Experimental research on the effect of silicon powder on the performance of cement mortar

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Abstract. To study the effect of the mechanical properties of silicon powder on cement admixture, the experiment was carried out, to investigate the consistency of mortar fluidity, breaking strength and compression strength test of the cement mortar samples with different dosage of silicon powder. The experimental results show that when the content of silicon powder is 0-4%, the consistency and fluidity of mortar can be improved, and the working performance of cement mortar can be improved; when the content of silicon powder continues to increase to 12%, the working performance of mortar decreases, but it still has good performance; when the content of silicon powder is 0-8%, the mechanical performance of mortar can be improved, if the content is too large, the compression strength and bending strength of mortar will be reduced, but it still plays a positive role in the strength of mortar.

1. Introduction
Cement mortar material is a rigid material which is commonly used at home and abroad, waterproof structure has higher strength and durability, but it is not easy close-grained, affecting the mechanical properties and durability of materials so that through the development of cement admixture types increase the dosage of admixture on cement mortar performance influence in order to solve the problem of slurry material industrialization is particularly important[1].

Silicon powder is a kind of pozzolanic materials with high vitreous content and very small particles can be highly dispersed in mortar, filling the gap between cement particles to make the mortar more dense, which can significantly improve the density, mechanical properties and durability properties of cement mortar [4].

In this paper, the mixing ratio of repairing mortar of concrete drainage pipe was taken as the benchmark, and the working and mechanical properties of cement mortar specimens with water-cement ratio of 1:2 were studied when the silicon powder content was 0%(blank group), 2%, 4%, 8%, 10% and 12%, respectively, in order to provide reference for the application of waterproof mortar with silicon powder.
2. Materials and Methods

2.1. Materials
The cement is South P.O 42.5 ordinary portland cement produced by South cement plant, with a density of 3.20g/cm$^3$ and qualified stability. It can be seen from table 1 and table 2 for chemical composition and physical properties [2].

The admixture is silicon powder produced by Lixinyuan micro silicon powder Co., Ltd. See Table 3 for chemical composition.

The fine aggregate is standard sand, the density of sand is 2.85g/cm$^3$, the water absorption is 0.2%, the mud content is 0.1%, the organic matter content is qualified, the fine powder content is 2.1%, and the fineness modulus is 1.50-2.65.

| Table 1. Chemical composition of South P.O42.5 ordinary portland cement. % |
|---------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| SiO$_2$ | Fe$_2$O$_3$ | Al$_2$O$_3$ | TiO$_2$ | CaO | MgO | SO$_3$ | Na$_2$O | K$_2$O | LL |
|--------|-------------|-------------|-------|----|----|-------|-------|-------|----|
| 20.60  | 3.61        | 6.09        | 0.21  | 58.82 | 3.05 | 3.04  | 0.31  | 0.86  | 3.42 |

| Table 2. Physical property of South P.O42.5 ordinary portland cement. |
|---------------------------------|-------|-------|-------|-------|
| standard setting time/min water demand/% | Initial setting | Final setting | bending strength/MPa | compression strength/MPa |
| 24 | 243 | 350 | 3.60 | 7.85 | 19.1 | 42.9 |

| Table 3. Chemical composition of silicon powder. % |
|---------------------------------|-------|-------|-------|-------|-------|-------|
| Admixture | SiO$_2$ | Fe$_2$O$_3$ | Al$_2$O$_3$ | CaO | MgO | SO$_3$ | LL |
| silicon powder | 94.1 | 0.63 | 0.41 | 0.49 | 0.47 | 0.38 | 3.52 |

2.2. Methods
- the fluidity test method shall be carried out in accordance with GB/T 50448-2015 “technical code for application of cement based grouting materials”.
- The consistency test method shall refer to JGJ/T70-2009 “test method for basic performance of building mortar” [5].
- the mechanical test method shall refer to DL/T 5126-2001 “test specification for polymer modified cement mortar”.

3. Test program and Analysis

3.1. Test program
In this paper, based on the technology of impermeable mortar, the influence of silicon powder on the performance of waterproof mortar is studied by using the principle of fine particle grading and densification and the principle of composite superposition. The mix proportion of mortar is cementitious material: Sand: water: water reducer=1:2:0.35:0.015. See Table 4 for the mix proportion of materials. In order to test the mechanical properties of mortar at the age and find out the law of the influence of admixture on the performance of mortar, silicon powder was added by replacing part of cement, and the amount of silica fume was 0% (control group), 2%, 4%, 6%, 8%, 10% and 12% of cementitious material respectively[3].

