Experimental Study on Comprehensive Performance of Full Tailings Paste Filling in Jiaojia Gold Mine.

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Abstract: Filling mining method is the main method of modern underground mining. High concentration cementation is carried out using coarse tailing of +37 µm, and the mine has maturely used classified tailings paste filling technology. The gold mine studied on the performance of full tailings paste filling in order to maximize the use of tailings, reduce -37 µm fine tailings discharged into the tailing pond, reduce mining cost and eliminate security risks. The results show that: comprehensive index of full tailings paste filling is higher than that of classified tailings high concentration cementation filling, and the full tailings paste filling of 76% mass concentration has the best comprehensive index of slump, expansibility, yield stress and viscosity to meet the mining method requirements, which can effectively reduce the mining loss rate and dilution rate.

1. Overview of mine filling status

Jiaojia Gold Mine is located in Jiaodong area of Shandong Province, and in the geotectonic it is located in the jiaodong uplift zone of the new Huaxia series second uplift zone. The northwestern of Jiaodong is to the west of Tanlu fault zone, and to the east of Mu-Ji fault zone. The Mine has a large ore reserve and high taste, which is one of the biggest gold mine inland. The shape of the ore body varies a lot, and the upper plate surrounding rock is broken. In the upper part of the ore body, there are farmland and houses, which needs protection in the mining process. In order to prevent the subsidence and reduce ore loss and dilution, tailings consolidation and filling system is designed specially. Upward stratified approach filling is the main mining method, which has a high requirement of the strength of filling body. With the increase of production capacity, filling system and process are improved continuously. As for filling material, ordinary 425 cement is first used as cementing material. Through the cooperation with related universities and designing institute, according to a large number of experiments and research, there is a new type of mine filling cementing materials developed which is of low cost, high water content, rapid hardening and high strength (modified C material). Aggregate mainly comes from the gold ore dressing plant tailing of processing classification desliming (i.e. +37 µm coarse tailing), and the remaining -37 µm fine particle tailing after cyclone classification is discharged to tailing pond.

Tailing classification desliming reduces the utilization rate of tailings (generally about 50%), and it is difficult to dam with fine clay backfilling. With the increase of tailing emissions, the economic costs and security costs of tailings are increasing. Graded tailings filling slurry in the stope after the process of dehydration will occur segregation and stratification, leading to low integrity and intensity of the filling body. What’s more, in the process of dehydration it will take away a part of the slurry, pollute underground work environment, and indirectly increase ore dilution rate.
In order to use tailings effectively, reduce the burden and safety hazards of tailings, we explore the use of full tailings paste filling. Paste filling has great advantage in the field of environmental protection, security and economic, and it is also of great importance in solving the deep ground pressure and temperature, maintaining stope stability, managing old empty area, recovering the remain mining pillar, controlling subsidence and protecting the ecological environment. This can not only solve the problem of tailing, but also guarantee the strength of the filling body.

2. Experiment scheme
Combining with the new advanced filling technology at home and abroad, the paste filling technology is the best one with high technical level. It is composed of the preparation, conveying and consolidation of the filling paste, so that the application effect of the whole process is influenced by the flow performance of the paste filling material, the rate of water secretion and the strength. Therefore, preliminary experiments are needed to achieve optimal filling ratio and parameters.

(1) Determine the physical properties of Jiaojia Gold Mine backfilling and the composition of colloidal materials.

(2) Determine the composition of different grading tailings according to experience(full backfilling, +0.038µm, +0.074µm), and determine slump, expansion, yield stress, viscosity, bleeding rate and other parameters.

(3) Combined with the mine's current production process, the strength of cemented filling should meet the conditions following: ①False bottom cementation filling at the age of 14d is not less than 5MPa; ②The strength of the stratified filling body was not less than 0.25MPa at the age of 3 days, and 0.7MPa at 14days; ③The strength of the glue filling body is not less than 0.45 MPa at the age of 3 days, and 1.2MPa at 14 days.

(4) Flow performance requirements of the full tailings paste filling: not settled, not isolated, not layered and not dehydrated; the slumping degree is 18 ~ 25cm; the content of -20µm is 15% ~ 20%; the bleeding rate is 1% ~ 5%; the slump is 18 ~ 25cm; Compression rate is less than 3%; yield stress is (200 ± 25) Pa above; stratification is less than 2cm.

