Effect of SAC Cement on Properties of Cement Based Grouting Material

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Abstract. To study the main properties of the SAC cement in cement-based grouting materials, including fluidity, setting time and compressive strength, a composite grouting material was made by combining ultrafine slag powder with cement. The cement slurry was prepared by replacing different proportions of Portland cement with 0%, 10%, 20%, 30%, 40%, and 50% of SAC cement, based on a water-cement ratio of 0.5. The main performance changes of the slurry were analyzed. The results showed that increasing the amount of ultrafine slag powder led to a significant decrease in the initial and final setting times of the slurry, while the interval between the initial and final setting times also decreased. As the amount of SAC cement increased, the compressive strength of the slurry's stone increased. At 40% SAC cement dosage, the 3-day compressive strength of the stone was the highest, which improved the early strength of the slurry's stone. Therefore, adding an appropriate amount of SAC cement can significantly improve the strength and other properties of the material.

Keywords: sulfoaluminate cement; cement-based grouting material; ultrafine slag powder; fluidity; setting time; compressive strength

1 Introduction

As urbanization continues to advance, more and more old buildings in cities need to be reinforced and repaired, making research on grouting materials increasingly important. Grouting refers to the process of injecting grouting material through a certain pipeline or pore to solidify it in the void, forming a process that has high strength and can strengthen soil or rock. Grouting materials can not only be used for engineering maintenance and reinforcement but also can be used for repairing and improving the soil environment, such as preventing soil erosion, protecting polluted soil, and other governance. With the continuous advancement of technology and the increasing demand for improving the safety, efficiency, and energy-saving of buildings, the demand for grouting materials will also continue to increase. Therefore, the quick hardening and early strength characteristics of grouting materials have important engineering application value.

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Many scholars have conducted extensive research around these objectives. Zhang et al. [1] studied the various strength and durability properties of early strength and fast hardening concrete prepared with sulfoaluminate cement, and tested the sulfoaluminate salt water mud based early strength concrete from three aspects: workability, mechanical strength, and durability. Adel Gorjinia Khoshkenari et al.[2] studied the effect of 0-2 mm fine aggregate on the compressive and splitting tensile strength of recycled concrete aggregate (RCA) concrete. He et al.[3,4] discussed the commonly used modification measures for sulfoaluminate cement and pointed out the development direction of existing sulfoaluminate cement. Saloni et al.[5] studied the performance of ultrafine slag (UFS) based sustainable geopolymer concrete, and the results showed that UFS improved the strength and durability of polymer concrete. Shi et al.[6] studied the changes in strength of cement mortar under the action of composite admixtures by adding fly ash and SAC to the cement mortar. Song et al.[7] studied the effect of composite addition of ultrafine slag powder and metakaolin on the performance of cement slurry and Li et al. [8, 9] studied the effect of adding different contents of ultra-fine slag powder (UFS) and other materials at different water cement ratios on the performance of grouting materials. The experimental results showed that an appropriate amount of ultra-fine slag powder can effectively control the viscosity and fluidity of the slurry, and improve the strength of the consolidated body. Ana Carolina Pereira Martins et al. [10] studied the interaction of modified admixtures in the performance of cement-based composites based on the addition of industrial waste. Osman Gencel et al. [11] introduced the research on fly ash and fine recycled concrete aggregate (RFA) foam concrete, and conducted tests to evaluate its compressive strength and dynamic elastic modulus.

The influence of mineral admixture and SAC cement on the properties of cement mortar is relatively complex, so it is necessary to carry out further research based on the work of predecessors. This article aims to explore the reuse of industrial waste slag and the preparation of composite grouting materials by combining ultrafine slag powder with cement. Cement slurry was prepared by replacing different proportions of Portland cement with different percentages of SAC cement, and the main performance changes of the slurry, including fluidity, setting time and compressive strength, were analyzed. The purpose is to improve the early strength of grouting materials to better meet the requirements of engineering and improve the safety and durability of the project.

2 Test

2.1 Raw materials

The basic materials used for the tests in this paper are sulfoaluminate cement, ultrafine slag powder and silicate cement.

2.2 Test procedure

Sulfoaluminate cement, ultrafine slag powder, silicate cement and water were mixed and stirred rapidly for about 3minutes, and then the determination of fluidity was carried out. After the determination, the mixture is stirred for 3minutes, the test block is made and the setting time is determined, and the cube compressive strength is maintained for 3d. After 28d, the cube compressive strength is determined.

2.3 Experimental protocol

The water-cement ratio of 0.5:1 was chosen for the test, and 12 different sets of tests were designed according to the amount of SAC cement admixture (0%, 10%, 20%, 30%, 40%, 50%) and the curing time of 3d and 28d, respectively, for slurry flowability, setting time and cube compressive strength, and the analysis of the admixture of SAC cement on the performance of cementitious grouting materials was derived The effect of SAC cement admixture on the performance of cementitious grouting materials was analyzed.

