Study on hydrodynamic properties of a common building material

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Abstract. The efficient self-leveling ability of self-compacting concrete is widely used in various industries and structures, but the influence mechanism and law on its flow performance have not been quantified, so it is urgent to find a suitable explanation method. Water film thickness is considered to be one of the key factors affecting the flow performance of mortar and cement paste, but there is a lack of research in concrete. In this paper, relevant experimental studies are carried out based on the theoretical innovation of water film thickness. In order to further improve the flow performance of self-compacting concrete, according to a certain gradient, 24 fresh self-compacting concrete flow performance tests and filling density measurement tests were carried out to observe the relationship between water film thickness and concrete flow performance. The results show that there is a strong correlation between the flow performance of concrete and the thickness of water film, and there is a positive correlation between them. The addition of talc powder can improve the flow performance of self-compacting concrete, and the flow performance is the best when 5% talc powder is added to replace cement.

1. Introduction

Self-compacting concrete is widely used in many components with complex structures, small working space and dense reinforcement because of its strong fluidity. At present, the influence mechanism and law on the flow performance of self-compacting concrete at home and abroad have not been quantified, so it is urgent to find a suitable theoretical explanation method, at the same time, in order to achieve the purpose of reducing the amount of cement and protecting the environment, it is necessary to find suitable fine mineral admixtures to replace or partially replace cement. Talc powder has excellent physical and chemical properties, such as lubricity, fire resistance, acid resistance, high melting point, strong adsorption. Therefore, it is very feasible and meaningful to study the effect of talc powder on the working performance of self-compacting concrete. In this study, through 24 groups of tests on rheological properties and filling density of solid materials, the appropriate proportion of talc replacement cement was obtained, and the influence mechanism of rheological properties of self-compacting concrete was revealed based on the theory of water film thickness.

2. Test material and scheme

2.1. Test material

Cement: Hailuo P·042.5R cement, density 33143kg, specific surface area 2365kg, quality meets the requirements of the current national standard "General Portland cement" (GB175-2007); talc: produced by Shanghai Yuanjiang Chemical Co., Ltd., 2000 mesh, measuring density 32750kg; pebbles: particle
size 510mm powder and particle size 1020mm cement are mixed according to: 1:1; sand: Foshan local river sand, fineness modulus 2.6, belongs to medium sand. Superplasticizer: Guangdong Ruian LS-JS polycarboxylic acid superplasticizer, in line with the current national standard "Technical Specification for the Application of concrete admixtures (with description)" (GB50119-2013); water: tap water.

2.2. Test scheme
In this study, 24 groups of experiments were prepared with different water-cement ratio, different cement slurry volume ratio and talc content. Among them, the volume ratio of water to cement (the mass ratio of water to cement is converted to the corresponding volume ratio) is 1.05 and 1.20, the volume ratio of cement slurry (the sum of the volume of cement, water and superplasticizer to the volume of concrete) is 0.34, 0.38 and 0.42, the volume ratio of talc replacement cement is 0, 5%, 10% and 20%, and the sand ratio is 0.5. The test blocks are numbered as "S-water-cement ratio volume ratio-cement slurry volume ratio-talc replacement cement volume ratio". The detailed matching data of each test are shown in Table 1.

| Proportion number | Mass mix ratio / (kg/m³) | Liquidity |
|-------------------|--------------------------|-----------|
|                   | Cement | French chalk | water | Water reducer | Sand | Crushed stone | Degree of expansion/mm | Outflow time/mm |
| S-1.05-0.34-0     | 521.3  | 0.0          | 166.6 | 7.8           | 819.4 | 857.0         | 560.0                   | 32.0           |
| S-1.05-0.38-0     | 582.6  | 0.0          | 186.1 | 8.7           | 769.7 | 805.1         | 580.0                   | 24.0           |
| S-1.05-0.42-0     | 643.9  | 0.0          | 205.7 | 9.7           | 720.1 | 753.1         | 590.0                   | 22.0           |
| S-1.05-0.34-5     | 495.2  | 22.8         | 166.6 | 7.8           | 819.4 | 857.0         | 610.0                   | 27.0           |
| S-1.05-0.38-5     | 553.5  | 25.5         | 186.2 | 8.7           | 769.7 | 805.1         | 630.0                   | 24.8           |
| S-1.05-0.42-5     | 611.7  | 28.2         | 205.8 | 9.6           | 720.1 | 753.1         | 645.0                   | 21.0           |
| S-1.05-0.34-10    | 469.2  | 0.0          | 166.6 | 7.7           | 819.4 | 857.0         | 660.0                   | 28.0           |
| S-1.05-0.38-10    | 524.3  | 21.3         | 186.3 | 8.6           | 769.7 | 805.1         | 680.0                   | 25.5           |
| S-1.05-0.42-10    | 580.5  | 24.0         | 205.9 | 9.5           | 720.1 | 753.1         | 695.0                   | 25.0           |
| S-1.05-0.34-20    | 417.0  | 0.0          | 166.7 | 7.6           | 819.4 | 857.0         | 660.0                   | 30.0           |
| S-1.05-0.38-20    | 473.2  | 21.0         | 186.4 | 8.5           | 769.7 | 805.1         | 690.0                   | 26.0           |
| S-1.05-0.42-20    | 529.1  | 24.0         | 205.6 | 9.4           | 720.1 | 753.1         | 715.0                   | 25.0           |
| S-1.20-0.34-0     | 485.7  | 0.0          | 178.4 | 7.3           | 819.4 | 857.0         | 620.0                   | 26.0           |
| s-1.2o-0.38-o     | 542.9  | 0.0          | 199.4 | 8.1           | 769.7 | 805.1         | 635.0                   | 24.0           |
| S-1.20-0.42-0     | 600.0  | 0.0          | 220.4 | 9.0           | 720.1 | 753.1         | 645.0                   | 22.0           |
| s-1.2o-0.34-5     | 461.4  | 21.3         | 178.4 | 7.2           | 819.4 | 857.0         | 620.0                   | 25.5           |
| S-1.2o-0.38-5     | 515.7  | 23.8         | 199.4 | 8.1           | 769.7 | 805.1         | 667.5                   | 25.0           |
| S-1.2o-0.42-5     | 570.8  | 0.3          | 220.4 | 8.9           | 720.1 | 753.1         | 680.0                   | 20.0           |
| S-1.20-0.34-10    | 437.2  | 42.5         | 178.5 | 7.2           | 819.4 | 857.0         | 610.0                   | 26.0           |
| S-1.20-0.38-10    | 488.6  | 7.3          | 199.5 | 8.0           | 769.7 | 805.1         | 635.0                   | 22.0           |
| S-1.20-0.42-10    | 540.0  | 42.5         | 220.5 | 8.9           | 720.1 | 753.1         | 645.0                   | 21.0           |
| S-1.20-0.34-20    | 388.6  | 85.0         | 178.6 | 7.1           | 819.4 | 857.0         | 615.0                   | 26.5           |
| S-1.20-0.38-20    | 434.3  | 95.0         | 199.6 | 7.9           | 769.7 | 805.1         | 625.0                   | 25.0           |
| S-1.20-0.42-20    | 480.0  | 150.5        | 220.6 | 8.8           | 726.1 | 753.1         | 630.0                   | 24.0           |

