particles (≥32μm) in cement is low and the content of fine particles (<32μm) is high, the dosage of polycarboxylate superplasticizer is higher. This is because the finer the cement particles, the higher the specific surface area, and the higher the water demand of the cement. In order to achieve the same fluidity in the case of a certain water-to-binder ratio, only increase the dosage of polycarboxylate superplasticizer.

3.4. Paste bleeding test

In order to investigate the effect of cement particle size distribution on the bleeding of polycarboxylate superplasticizer added to the paste, the cement with different particle size distribution is mixed with polycarboxylate superplasticizer. By adjusting the dosage of polycarboxylate superplasticizer, the fluidity of the paste is 230±10mm, and the amount of bleeding is tested after standing for 3h to calculate the bleeding rate of the paste. The data on the polycarboxylate superplasticizer dosage points of different cements are shown in table 4.

Table 4. Paste bleeding rate data of different cements

| Cement number | ball milling time /min | < 3μm(%) | 3-32μm(%) | 32-65μm(%) | > 65μm(%) | ≥80 m(%) | Paste bleeding rate /% |
|---------------|-----------------------|----------|-----------|------------|-----------|----------|------------------------|
| C0            | 0                     | 14.847   | 55.659    | 25.286     | 4.208     | 1.847    | 7.54                   |
| C5            | 5                     | 14.343   | 56.736    | 25.137     | 3.784     | 1.636    | 7.16                   |
| C10           | 10                    | 15.149   | 59.704    | 22.88      | 2.267     | 0.806    | 6.32                   |
| C15           | 15                    | 15.527   | 61.007    | 21.938     | 1.528     | 0.463    | 5.59                   |
| C20           | 20                    | 16.818   | 62.486    | 19.298     | 1.498     | 0.399    | 3.16                   |

It can be seen from table 4 that as the cement ball milling time increases, the slurry bleeding rate decreases. When the content of coarse particles (≥32μm) in cement is high, and the content of fine particles (<32μm) is low, it is easy to cause bleeding. This is because the coarser the cement particles, the smaller the specific surface area, the lower the degree of early hydration, the less bound water, and the more free water. Too many coarse particles cannot be dense with each other, and after standing, free water in the concrete is secreted. In addition, less hydration products are not sufficient to plug the pores in the concrete, resulting in more and more free water flowing out, and delayed bleeding.
3.5. Effect of hydration heat test

The hydration heat of different cements mixed with polycarboxylate superplasticizer was tested by microcalorimeter. The hydration heat release curve is shown in figure 1, and the dosage is 0.1%.

![Figure 1. Hydration heat release curve](image)

It can be seen from figure 1 that after the polycarboxylate superplasticizer is incorporated, the hydration heat release rate of the cement with different particle size distributions is different in the early hydration process. As the ball milling time is prolonged, the maximum hydration temperature time is shortened, and the hydration heat release rate is accelerated. This is because after the cement ball milling, the cement fine particles increase and the cement particle specific surface area increases, the surface area that reacts with water and the polycarboxylate superplasticizer is increased.

4. Conclusions

(1) Cement with different particle size distributions were prepared by controlling the ball milling time. The results of laser particle size test showed that the particle size distribution of the cement was close to the small particle size as the ball milling time increased.

(2) It can be seen from the paste test results that with the increase of cement fine particle components, the dosage of polycarboxylate superplasticizer increases.

(3) It can be seen from the paste bleeding test results that with the increase of cement fine particle components, the bleeding rate of cement paste decreases.

(4) It can be seen from the hydration heat results that after the same polycarboxylate superplasticizer is added, the maximum hydration temperature time is shortened and the hydration reaction speed is accelerated as the cement fine particle content increases.

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