According to DL/T 5126-2001 "polymer modified cement mortar test code", before pouring the test piece, carry out the consistency and fluidity test of mortar material. There are 3 formed mortar test pieces in each group, and the specification of test pieces is 40mm×40mm×160mm. The template shall be removed one day after forming, and then placed in the standard curing room for curing to the specified age. Take it out and wait for the surface to dry, then carry out the mechanical test.
Table 4. Test mix ratio of test block.  g

| test | silicon powder | cement  | sand  | water | polycarboxylate superplasticizers |
|------|----------------|---------|-------|-------|----------------------------------|
| A    | 0.0            | 675.0   | 1350  | 236   | 10.13                            |
| B    | 13.5           | 661.5   | 1350  | 236   | 10.13                            |
| C    | 27.0           | 648.0   | 1350  | 236   | 10.13                            |
| D    | 40.5           | 634.5   | 1350  | 236   | 10.13                            |
| E    | 54.0           | 621.0   | 1350  | 236   | 10.13                            |
| F    | 67.5           | 607.5   | 1350  | 236   | 10.13                            |
| G    | 81.0           | 594.0   | 1350  | 236   | 10.13                            |

3.2. Analysis

3.2.1. working performance. The influence of different content of silicon powder on the working performance of cement mortar was shown in Fig. 1.

It can be seen from Figure. 1 that with the increase of silicon powder content, mortar consistency value increases first and then decreases, and mortar fluidity tends to decrease. With the addition of silicon powder from 0% to 4%, the consistency of mortar increases. When the addition of silicon powder is 4%, the consistency of mortar reaches the maximum of 62.9cm; when the addition of silicon powder is increased, the consistency of mortar decreases. When the addition of silicon powder is 12%, the consistency reaches the minimum of 41.1cm. With the addition of silicon powder from 0% to 12%, the fluidity of mortar decreases. When the addition of silicon powder is 12%, the fluidity of mortar reaches a minimum of 19.7cm.

This is mainly due to the large specific surface area of silicon powder particles and the large water demand for surface wetting, which leads to the decrease of mortar fluidity. A certain amount of silicon powder particles are dispersed in the slurry, and the "micro bead effect" produced by it will have a certain promotion effect on the consistency of the mortar. Therefore, when the content is 0% to 4%, the consistency value of the mortar material will increase, but with the increase of the content, the water demand of the slurry will increase, and the water volume in the system will be certain, so when the content is 4% to 12%, the consistency value of the slurry will decrease. Therefore, the working performance of mortar has a certain degree of decline, but under the use of superplasticizer, the working performance of the whole material is still relatively good, meeting the performance index of the slurry under the test requirements.

![Figure 1. Influence of silicon powder content on consistency and fluidity of mortar](image)

3.2.2. compression strength. The influence of different content of silica fume on the compression strength of mortar was shown in Fig. 2.

It can be seen from Figure. 2 that the compression strength of mortar increases with the increase of silicon powder content. With the addition of silicon powder from 0% to 10%, the compression strength
of the specimen increases. When the addition of silicon powder is 10%, the compression strength of the specimen reaches the maximum value of 49.5MPa in 28d, and then the strength of the specimen decreases with the addition of silicon powder.

This is mainly because silicon powder is a two time excitation material, which can react with Ca(OH)$_2$ micro-crystals produced during hydration of cement clinker, and generate new calcium silicate gel. The filling effect between cement particles is more prominent, which makes the structure of cement mortar more encrypted and significantly improves its compression strength. With the increase of its dosage, the cement is more than 10%. The amount of material is reduced and some defects appear in the specimen, which leads to the decrease of strength.

![Figure 2. Influence of silicon powder content on compression strength of mortar](image)

3.2.3. bending strength. The influence of different content of silicon powder on the bending strength of mortar was shown in Fig. 3. It can be seen from Figure. 3 that the bending strength of mortar increases first and then decreases with the increase of silicon powder content. With the addition of silicon powder from 0% to 8%, the bending strength of the specimen increases gradually. When the addition of silicon powder is 8%, the bending strength of the specimen reaches the maximum value of 9.2MPa at 28d, and then decreases to 8.9MPa at 12%.

This is mainly due to the ultra-fine addition of silicon powder, the internal stability of the specimen is greatly improved, the particle distribution is more reasonable, and the amorphous SiO$_2$ of silicon powder can combine with Ca(OH)$_2$ to form calcium silicate-gel with low calcium to silicon ratio, thus improving the bending properties of the mortar specimen. With the further increase of the dosage, the excess SiO$_2$ will hinder the gel element density of the specimen. Solid forming leads to the decrease of bending strength.
4. Conclusion

- The content of silicon powder has a significant effect on the consistency and fluidity of cement mortar. With the increase of silicon powder content, the working performance of mortar will decline to some extent.
- The amount of silicon powder has a great influence on the mechanical properties of cement mortar. With the increase of silicon powder, the mechanical properties of mortar tend to increase. The appropriate amount of silicon powder is 8% - 10%.

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