Study on the influence of waste residue of mixing station, slag and water slag on the strength of cement mortar

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Abstract. In their paper. In this paper, the influence of the waste residue of the mixing station on the strength of cement mortar was studied. And the influence of the different content of the waste residue of the mixing station, slag and water slag on the strength of cement mortar was studied to get the optimal proportion. The study showed that when the mass ratio of the waste residue of mixing station, slag and water slag is 3:3:4 and 3:2:5, the synergistic effect of the three materials can be fully exerted, the grinding characteristics of the waste slag of the mixing station can be effectively improved, and the hydration activity of the waste slag of the mixing station can be improved.

1. Introduction

The waste residue of the mixing station is the solid waste produced in the operation and maintenance of the mixing station. Under the background of green and clean production in ready mixed concrete industry, the large-scale utilization of waste residue in mixing plant is paid more and more attention[1].

Some researchers [2] have found that the fluidity ratio and activity of waste residue are low due to the irregular particle shape, complex composition and other factors by means of XRD, SEM, laser particle size analysis and mortar strength test. Mechanical grinding and high-temperature calcination can improve the activity of waste residue, but the improvement range is limited, which makes the high-efficiency utilization technology of waste residue in the mixing station has not been broken through. But mineral admixture is an important part of concrete, and high-quality concrete admixture is increasingly scarce. If it can improve the hydration activity of the waste residue in the mixing plant and prepare high-quality concrete admixture, it can not only realize the self absorption of the waste residue in the mixing plant, meet the production requirements of green composite, but also meet the increasing demand of mineral admixture.

In this paper, the influence of the waste residue of the mixing station on the strength of cement mortar was studied. And the influence of the different content of the waste residue of the mixing station, slag and water slag on the strength of cement mortar was studied to get the optimal proportion. According to the research, it is expected to provide the basis for the recovery and utilization of the waste residue in concrete.
2. Experiment

2.1. Raw materials

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Huaxin P ·O 42.5 ordinary portland cement is used in the test, and its chemical composition and basic performance indexes are shown in Table 1. The waste residue of the mixing station is the wet waste residue separated by the sand separator. Its chemical composition and basic performance indexes are shown in Table 2. The slag and water slag used in the test are from ethylene power plant and WISCO. The chemical composition of slag and water slag is shown in Table 3 and table 4.

| Table 1. The chemical composition of P. O 42.5 Ordinary Portland cement (%)
| Al₂O₃ | SiO₂ | Fe₂O₃ | CaO | K₂O | SO₃ | Na₂O | MgO | LOS |
|-------|------|-------|-----|-----|-----|------|-----|-----|
| 5.18  | 21.41| 3.51  | 60.18| 0.63| 2.17| 0.20 | 2.13| 3.70|

| Table 2. The chemical composition of waste residue of the mixing station (%)
| CaO | SiO₂ | Al₂O₃ | Fe₂O₃ | SO₃ | MgO | LOI |
|-----|------|-------|-------|-----|-----|-----|
| 29.48| 34.5 | 11.6  | 3.37  | 2.1 | 2.62| 13.45|

| Table 3. The chemical composition of waste residue of slag (%)
| CaO | SiO₂ | Al₂O₃ | Fe₂O₃ | SO₃ | MgO | Cl   | Rb₂O | Y₂O₃ | CeO₂ | LOS |
|-----|------|-------|-------|-----|-----|------|------|------|------|-----|
| 4.51| 63.34| 21.32 | 4.1   | 0.20| 0.60| 0.02 | 0.01 | 0    | 0.06 | 3.50|

| Table 4. The chemical composition of waste residue of water slag (%)
| CaO | SiO₂ | Al₂O₃ | Fe₂O₃ | SO₃ | MgO | Cl   | Na₂O | LOS |
|-----|------|-------|-------|-----|-----|------|------|-----|
| 39.05| 32.81| 14.04 | 0.43  | 1.95| 8.72| 0.025| 0.25 | 0.54|

2.2. Test method

The test method of mortar strength and fluidity refer to GB / t17671-1999 test method.

