Sedimentation study on separation tailings and backwater of a water-quenched copper slag

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Abstract. The sedimentation test of separation tailings and backwater of a water-quenched copper slag were carried out. The experimental contents included: chemical analysis of multi-elements of tailings, particle size analysis of tailings, tailings sedimentation test, natural sedimentation of backwater, sedimentation test of backwater with reagents, etc. The results shown that the tailing granularity was very thin, almost all passed the 0.037 mm sieve. Under different concentration, when the settling time of 180 min, tailings could be settled completely and concentration without influence, thus settling time determined to 180 min. With the same dosage, KAl(SO₄)₂ had a better sedimentation effect than CaCl₂. In this test, KAl(SO₄)₂ 200 g/m³ was recommended in consideration of reagents dosage and backwater sedimentation rate and CaCl₂ 200 g/m³ was recommended in consideration of drug price and treatment cost.

1. Sample properties

1.1. Chemical multi-element analysis
The multi-element chemical analysis results of tailings were shown in Table 1.

Table 1. Analysis results of main chemical composition of water-quenched slag tailings /%

| Chemical composition | Cu   | Pb   | Zn   | Fe   | S    | SiO₂ |
|----------------------|------|------|------|------|------|------|
| Contents             | 0.46 | 0.24 | 1.10 | 39.71| 0.92 | 26.28|
| Chemical composition | Al₂O₃| CaO  | MgO  | Na₂O | K₂O  |
| Contents             | 2.17 | 2.53 | 2.15 | 0.49 | 0.65 |

1.2. Tailings particle size analysis
The particle size analysis results of tailings were shown in Table 2.

Table 2. Size distribution results of tailings /%

| Size distribution (mm) | Yield | Downsize Cumulative yield | Undersize Cumulative yield |
|------------------------|-------|----------------------------|----------------------------|
| +0.045                 | 0     | 0                          | 0                          |
| -0.045+0.037           | 0.8   | 0.8                        | 100                        |
| -0.037+0.025           | 14.20 | 15.00                      | 99.20                      |
As can be seen from Table 2, the particle size of the tailings was very fine, almost all of which passed 0.037mm sieve.

2. Experiments

2.1. Tailings settlement test

The settlement test conditions of tailings at different concentrations were shown in Table 3.

Table 3. The settlement test conditions of tailings

| Product name | Pulp density /% | Measuring cylinder section diameter /mm | Initial height of slurry /mm |
|--------------|-----------------|----------------------------------------|------------------------------|
| Tailings 20  | 20              | 49.52                                  | 350                          |
| Tailings 25  | 25              | 49.60                                  | 350                          |
| Tailings 30  | 30              | 48.50                                  | 276                          |

The distribution of test results under the concentration of 20%, 25% and 30% tailings were shown in Figure 1, 2 and 3.

Figure 1. Tailings settlement curve at 20% concentration

Figure 2. Tailings settlement curve at 25% concentration
As can be seen from Fig. 1, 2 and 3, when the settling time reached 180 min, the tailings could be basically completely settled at different concentrations, with little relation to the concentration. Therefore, the settling time of tailings should be 180 min.

2.2. Backwater settlement test

2.2.1. Natural settlement test of backwater

The backwater was directly taken from the upper clarifying liquid of closed-circuit tailings settled after 3 hours. There was no obvious difference between the settling zone, depression zone, transition zone, compression zone and coarse grain zone. The backwater concentration of tailings natural settlement test was 1.2%, the diameter of beaker section was 131.9 mm, and the initial height of slurry was 154.8 mm. The test results were shown in Figure 4.

It can be seen from Figure 4 that after 168 h of settlement, the height of backwater clarification zone of the tailings was still 2-3mm, and the backwater settlement was not obvious. The reason may be that the particles were too fine, so it was necessary to add flocculant to the backwater of the tailings.

2.2.2. Flocculant type test

1) Contrast test of PAM、CaCl2、CaCl2+PAM

Three 500 mL measuring cylinders were used to measure the backwater of tailings respectively. PAM 8 g/m³, CaCl2 200 g/m³ and CaCl2+PAM 200 g/m³+8 g/m³ were added after 5min of standing. The test results were shown in Table 4.

