Study on the particle size distribution characteristics and cementitious activity of different fineness components in cement

Chaocheng Yu, Yongping Zhang and Zaibo Li*

School of Chemistry and Civil Engineering, Shaoguan University, Shaoguan, Guangdong, 512005, China

*Corresponding author’s e-mail: lizaibo@sgu.edu.cn

Abstract. In order to obtain the change law of the cementitious activity of the different fineness components in the Portland cement, the cement was classified by the air classifier and six components with different fineness were obtained. The particle size distributions of the six components were measured and their cementitious activities were evaluated. The results show that the cement powder obtained by classification basically conforms to the distribution model of Rosin-Rammler-Bennet equation. The fluidity of the mortar of different fineness components in cement does not change significantly with the change of fineness. The greater the fineness of each component is, the higher the early strength of their mortar test will be, but as the curing age increases, the strength increase is not obvious. The sample obtained by mixing three finer-grained components has the highest mortar compressive strength in the early age, and the strength increase in the later age is stable.

1. Introduction

Usually, the finer the particle size of cement, the stronger its mechanical strength (especially the early strength) and the higher the cementitious activity. Under the condition that the chemical composition and mineral composition are basically the same, the strength of cement mortar specimens depends to a large extent on the particle size distribution of cement particles [1, 2]. When the distribution of cement particles is reasonable, the fine particles can be filled into the three-dimensional network structure composed of larger particles, thereby reducing the void ratio of the cement particles, making the cement cementing system more closely packed, and finally increasing the cement strength [3, 4]. In order to give full play to the role of each fineness component in improving cement cementitious activity, it is necessary to evaluate the cementitious activity of the different fineness components of cement.

In this study, Portland cement was classified by an air classifier, and six components with different fineness were obtained, and their particle size distribution characteristics were measured. The cement mortar strength test method is used to evaluate the cementitious activity of these six fineness components to obtain the change law of the mortar strength of different fineness components in cement. The results provide important reference significance for evaluating the contribution of different fineness components of cement to its cementitious activity.
2. Raw material and Methods
Portland cement with 42.5 grade produced by Beijing Xingfa Cement Co., Ltd. is used in this paper. The chemical composition is shown in Table 1.

| Raw material | CaO   | SiO₂  | Al₂O₃ | Fe₂O₃  | MgO   | SO₃   | MnO   | Loss |
|--------------|-------|-------|-------|--------|-------|-------|-------|------|
| Portland cement | 62.75 | 22.02 | 4.19  | 2.71   | 2.36  | 2.78  | 0.33  | 2.01 |

The Portland cement is classified by JFC-20F airflow classifier. By changing the speed of the classifier, six cement components of different fineness are obtained. Among them, the C6 component is obtained by mixing the three powders obtained by the classifier rotating speed of >2000 rpm, 2000-2500 rpm, and >2800 rpm during the classification process with a V-type mixer. The physical properties and chemical composition of different fineness cement components are shown in Table 2 and Table 3. The particle size distributions of the powders are measured by the Malvern Mastersizer2000 laser particle size analyzer. According to GB/T 17671-1999 cement mortar strength test method (ISO method), the fluidity and activity index of mortar of different fineness cement components are measured.

3. Results and analysis
3.1. The morphology and particle size distribution characteristics of different fineness cement components
Figure 1 shows the SEM images of three fineness cement components. Figure 2 shows the particle size distribution test results of different fineness cement components measured by a laser particle size analyzer. According to the test results, the statistical results of the particle size distribution characteristics of different fineness components are shown in Table 4, where D (0.1), D (0.5) and D
(0.9) represent the particle size respectively which the distribution is accumulated to the particle size corresponding to 10%, 50% and 90%, D (0.5) is also called the median diameter.

Fig. 1 The SEM images of the C2, C4 and C6 powders

![Fig. 1 The SEM images of the C2, C4 and C6 powders](image)

Fig. 2 Particle volume distribution of different fineness cement

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| Samples | D (0.1)  | D (0.5)  | D (0.9)  |
|---------|----------|----------|----------|
| C1      | 18.661   | 35.734   | 71.508   |
| C2      | 10.629   | 27.197   | 52.814   |
| C3      | 7.777    | 22.502   | 46.377   |
| C4      | 6.081    | 19.135   | 41.345   |
| C5      | 1.773    | 8.726    | 157.392  |
| C6      | 0.834    | 4.486    | 136.151  |

Table 4 D values of different fineness components (μm)

It is found that the particle size distribution of cement and powders such as blast furnace slag, steel slag and fly ash used as concrete admixtures are in good agreement with the Rosin-Rammler-Bennet (RRB) equation [5]. In this study, two characteristic parameters of characteristic particle size De and uniformity coefficient n in the RRB equation are used to determine the overall characteristics of the particle size distribution of cement with different fineness components. The RRB equation is expressed as follows:

Here, R (%) is mass percentage of sieve residue of particle size D (μm). De (μm) is the characteristic particle size indicates the thickness of the particle group, and its physical meaning is the particle size when R=36.8%. n is the uniformity coefficient indicates the width of the particle size
distribution. The range of particle size distribution becomes wider as the value of \( n \) decreases, and becomes narrower as the value of \( n \) increases; the larger the value of \( n \) is, the better the uniformity of the particle distribution in the sample will be.

