Research and preparation of waste cement slurry as concrete admixture

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Abstract. The application of waste cement slurry as concrete admixture was studied. The chemical constituents, the particle size distribution and concrete test of waste cement slurry were investigated. The results show that the addition of a suitable amount of WS-1 will not have a great impact on the strength of concrete, while improving the workability of the concrete. According to the paper, WS-1 can be used as an admixture to adjust the workability of concrete.

1. Introduction
Waste cement slurry is produced after washing the mixer and transporter used in ready-mixed concrete, which contains cement, aggregates, promoter and impurities[1]. Nowadays, the widely used method of treating waste cement slurry is using the sedimentation tank for separation, the separated waste water is discharged, and the waste cement slurry is transported out and buried[2]. The wastewater contains surfactants and soluble phosphates, which cause great pollution to the environment, and the waste cement slurry requires a lot of manpower, material resources and site. Therefore, how to effectively treat these waste cement slurries has become a problem to be solved. This paper mainly studies the application of new material WS-1 obtained after treatment of waste cement slurry.

2. Experimental

2.1. Materials
WS-1: A material which is made from waste cement slurry which generated after washing the mixer and transport truck used in the ready-mixed concrete, after being treated by the filter press, dried, screened, broken and crushed; cement: P.O42.5R cement; sand: desalination sea sand, fineness of grinding is 2.7; gravel: crushed stone with particle size of 10mm-20mm; ore powder: S95 grade mineral powder; fly ash: second class powered coal ash.

2.2. Performance test method

2.2.1. Chemical position test. The concrete test is conducted in accordance with GB/T176-2017" Method for chemical analysis of cement".
2.2.2. **SEM test.** Using EM-20 scanning electron microscope and the ion sputtering ion sputtering equipment is ETD-2000, the pressure of the ion sputtering equipment is 2 MPa, the ion current is maintained between 6-8 mA, the sputtering time is 120 s.

2.2.3. **Particle size test.** Refer to the "winner 3003 dry powder laser particle size distribution instrument standard operating procedures" for testing.

2.2.4. **Concrete test.** The concrete test is conducted in accordance with GB/T 50080-2016 "Standard Test Methods for Performance of Common Concrete Mixtures".

3. **Experimental results and discussion**

3.1. **chemical analysis of WS-1**

The chemical composition of WS-1 was analyzed and tested, the results are shown in table 1:

| composition | SiO$_2$ | MgO | Fe$_2$O$_3$ | Al$_2$O$_3$ | CaO |
|-------------|--------|-----|-------------|-------------|-----|
| content/%   | 81.79  | 0.28| 3.16        | 4.86        | 2.96|

Compared with the cement, it can be found from table 1 that the content of SiO$_2$ is higher than cement, while the content of CaO is lower. Due to the low CaO content, C$_3$S, C$_2$S and other substances that affect the main strength properties of the concrete become less, a high amount of WS-1 may reduce the strength of the concrete. The content of SiO$_2$ and Al$_2$O$_3$ is high, which is the main components of aluminosilicate. When adding it to concrete, it can react with Ca(OH)$_2$, which is precipitated by cement, forming a product which is similar to cement hydration, enhancing the activity of the reactants.

3.2. **SEM analysis of WS-1**

WS-1 was observed by scanning electron microscope, the results are shown in figures 1, figures 2, and figures 3:

![Figure 1. SEM images (500X)](image1.png)
![Figure 2. SEM image (1000X)](image2.png)
![Figure 3. SEM images (2000X)](image3.png)

It can be seen from figure. 1 that the particle size is mostly below 10 μm, and the block is mainly composed of a diameter of about 8 μm, and some of the spherical particles having a diameter of about 10 μm which can be seen clearer in figure. 4. According to the high content of SiO$_2$ and Al$_2$O$_3$, as well...
as the morphology of the fly ash described in the literature\textsuperscript{3}, it can be sure that the spherical particles are fly ash particles. From figure 2, a lot of white irregular polyhedral structure particles can be observed, which are identified as mineral powder particles after reference\textsuperscript{4}. It can also be seen from the figure 3 that the surface of the particles is uneven, and the convex portion is a particle having a diameter of about 1 μm. The voids between salient and the particles may impart a large specific surface area to the WS\textsubscript{-}1, which is likely to contribute to the improvement of the workability of the concrete.

3.3. particle size analysis of WS\textsubscript{-}1

WS\textsubscript{-}1 was detected by laser particle sizer, the results are shown in table 2 and figure 5:

| X\textsubscript{AVG}(μm) | 0-3μm(%) | 3-32μm(%) | 32-65μm(%) | 65-80μm(%) | 80-120μm(%) |
|-------------------------|----------|-----------|------------|------------|------------|
| 10.233                  | 35.433   | 56.651    | 5.748      | 1.201      | 0.348      |

Figure 4. Particle size distribution

It can be seen from table 2 and figure 4 that the particle size is mainly distributed in the interval of 0-32 μm, and only about 8% in the interval of >32 μm. According to the literature, it is determined that the specific surface area depends on particles less than 5μm, and particles 3-32μm dominate the development of strength of cement, which has a great improvement on cement strength\textsuperscript{5}. About 35% of the particles have a particle size of less than 5 microns, which proves that WS\textsubscript{-}1 has a large specific surface area certainty; particle size in the 3-32μm volume fraction accounted for 57.651%, which is presumed to have a positive effect on the strength growth of the concrete.