2.4 Test method

Determination of fluidity.

(1) By placing the transparent plastic sheet on a horizontal surface and wetting it with water, the surface is made wet and without water stains.

(2) Place the mold in the middle of the plastic plate, pour in the slurry and smooth out the mouth of the mold.

(3) Lift the mold, record the length in two different directions and take the average value, i.e. the flow degree value.

(4) Repeat the above steps.

Determination of setting time.

The setting time of cement is determined in the laboratory at standard consistency and standard temperature. There are many factors affecting the setting time of cement, such as water-cement ratio and temperature, which have a great influence on the setting of cement. The smaller the water-cement ratio, the shorter the setting time; the higher the temperature, the faster the cement sets, and vice versa, the slower it sets.

We will use a setting time tester to determine the setting time of cement. Cement mortar made with water of standard consistency will be loaded in a test mold and then tested with a standard needle on a setting time tester. From the time of adding water to the time when the test needle sinks into the mud 2-3mm from the bottom plate is the "initial setting time"; from the time of adding water to the time when the test needle sinks into the mud not more than 1-0.5mm is the "final setting time".

Determination of cube compressive strength.

Pour the slurry into the 70.7 standard mold, demold after 24h, curing 3d and 28d, take out after the curing time, measure its cube compressive strength, three test blocks per group, and take its average value.

2.5 Matching ratio

The fits for this experiment are shown in Table1

Table 1. Cement-based slurry matching ratio

Number	Proportioning design
1	0% SAC cement + 100% cement
2	10% SAC cement + 90% cement
3	20% SAC cement + 80% cement
4	30% SAC cement + 70% cement
5	40% SAC cement + 60% cement
6	50% SAC cement + 50% cement

3 Data Analysis

3.1 Flowability

The test shows that the better the fluidity indicates the greater the diffusion range, the better the flowability of the slurry and the easier it flows down. The results of the composite cement-based slurry fluidity test are shown in Table 2. The test is shown in the Figure 1.

Table 2. Fluidity of cement-based slurry

Test number	Flow degree/mm
1	160.5
2	159.3
3	158.1
4	156.6
5	154.5
6	151.2

According to Table 2, a line graph of slurry flowability is drawn Figure 2. From the graph, the variation of the flowability of the grouting material with the increase of the SAC cement admixture can be seen more intuitively.

Fig. 1. Liquid flow test of slurry injection

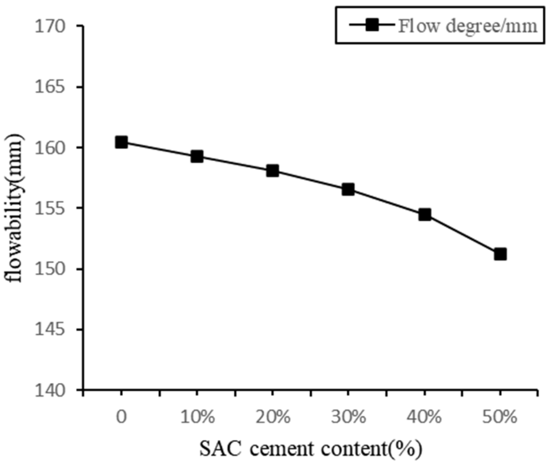

Fig. 2. Effect of SAC cement admixture on slurry flow

The flowability of the slurry with a water-cement ratio of 0.5 is shown in the table above. It can be concluded that the flow value of the slurry is maintained between 150mm and 165mm. Compared with cement slurry, the best flowability is achieved when SAC cement is mixed at 0% and composite grouting material is mixed at 100%.

With the increase of SAC cement admixture, the flowability of the slurry deteriorates and the flow radius steadily decreases, which also side reflects the characteristic that sulfoaluminate cement is more water-absorbent than silicate cement.

3.2 Setting time

The setting time of cement is crucial for the construction of cement concrete. The setting time of cement is the guarantee of construction conditions. If the initial setting time is too short, it will affect the transportation and pouring of the concrete mix; while the final setting time is too long, it will affect the construction progress of the concrete project. Therefore, it is very important to ensure that the setting time of cement is within the right range. The results of the cement-based slurry setting time tests are shown in Table 3. The test is shown in the Figure 3.

Table 3. Setting time of cement-based slurry

Setting time (min)	
Initial condensation	Final condensation
190	287
116	235
92	191
61	132
45	98
33	65

Based on Table 3, a line graph of the setting time of the slurry is plotted Figure 4 From the graph, it can be seen more intuitively that the setting time of the grouting material changes with the increase of the SAC cement admixture.