According to Table 4, after adding 8 g/m³ PAM, the backwater settlement of the tailings was faster before 24min, the settlement height was 7-8m, and the backwater settlement of the tailings was almost unchanged after 24min. After adding 200 g/m³ CaCl2, the backwater contained a small amount of suspended particles in the settling fluid for 48 min, and the backwater was basically clarified. After adding 200 g/m³ CaCl2+8 g/m³ PAM, the tailings backwater was clarified began after 60min, indicated that the settlement effect of adding 200 g/m³ CaCl2+8 g/m³ PAM was not as good as that of adding 200 g/m³ CaCl2. According to the above analysis, the backwater settlement effect of tailings was the best when CaCl2 was added as flocculant.

| Time(min) | 0 | 12 | 24 | 36 | 48 | 60 | 72 | 84 | 96 |
|-----------|---|----|----|----|----|----|----|----|----|
| Clarity height(mm) | 0.0 | 7.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 |
| Time(min) | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 | 204 |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Clarity height(mm) | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 |

| Time(min) | 0   | 12  | 24  | 36  | 48  | 60  | 72  | 84  | 96  |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Clarity height(mm) | 0.0 | 7.0 | 9.0 | 25.0 | -   | -   | -   | -   | -   |

| Time(min) | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 | 204 |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Clarity height(mm) | -   | -   | -   | -   | -   | -   | -   | -   | -   |

| Time(min) | 0   | 12  | 24  | 36  | 48  | 60  | 72  | 84  | 96  |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Clarity height(mm) | 0.0 | 7.0 | 9.0 | 25.0 | -   | -   | -   | -   | -   |

| Time(min) | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 | 204 |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Clarity height(mm) | -   | -   | -   | -   | -   | -   | -   | -   | -   |

Note: - means that there were a small amount of suspended particles in the settling fluid, but it had been basically clarified. The meaning in the following table was the same.

(2) Contrast test of KAl(SO4)2, KAl(SO4)2+PAM, CaCl2+PAM
KAl(SO4)2, KAl(SO4)2+PAM and CaCl2+PAM were compared in this experiment. The dosage of KAl(SO4)2, KAl(SO4)2+PAM and CaCl2+PAM were 200 g/m3, 200 g/m3+10 g/m3 and 200 g/m3+10 g/m3 respectively. The test results were shown in Table 5.

Table 5. Test results of backwater settlement after adding other different flocculant

| Time(min) | 0   | 12  | 24  | 36  | 48  | 60  | 72  | 84  | 96  |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Clarity height(mm) | 0.0 | 20.0 | 25.0 | -   | -   | -   | -   | -   | -   |

| Time(min) | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 | 204 |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Clarity height(mm) | -   | -   | -   | -   | -   | -   | -   | -   | -   |

| Time(min) | 0   | 12  | 24  | 36  | 48  | 60  | 72  | 84  | 96  |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Clarity height(mm) | 0.0 | 20.0 | 24.0 | -   | -   | -   | -   | -   | -   |

| Time(min) | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 | 204 |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Clarity height(mm) | -   | -   | -   | -   | -   | -   | -   | -   | -   |

| Time(min) | 0   | 12  | 24  | 36  | 48  | 60  | 72  | 84  | 96  |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Clarity height(mm) | 0.0 | 12.0 | 15.0 | 30.0 | 45.0 | -   | -   | -   | -   |

| Time(min) | 108 | 120 | 132 | 144 | 156 | 168 | 180 | 192 | 204 |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Clarity height(mm) | -   | -   | -   | -   | -   | -   | -   | -   | -   |

According to Table 5, the backwater of tailings added with 200 g/m3 KAl(SO4)2 and 200 g/m3+10 g/m3 KAl(SO4)2+PAM were basically clarified after 36 min. However, the backwater settlement effect of tailings added with KAl(SO4)2 alone was better than that with KAl(SO4)2+PAM. The backwater of CaCl2+PAM tailing was basically clarified after 60 min with adding 200 g/m3+10 g/m3, which indicated that the settlement effect of KAl(SO4)2+PAM combined agent as flocculant was much better than that of CaCl2+PAM combined agent as flocculant. It also indirectly indicated that the settlement effect of KAl(SO4)2 was better than that of CaCl2. Based on the above, it could be seen that the settlement effect of adding KAl(SO4)2 alone was the best.