3. The physical and chemical properties of materials
3.1 The physical properties of materials

| Table 1. The physical properties of materials |
|---|---|---|---|
| Tailings | Full tailings | +0.038µm | +0.074µm |
| proportion (g/cm³) | 2.67 | 2.64 | 2.65 |
| volume-weight (g/cm³) | 1.123 | 1.222 | 0.579 |
| porosity (%) | 57.9 | 53.7 | 77.5 |
| permeability coefficient (%) | 12.13 | 14.32 | 5.6 |
3.2 The chemical properties of materials

Table 2. The chemical properties of materials

| Composition       | SiO\textsubscript{2} | Al\textsubscript{2}O\textsubscript{3} | K\textsubscript{2}O | CaO | Fe\textsubscript{2}O\textsubscript{3} | Na\textsubscript{2}O | SO\textsubscript{3} | MgO |
|-------------------|-----------------------|-------------------------------|-----------------|-----|------------------|----------------|----------|------|
| Full tailings     | 64.83                 | 14.72                         | 4.723           | 2.31| 2.208            | 1.95           | 0.574    | 0.479|
| Coarse tailing    | 64.64                 | 14.23                         | 5.294           | 2.40| 1.18             | 1.88           | 0.195    | 0.14 |
| Fine tailing      | 60.22                 | 18.19                         | 5.538           | 2.35| 2.303            | 2.22           | 0.291    | 0.524|

Combined with X-ray diffraction analysis, the results show that the main mineral composition in the tailing is quartz, illite, albite and potassium feldspar.

3.3 Physical properties of slag

The physical properties of slag: 2.83 g/cm\textsuperscript{3} of density; 452 m\textsuperscript{3}/kg of specific surface area; 1.12 M of alkaline coefficient; 1.97 K of quality factor; 7d and 28d are 80.22% and 112.08% respectively of the active index.

3.4 Chemical properties of slag

The slag powder has a potential hydraulic similarity to the cement: the higher the alkalinity of the slag, the stronger the potential activity. The chemical composition of the slag is analyzed by atomic absorption spectroscopy and the result is as following: the content of CaO is 43.1, SiO\textsubscript{2} is 31.1, Al\textsubscript{2}O\textsubscript{3} is 13.7, SO\textsubscript{3} is 2.1, Fe\textsubscript{2}O\textsubscript{3} is 0.5, TiO\textsubscript{2} is 0.9, K\textsubscript{2}O is 0.5, Na\textsubscript{2}O is 0.3, MnO\textsubscript{2} is 0.5.

4. Comparison experiment of filling performance of different concentration tailings at different concentrations

The strength of the filling body directly affects whether the ore body can be safely and continuously mined, so it is of great significance to analyze the factors that affect the strength of the filling body. There are many factors that affect the strength of the filling body, including the material factors, the preparation factors, the construction conditions and so on. The strength of the prepared gut strength is the result of the combined effect of various factors. The factors are determined by the parameters such as slump, expansion, yield stress, viscosity, bleeding rate and stratification. In order to determine the filling ratio, concentration and curing period of the cementing material produced by the mine, the whole tailings, the graded tailings (+0.038µm) and the fine mud (-0.074µm) are used to test the cementing material produced by the mine respectively.

Aggregate is the basic part of cementing filling body. Aggregate gradation and quality has a great influence not only on the workability of cemented material, but also on strength. Therefore, the particle size of aggregate is selected to study the strength. Under the condition of room temperature, the slurry is poured into the 7.07cm × 7.07cm × 7.07cm standard triple metal touch, and the test piece in the initial condensate after stripping is put into the conservation box for standard maintenance. When reaching the specified age, the uniaxial compressive strength test was carried out on a press.

Filling body ratio and the main parameters are as follows:
(1) simulated filling ratio of 1:20 (refer to the main use of the filling ratio);
(2) the conservation period is 3d, 7 d, 14 d.

4.1 Strength test of various grading filling

To find out the tailing gradation which meets the filling strength requirements, the optimum particle size is determined by measuring the filling strength at different particle sizes (gray sand ratio is 1:20, and the same below). The test data is showed in figure 1.
Figure 1. Filling strength of various grading

We can see from figure 1 that Jiaojia gold tailing is filled with the highest strength.