3.4. Relationship between mix amount of WS\textsubscript{-}1 and slump and compressive strength

In the concrete test, part of the cement was replaced by WS\textsubscript{-}1. The relationship between the concrete slump, the slump flow and the strength of the obtained concrete and the mixing amount of WS\textsubscript{-}1 are shown in figure 2, figure 3 and figure 5.

Figure 5. Relationship between mixing amount and slump

Figure 6. Relationship between mixing amount and slump flow
Figure 7. Relationship between mixing amount and compressive strength

It can be seen from figure 5 that the slump of concrete is increasing when the mixing amount of WS-1 is less than 10%, and the slump is 190 mm when the dosage is 5%, which is larger than the initial slump. After the mixing amount exceeds 10%, the slump decreased with the increase of the mixing amount.

It can be seen from figure 6 that the slump flow of the concrete is increasing when the mixing amount of WS-1 is less than 10%, and the slump flow is 350 mm when the mixing amount is 10%, which is larger than the initial slump flow. When the mixing amount exceeds 10%, the degree of slump flow decreases as the mixing amount of WS-1 increases. Based on the experimental results of slump and slump flow, it can be found that the incorporation of WS-1 with a mass fraction of less than 10% in the cement can improve the workability of the concrete.

It can be seen from figure 7 that the strength of the concrete test piece decreased after the addition of different proportions of WS-1 compared with the un-incorporated WS-1 test block. When the mixing amount is 5%, the strength of each age is about 95% of the blank control; when the mixing amount is 10%, the intensity of each age is about 90% of the blank control, and after the mixing amount is more than 10%, the strength decrease fast. In addition, it can be seen that the compressive strength ratio of the test piece incorporating WS-1 to the test piece not incorporating WS-1 is rising in the same mixing amount when the age of the test piece is rising. The reason why it happened is probably because of the high content of SiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> in WS-1, there are many hydrated calcium aluminosilicates with gelation properties formed by hydration, and the improvement of strength should be reflected in the late stage of cement hardening.

In summary, the mixing amount of WS-1 has a great influence on the workability of concrete. In order to achieve good workability, it is more suitable to select a mixing amount of less than 10%. In terms of strength, when the mixing amount of WS-1 is less than 10%, the strength of the concrete is not greatly affected. Considering the practicality, 10% is a suitable mixing amount, which the concrete workability is greatly improved, and the strength is less than that when WS-1 is not added.

3.5. Performance comparison with other admixtures

In the concrete test, 10% of the cement (mass fraction) was replaced by WS-1, mineral powder and fly ash respectively, while other conditions remaining unchanged. Test results of slump, slump flow and strength of the concrete are shown in table 3.

| admixture  | slump flow/mm | slump/mm | compressive strength/MPa |
|------------|----------------|----------|-------------------------|
|            |                |          | 3d    | 7d    | 28d   |
| WS-1       | 290            | 180      | 14.98 | 22.94 | 37.98 |
| mineral powder | 370          | 180      | 14.7  | 22.7  | 38.1  |
| fly ash    | 370            | 180      | 15.1  | 23.3  | 38.3  |
From the data of concrete slump and slump flow in the table 3, it can be seen that when used as a blending material with cement, WS-1 has almost the same effect as fly ash and ore powder in improving concrete workability; The compressive strength data shows that the replacement of part of the cement will slightly reduce the concrete strength, and the reduction range is basically the same as the incorporation of the same amount of fly ash and mineral powder. In summary, we can conclude that when the waste cement slurry is used as a mixture, it is equivalent to fly ash and ore powder in terms of workability adjustment and strength, and can be used as an admixture.

4. Conclusion
From what has been discussed above, we may safely draw the conclusion above:

(1) The content of SiO$_2$ and Al$_2$O$_3$ in the WS-1 is very high, and the content of CaO is low.

(2) Scanning electron microscopy showed that most of the WS-1 particles were massive particles, including a small amount of spherical particles and white irregular massive particles. After consulting the literature, it was judged that the pressure filter slurry contained fly ash and mineral powder; The morphology can be judged to have a large specific surface area.

(3) The particle size of the pressure filter slurry is mainly distributed in the interval of 0-32 μm, and the average particle diameter is 10.233 μm.

(4) The addition of a small amount of WS-1 to the concrete can improve its workability and slightly reduce its strength. For comprehensive workability and strength considerations, the recommended mixing amount is 10%.

(5) WS-1 has similar effects to mineral powder and fly ash in improving the workability of concrete. The strength is approximately equal to that of the same amount of mineral powder and fly ash. Therefore WS-1 can be used as concrete admixture.

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