2.3. Flocculant dosage test

2.3.1. KAl(SO4)2 dosage test
According to the above tests, the use of KAl(SO4)2 alone as flocculant was better than the combination of KAl(SO4)2+PAM and CaCl2+PAM. In order to determine the optimal dosage of KAl(SO4)2, this experiment conducted a comparative settlement test with the dosage of KAl(SO4)2 being 100 g/m3, 200 g/m3 and 300 g/m3 respectively. Only 60min was observed in this experiment, the following was the same. The test results were shown in Table 6.
Table 6. Test results of backwater settlement after adding KAl(SO4)2

| Dosages      | Time(min) | 0 | 12 | 24 | 36 | 48 | 60 |
|--------------|-----------|---|----|----|----|----|----|
| 100 g/m3 KAl(SO4)2 | 0.0       | 12.0 | 14.0 | 15.0 | 15.0 | 15.0 |  |
| 200 g/m3 KAl(SO4)2 | 0.0       | 20.0 | 24.0 | -   | -   | -   |  |
| 300 g/m3 KAl(SO4)2 | 0.0       | 40.0 | -   | -   | -   | -   |  |

It can be seen from Table 6 that the backwater of tailings added with 100 g/m3 KAl(SO4)2 hardly settled after 36min. The backwater of tailings added with 200 g/m3 KAl(SO4)2 was clarified after 36min. The backwater of tailings added with 300 g/m3 KAl(SO4)2 was basically clarified after 24min. This indicated that with the increased of KAl(SO4)2 dosage, the backwater settlement effect of tailings was better. Considered the dosage and settlement effect of KAl(SO4)2, this test recommended that the dosage was 200 g/m3.

2.3.2. CaCl2 dosage test

According to the previous tests, the single use of CaCl2 as flocculant was more effective than the combination of PAM and CaCl2+PAM. In order to determine the optimal amount of CaCl2, this test conducted a comparative settlement test with the amount of CaCl2 at 100 g/m3, 200 g/m3 and 300 g/m3 respectively. The test results were shown in Table 7.

Table 7. Test results of backwater settlement after adding CaCl2

| Dosages      | Time(min) | 0 | 12 | 24 | 36 | 48 | 60 |
|--------------|-----------|---|----|----|----|----|----|
| 100 g/m3 CaCl2 | 0.0       | 4.0 | 7.0 | 10.0 | 10.0 | 10.0 |  |
| 200 g/m3 CaCl2 | 0.0       | 7.0 | 9.0 | 25.0 | -   | -   |  |
| 300 g/m3 CaCl2 | 0.0       | 8.0 | 12.0 | -   | -   | -   |  |

It can be seen from Table 7 that the backwater of tailings with 100 g/m3 CaCl2 was almost not settled after 36min. The backwater of tailings with 200 g/m3 CaCl2 was basically clarified after 48min. The backwater of tailings added with 300 g/m3 CaCl2 was basically clarified after 36min. This indicated that with the increased of CaCl2 dosage, the settlement effect of tailings backwater was better. Considering the amount of CaCl2 and the settlement effect, the recommended amount of CaCl2 in this test was 200 g/m3.

3. Conclusions

Due to the large number of fine particles in the backwater of the tailings, it was necessary to add flocculant to settle the backwater of the tailings as soon as possible. The results of the test were as follows: Among CaCl2, CaCl2+PAM and PAM, CaCl2 had the best effect, CaCl2+PAM came second and PAM was the worst. Compared with KAl(SO4)2, KAl(SO4)2+PAM and CaCl2+PAM, KAl(SO4)2 had the best effect, followed by KAl(SO4)2+PAM and CaCl2+PAM. The larger the amount of CaCl2+PAM, the better the effect. The greater the amount of CaCl2, KAl(SO4)2, the better the settlement effect. Under the same dosage, KAl(SO4)2 had a better settlement effect than CaCl2. In this study, KAl(SO4)2 of 200 g/m3 was recommended in consideration of dosage of reagents and backwater sedimentation rate. CaCl2 of 200 g/m3 was recommended in consideration of drug price and treatment cost.

Acknowledgements

We gratefully acknowledge the financial assistance of Yunnan Provincial Education Department Project (No: 2019J0738), National Natural Science Foundation (No: 51964044), Yunnan Local...
Colleges Applied Basic Research Projects (No: 2018FH001-051), Yunnan University Students Innovation and Entrepreneurship Training Program (No: 2019B20, 2020B28).

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