4.2 Performance parameters of tailings with different concentrations of filling slurry

Prepare different concentrations of filling slurry according to gray sand ratio of 1:20 and determine the content of -20μm, slump, expansibility, yield stress, viscosity, bleeding rate and filling strength to determine the comprehensive performance index of whole tailing paste. The test data are as follows:

| grading | Concentration (%) | Filling strength (MPa) | Yield stress (Pa) | Viscosity (Pa·s) | Divergence (mm) | Slump (mm) | Bleeding rate (%) |
|---------|------------------|-----------------------|------------------|-----------------|----------------|------------|-----------------|
|         | Full tailings    |                       |                  |                 |                |            |                 |
|         | 80               | 0.23                  | 0.47             | 1.02            |                | 58         | 90              | 3.25            |
|         | 78               | 0.28                  | 0.50             | 1.11            | 1282           | 61         | 150             | 3.33            |
|         | 77               | 0.37                  | 0.55             | 1.11            | 350            | 332        | 63              | 159             | 5.00            |
|         | 76               | 0.42                  | 0.58             | 1.34            | 300            | 249        | 65              | 195             | 6.00            |
|         | 75               | 0.33                  | 0.51             | 1.04            | 128            | 130        | 71              | 250             | 6.25            |
|         | 70               | 0.31                  | 0.50             | 0.95            | 67             | 103        | 193             | 277             | 19.84           |
|         | 65               | 0.21                  | 0.23             | 0.62            | 18             | 26         | 203             | 28              | 28.51           |
| +400    | 76               | 0.26                  | 0.44             | 0.82            | 85             | 111        | 134.5           | 277             | 15              |
|         | 75               | 0.24                  | 0.42             | 0.79            | 78             | 111        | 134.5           | 277             | 18              |
| -200    | 76               | 0.07                  | 0.21             | 0.56            |                | \          | \               | \               | \              |
|         | 75               | 0.05                  | 0.20             | 0.56            |                | \          | \               | \               | \              |

It can be clearly found from the table that the content of -20μm full tailings is 18%. The concentration of 76% have the highest strength, and yield stress is 300 Pa, viscosity is 249 Pa·s, expansion is 63 mm, slump is 19.5 cm, bleeding rate is 12.2%. In addition to high bleeding rate
indicators, the other performance indicators are in line with the requirements.

The mine mainly adopts the mechanization to the horizontal road cementing filling mining method, therefore in the process of mining the required strength of the filling body is higher, and the choice of full tailings filling can better meet the mining method requirements that both reduce the tailing dilution and ensure the safety of recovery.

5. Conclusion

Through the experiment, it is concluded that the grading of the full tailings of the Jiaojia Gold Mine is the best, and the comprehensive index of the full tailings paste filling is higher than graded tailings high concentration cementation filling. The full tailings paste filling of 76% mass concentration has the best comprehensive index of slump, expansibility, yield stress and viscosity to meet the mining method requirements, and can effectively reduce the mining loss rate and dilution rate.

The use of full tailings paste filling not only improves the strength of the filling body, reduces the rate of depletion of the production, but also reduces the emission of fine tailings, the burden of tailings, the cost of tailings construction and the security risks.

But the test is only laboratory data, due to conditions, no loop test and industrial test is taken. But there will be loop test and industrial test in the next step based on the specific circumstances of the mine or outside association, to service for the mine filling technology.

References
[1] Zhongliang Y. Comments on the mine fill gel materials. World mining express 1996; (10):17-20.
[2] Shihu S, Lisheng Y and Haoyu L. Research and application of complete tail-sand filling technique. China Mine Engineering. 2009;38 (6): 50-52.
[3] Zhexiang H, Kaiwei X and Aimin Z. The research and practice of full tailings consolidation technique. T NONFERR METAL SOC. 1998.8; (4):739-744.
[4] Aimin Z. Consolidation of mine waste. Metallurgical Industry Press. 2007.
[5] Dianhua L and Xianzhen W. Application and development of full tailingss filling technology. World Nonferrous Metal. 2012; (8):44-45.