3. Discussion

3.1. Study on the performance of waste residue on mortar strength

Replace the cement with 10%, 20%, 30%, 40%, 50% and 60% replacement rates respectively of waste residue of the mixing station to study the influence of the waste residue before and after grinding on the strength with different dosage in different age. (Figure 1-3)

Figure 1 shows that the mortar strength of waste residue powder after grinding is significantly higher than that of waste residue powder without grinding. The results showed that the activity of waste residue was improved by grinding. This is because the particle size of waste slag can be made fine by grinding, and the chemical reaction area and reaction speed of the particle can be increased, thus improving the activity. Moreover, a certain effect of particle accumulation may be formed between fine powder and cement particles. The smaller the particle size, the more obvious the effect.
As can be seen from Figure 2, the strength of mortar strength decreases with the increase of waste residue content. When the content of waste residue in cement was 10%, the strength of cement on 7d and 28d age is reduced by 1.75% and 16.1%, respectively, compared with that of pure cement. With the increase of the content of waste residue, the strength of cement at each age gradually decreases. Under the content of no more than 20%, the strength at 7d age decreases slightly, while that of 28d decreases greatly. When the content of waste slag is 30%, compared with pure cement, the decrease range is 47.9%, and the 28d strength of cement mortar decreases from 52MPa to 29MPa. This restricts the large-scale application of waste residue with high content in cement and concrete industry. The reason for the above phenomenon is primarily with the increase of waste residue adding inert component in the gel system, fine aggregate can micro aggregate effect at early age, so the 7 d mortar strength decline slightly. But the activity of waste residue at 28 d mixing station is insufficient, which leads to slag can't display the pozzolanic characteristic.

**Figure 2.** Influence of waste residue with different mixing amount after grinding

It can be seen from Figure 3, the strength of each system increases with age. The strength of pure cement system developed quickly at the early stage, while the strength of sample mixed with waste residue powder developed slowly in the early stage. This is because the activity in the early waste
residue powder is not strong after mechanical activation, and its incorporation mainly played a role in the filling effect and dilution effect of microaggregates, so the hydration products of cement-based materials per unit volume are reduced and the strength is reduced. The late development of mortar strength is increased because of the gradual release of pozzolanic activity of waste residue powder.

![Figure 3. The mortar strength of waste residue powder at different age](image)

### 3.2. Research on the properties of concrete admixtures prepared by different proportions of industrial waste slag

The mortar strength of low carbon admixtures with different compositions was tested (table 5). The water-cement ratio is 0.5. The colloidal sand ratio is 1:3. The effect of waste residue on the performance improvement of activated slag powder was studied. The waste residue and slag are respectively ground for 40 minutes, and the dosage of the low carbon admixture is controlled to be 50%. The ratio of the waste residue powder to the slag powder is adjusted to be 8:2, 7:3, 6:4, 5:5, 4:6, 3:7, 2:8.

| Number | Cement (g) | Waste residue: slag | Waste residue (g) | Slag (g) |
|--------|------------|---------------------|-------------------|---------|
| A0     | 225        | /                   | 0                 | 225     |
| A1     | 225        | 8:2                 | 45                | 180     |
| A2     | 225        | 7:3                 | 67.5              | 157.5   |
| A3     | 225        | 6:4                 | 90                | 135     |
| A4     | 225        | 5:5                 | 112.5             | 112.5   |
| A5     | 225        | 4:6                 | 135               | 90      |
| A6     | 225        | 3:7                 | 157.5             | 67.5    |
| A7     | 225        | 2:8                 | 180               | 45      |
| A8     | 225        | /                   | 225               | 0       |

The mechanical properties of cement mortar prepared from different proportions of cement-waste powder-slag powder is shown in figure 4. It can be seen from figure 4 that as the relative proportion of waste residue to slag powder increases, the change trend of mortar strength is not obvious, which may be because the early activity of waste residue powder and slag powder is low, though the ratio of the two changes, the total amount is constant. When the mass ratio of the waste residue powder to the slag...
The single-mixed waste residue powder and the slag powder sample. Under these two ratios, the particle distribution after mixing is more reasonable and tends to be closely packed. According to the "composite admixture for concrete" JG/T486-2015, the activity index of the sample with the mass ratio of waste residue to slag powder of 3:7 and 6:4 respectively is analyzed. The analysis results are shown in Fig. 5. It can be seen that the activity indexes of the two sets of samples have just reached the standard of the class II composite admixture, and have not reached the standard of the class I composite admixture, so it is necessary to further enhance the activity.