The increase in the amount of SAC cement causes a significant decrease in the initial and final setting time of the slurry, as well as a decrease in the interval between the initial and final setting time of the slurry. The application of this characteristic can meet both the general application under normal process conditions and the special application of spray anchor support, plugging and repair, and rapid construction.

Fig. 3. Experiment on setting time of grouting material

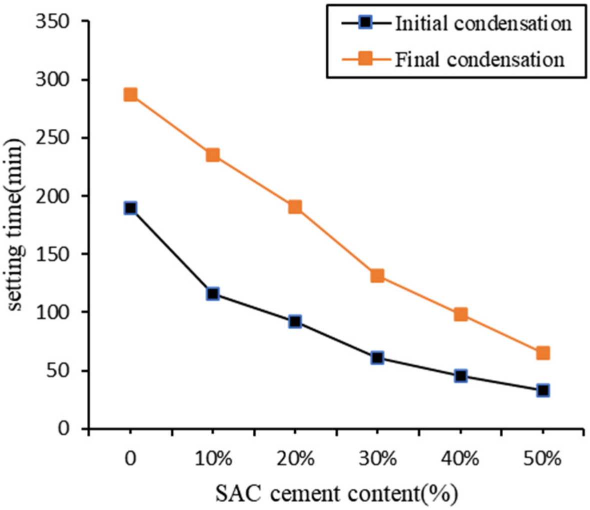

Fig. 4. Effect of SAC cement admixture on the setting time of slurry

3.3 Compressive strength

Cube compressive strength is a representative sign of the slurry, the higher its strength, the better the bearing capacity of the slurry. Early strength and fast hardening is the most needed excellent characteristic for building construction it can accelerate the project progress. The cube compressive strength test results of the composite cement-based slurry are shown in Table 4.The test is shown in the Figure 5.

Table 4. Strength test results

Test number	Cube compressive strength/Mpa	
	3d	28d
1	14.82	42.02
2	13.77	43.23
3	16.05	44.70
4	18.11	47.15
5	18.93	47.03
6	17.76	43.76

According to Table 4, the compressive strength of the slurry is plotted on a line Figure 6. From the graph, the change of compressive strength of the grouting material with the increase of SAC cement admixture can be seen more intuitively.

a. Universal Testing Machine b.Crushing failure mode of test block

Fig. 5. Block compressive strength test

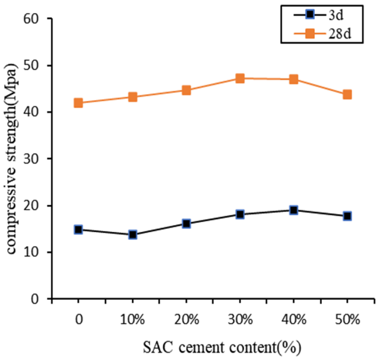

Fig. 6. Effect of SAC cement admixture on the compressive strength of slurry

The compressive strength of pure cement slurry was 14.82 MPa for 3 d and 42.02 MPa for 28 d at a water-cement ratio of 0.5. From Tables 4, it can be concluded that the highest cube compressive strength was obtained when 40% SAC cement was incorporated at 3 days of curing, and the highest cube compressive strength was obtained when 30% SAC cement was incorporated at 28 days of curing.

4 Conclusion

The effects of SAC cement on the fluidity, setting time, and compressive strength of cement-based grouting materials were investigated through fluidity tests, setting time tests, and compressive strength tests. The following conclusions were drawn:

(1) In the ordinary Portland cement-based grouting material, the amount of SAC cement is inversely proportional to the fluidity and setting time of the grouting material, while it is directly proportional to the compressive strength. As the amount of SAC cement increases, the fluidity of the slurry decreases and the flow radius decreases steadily, which reflects the characteristic of SAC cement being more water-absorbent than Portland cement.

(2) Increasing the amount of ultrafine slag powder significantly reduces both the initial and final setting times of the slurry, and the interval between the initial and final setting times also decreases.

(3) With an increase in the amount of SAC cement, the compressive strength of the stone in the slurry increases, but the overall increase is not significant. The slurry's compressive strength with 3-day curing time can reach around 13-18Mpa when SAC cement is added. The 3-day compressive strength reaches 18.93Mpa when the SAC cement dosage is 40%, which improves the early strength of the slurry's stone.

The study shows that adding an appropriate amount of SAC cement can significantly improve the strength and other properties of the material. The conclusions of this study have certain guiding significance for the practical work of using SAC cement to reinforce cement-based grouting materials. In the future, we can further improve the performance of single-doped SAC cement grouting materials by improving the material composition and grouting process, while considering its cost and environmental protection, and ultimately achieve a balance between material quality and construction efficiency.

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