3. Measurement of filling density and calculation of Water Film thickness

3.1. Testing method
The water compactness method is often used to measure the filling density of cementitious materials. the test group is prepared according to the mixture ratio of the solid phase materials. the maximum filling rate that can be achieved by the solid phase material is gradually added, which is the maximum filling density. in this state, the outer layer of the cementitious material particles happens to be fully wrapped, there is no gap between the particles, in the most compact state. Theoretically, the filling density will increase with the increase of water addition, and then decrease after reaching a peak value. The reason is that too high water-cement ratio leads to too much free water, and the particles are suspended in the slurry, so that the compactness between particles decreases. Considering the influence of air, water addition and superplasticizer, this method simulates the suspension state of solid material in concrete, which considers more influence factors than the previous dry measurement method, and is more consistent with the actual situation of concrete, and the result is more accurate.
3.2. Result analysis

The variation of the water film thickness with the cement slurry volume ratio in each group is shown in figure 2: with the increase of the cement slurry volume ratio, the water film thickness increases gradually. This is because the increase of liquid water in the experimental mixture ratio makes the remaining water volume too large after filling the gap between the solid materials, which leads to the increase of the thickness of the water film. However, if the volume ratio of cement slurry is too large, it is easy to separate and bleed, which makes the testing performance of concrete can not meet the requirements of the code.

Figure 2 Variation of water film thickness with cement slurry volume ratio

4. Study on the influence of Water Film thickness on the fluidity of concrete

The relationship between the thickness of water film and the slump extension of self-compacting concrete is shown in figure 3, and the correlation coefficient between them has reached 0.806, indicating that there is a great correlation between the thickness of water film and the slump extension. It can also be considered that the slump extension of self-compacting concrete is largely determined by the thickness of water film. With the increase of the thickness of water film, the slump expansion increases rapidly, and then when the thickness of water film continues to increase, the collapse expansion tends to be smooth, and the expansion of self-compacting concrete mixed with talc powder is larger than that of self-compacting concrete mixed with talc powder.
Figure 3 The variation of slump expansion with the thickness of water film and the outflow time of V-type instrument with the thickness of water film.

The relationship between the thickness of water film and the outflow time of self-compacting concrete V-rheometer is shown in figure 3. The correlation coefficient between water film thickness and outflow time has reached 0.862. According to the image results, with the increase of water film thickness, the outflow time of V-shaped instrument decreases and the flow performance of concrete increases, indicating that the addition of talc powder into self-compacting concrete can increase the water film thickness of self-compacting concrete to a certain extent, and then promote its flow.

5. Conclusion

Through 24 tests of flow performance and filling density of self-compacting concrete mixed with talc powder, the relationship between water film thickness and flow performance is analyzed, and the following conclusions are drawn: the addition of talc powder can improve the cohesion of concrete, the ability of mortar to wrap aggregate is enhanced, which can avoid bleeding and slurry to a certain extent. With the increase of talc content, the slump expansion increases and the V-shaped instrument outflow time decreases, indicating that talc powder can improve the flow performance of self-compacting concrete. When the water-cement ratio is 1.05 and the talc content is 5%, the flow performance of self-compacting concrete is improved most obviously, the maximum increase in expansion is 8.9%, and the maximum increase in outflow time is 15.6%. Therefore, the thickness of water film can be used as an index to assess the flow performance of self-compacting concrete, which can be considered in the design of concrete mix ratio. Based on this study, it is known that the addition of quantitative talc powder has a certain application prospect in practice. For concrete components with low strength requirements but dense steel network, the addition of talc powder to replace cement can reduce the environmental pollution caused by cement to a certain extent, and the addition of talc powder can reduce the sand rate under the condition that the flow performance reaches the standard, and achieve the purpose of rational utilization and protection of river sand resources.

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