![Figure 4. Mortar strength of different content](image1)

![Figure 5. Analysis of activity index of different content](image2)

The test design by introducing water slag is shown in Table 6. The waste residue, slag and water slag are respectively ground for 40 minutes, and the amount of low carbon admixture is controlled to be 50%. The ratio of waste residue powder, slag powder and water slag powder is 3:6:1, 3:5:2, 3:4:3, 3:3:5:3.5, 3:3:4, 3:2:5, 3:1:6. The water-cement ratio is 0.5 and the ratio of sand to sand is 1:3.

| Number | Cement (g) | Waste residue: Slag: Water slag | Waste residue (g) | Slag (g) | Water slag (g) |
|--------|------------|---------------------------------|------------------|----------|----------------|
| B0     | 225        | 3:6:1                            | 67.5             | 135      | 22.5           |
| B1     | 225        | 3:5:2                            | 67.5             | 112.5    | 45             |
| B2     | 225        | 3:4:3                            | 67.5             | 90       | 67.5           |
| B3     | 225        | 3:3.5:3.5                        | 67.5             | 78.75    | 78.75          |
| B4     | 225        | 3:3:4                            | 67.5             | 67.5     | 90             |
| B5     | 225        | 3:2:5                            | 67.5             | 45       | 112.5          |
| B6     | 225        | 3:6:1                            | 67.5             | 22.5     | 135            |
By introducing water slag, the activity of the low carbon admixture system is further improved. Figure 6 shows the synergistic effect of cement, waste residue, slag and water residue sand in different proportion. When the mass ration of waste residue powder, slag powder to water slag powder is 3:3:4 and 3:2:5, the strength of the cementing system is slightly higher, and the growth rate is more than 80% compared with the pure waste residue powder system. Its activity index reached the standard of grade I composite admixture (Figure 7). This may be because: first, water slag activity is higher than slag and waste residue, the amount of water slag plays a key role. Second, waste residue, slag and water slag play a microaggregate effect. Third, the mixing of the three gives play to the synergistic effect, and the particle grading is more reasonable. In addition, compared with the pure waste slag system, the strength growth rate of 28d is about 110%, which was higher than that at 7d age. This is possibly because, with the growth of age, the activity of slag powder was gradually released. And Aluminum phase of water slag powder and slag powder induce the change of hydrated calcium silicate gel into type III hydrated calcium silicate gel, whose structure is more stable[3].

Activity indexes of B3, B4 and B5 samples were analyzed according to GB/T486, and the analysis results are shown in figure 7. The activity index of these B4 and B5 samples just reached the activity standard of grade I composite admixture.

4. Conclusion

In terms of the mineral composition of mixing station waste slag, mixing station waste residue as concrete admixture is feasible. However, the content of waste residue stone powder is high, the activity is low, when used as a single admixture, the content of the mixture should not exceed 30%.

Slag can be used to delay or eliminate the phenomenon of ball enveloping in single grinding waste slag and improve the grinding efficiency. Adding water slag can optimize the overall fragility of materials and improve the mechanical properties of composite admixture.

When the mass ratio of the waste residue of mixing station, slag and water slag is 3:3:4 and 3:2:5, the synergistic effect of the three materials can be fully exerted, the grinding characteristics of the waste slag of the mixing station can be effectively improved, and the hydration activity of the waste slag of the mixing station can be improved.

References

[1] A. Petek Gursel, Masanet Eric, Horvath Arpadet al. Life-cycle inventory analysis of concrete production: A critical review[J]. Cement and Concrete Composites. 2014. 51: 38-48
[2] Karim, Md. Rezaul, Zain, M F M. Influence of Slag and Slag Cement on the Strength of Sustainable Concrete[J]. Advanced Materials Research, 383-390:3410-3415.
[3] Zhang Wensheng, Wang Hongxia, Ye Jiayuan. Structure and variation of hydrated calcium silicate[J]. Journal of The Chinese Ceramic Society. 2005. 33(1): 63-68