Processing the laser particle size test data of different fineness cement components, taking \( \ln(\ln(100/R)) \) as the ordinate, and \( \ln(D) \) as the abscissa, and performing linear regression through Origin software, the powder uniformity coefficient \( n \) value and characteristic particle size \( D_e \) value are obtained. The calculation results are shown in Table 5.

| Samples | \( n \) | \( D_e (\mu m) \) | \( R \) |
|---------|-------|----------------|------|
| C1      | 2.08  | 50.60          | 0.988|
| C2      | 1.53  | 40.13          | 0.978|
| C3      | 1.51  | 33.80          | 0.982|
| C4      | 1.50  | 31.93          | 0.985|
| C5      | 0.67  | 29.72          | 0.967|
| C6      | 0.49  | 18.23          | 0.936|

From the correlation coefficient \( R \) in the data in Table 4, it can be seen that the Portland cement powder classified by the classifier basically conforms to the RRB equation distribution model. As the speed of the classifier increases, the characteristic particle size \( D_e \) and the uniformity coefficient \( n \) of Portland cement show a decreasing trend. The C1 component has the largest \( n \) value and the narrowest curve distribution, indicating that the classifier has the best classification effect on this fineness component; the C5 component has the smallest \( n \) value, its curve distribution is the widest, and its classification effect is the worst.

3.2. The cementitious activity of different fineness components cement

For six components with different fineness, the flexural strength and compressive strength of hardened mortars with different curing ages were measured by the cement mortar strength test method. The test results are shown in Table 6.

| Samples | Fluidity /mm | Flexural strength (MPa) | Compressive strength (MPa) |
|---------|--------------|-------------------------|---------------------------|
|         |              | 7d         | 28d      | 7d       | 28d      |
| C1      | 232          | 2.6        | 4.2      | 14.2     | 28.3     |
| C2      | 235          | 1.5        | 6.9      | 17.3     | 38.6     |
| C3      | 244          | 4.2        | 8.3      | 21.7     | 41.3     |
| C4      | 239          | 6.4        | 8.7      | 29.9     | 51.5     |
| C5      | 236          | 5.4        | 6.9      | 22.8     | 32.9     |
| C6      | 228          | 8.0        | 8.1      | 44.9     | 57.6     |

It can be seen from the results that, the fluidity of mortar with different fineness components of cement does not change significantly after being classified by the classifier. The compressive strength of mortar under various curing ages basically showed a gradually increasing pattern with the increase of component fineness, which was more obvious in the early strength. This is because the finer the cement particles, the larger the surface area that reacts with water. So the hydration reaction is faster, more complete, and the early strength is higher. The C6 component has the best mechanical properties of mortar. The reason is not only related to the greater fineness of this component, but also related to the sample being mixed with three different fineness powders. Due to the formation of a more reasonable particle size distribution, the cement cementing system reaches a tighter packing state, which ultimately increases the strength of cement mortar. It can be seen from Figure 3 that the test
results of the heat of hydration of the cement with different fineness components are consistent with the test results of the compressive strength of the mortar.

In terms of the flexural strength of mortar, except for the C6 component, the 28d compressive strength of cement with different fineness components has a significant increase compared with the 7d compressive strength. As the curing age increases, the flexural strength of the C6 component hardly increases. The reason may be that the fineness of the C6 component is small, the early hydration degree is high, the amount of remaining clinker is small, and the hydration is formed in the middle and late ages. The amount of hydration product is less than other components.

Fig. 3 The heat of hydration of different fineness components cement

4. Conclusions
The Portland cement powders with different fineness components obtained by the classifier basically conform to the RRB equation distribution model. The classifier has a more ideal classification effect on the larger fineness components in cement, and the uniformity of particle distribution is better. The mortars fluidity of cement with different fineness components does not change significantly. The greater the fineness of the different fineness components is, the higher the early mortar strength will be, but with the increase of the curing age, the strength increase is not obvious. For the sample obtained by mixing three finer fineness components, the mortar has the highest strength in the early age, and the strength growth in the later age is stable. The reason is that a more reasonable particle size distribution is formed.

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