Test and research on red mud used in bauxite washing mud solidification

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Abstract. Bauxite washing mud is the high water content and strong fluidity material. After being dehydrated to water content of less than 40% with dehydrating agent, it is still in a flow-plastic state. In order to eliminate the potential safety hazards of washing mud pond, it can be solidified. In order to solidify Pingguo bauxite washing mud, Prepared of curing agent with red mud, cement, fly ash and desulfurization gypsum, then added into the washing mud at a weight ratio of 10% of the dry amount of the washing mud. This study shown that after adding curing agents, the water content of the washing mud is further reduced, the liquid limit and plastic limit are further increased, the particle size is increased, and the plastic state is changed to a hard state, which greatly reduces the safety hazards of the washing mud pond. Through the screening test of curing agent, this study found that the reasonable and effective curing agent formula is: 15% fly ash, 25% cement, 15% gypsum, 45% red mud, the liquid limit index of the cured material is reduced to -0.27, which is in a hard state, the clay washing mud was changed to clay loam, which is suitable for dry tailings storage.

Keywords: Bauxite washing mud, red mud, water content

1. Introduction
The mineral components of bauxite washing mud are mainly kaolinite, diaspore, hematite, etc., which belong to the category of clay, with extremely fine particle size, high water content and strong fluidity. After dehydrated to water content of less than 40% using dehydrating agent [1], it is still in a flow plastic state. After entering washing mud pond, it is easy to sink. In order to eliminate the safety hazards of entering the washing mud pond, it can be solidified.

Regarding the solidification of bauxite, lime, fly ash, cement and other materials are mostly used at home and abroad, and the principle of hydration reaction is used to improve its strength. Du Changxue conducted research on the physical and mechanical properties of bauxite washing mud and solidification technology. After screening the curing agent formula, he found the curing agent formula of Pingguo bauxite washing mud: lime 72%, gypsum 20%, fly ash 5%, sodium sulfate 3%. The 28d strength of curing test block can reach 5.27MPa [2]. Tang Zhenhong conducted research on the physical and chemical properties and curing mechanism of Guangxi Pingguo bauxite washing mud. Using fly ash, lime, cement, and gypsum as washing mud curing agents, the flexural strength and compressive strength of 3d, 7d and 28d were measured, The maximum compressive strength is 4.8MPa [3]. At present, there is no relevant research on the solidification effect of the washing mud using the solid waste red mud of the
bauxite mining enterprise. This paper investigates the solidification test effect of Pingguo bauxite washing mud by using red mud, fly ash, desulfurization gypsum, and auxiliary with cement compounding, and explores the solidification and dry-tailings stacking scheme of bauxite washing mud.

2. Test part

2.1 Samples, reagents and instruments

Bauxite washing mud and red mud samples are from Pingguo Aluminum Company. X-ray diffraction analysis was performed on the bauxite washing mud and red mud samples. The analysis results are shown in Figure 1 and Figure 2.

![Figure 1. X-ray diffraction pattern of washing mud](image1)

![Figure 2. X-ray diffraction pattern of red mud](image2)

It can be seen from Figure 1 that the mineral composition of the washing mud is mainly diaspore (Al(OH)₃) and kaolin (Al₂Si₂O₅(OH)₄). It can be seen from Figure 2 that the mineral composition of red mud is mainly hydrated garnet (CaO·Al₂O₃·SiO₂·nH₂O), hematite (Fe₂O₃).

The fly ash used in the test is from a power plant, the desulfurized gypsum is from Shao Smelter, and the cement is ordinary Portland cement.

The experiment uses a cement mixing tank for mixing.

2.2 Test principle and method

(1) Test principle

Choose Bayer red mud, cement, fly ash and desulfurized gypsum to solidify bauxite sludge. Cement contains dicalcium silicate, tricalcium silicate, tricalcium aluminate, tetracalcium aluminate and other compounds. When it meets water, the hydration reaction is activated. The products are calcium hydroxide and acid crystals of hydrated calcium silicate, hydrated calcium aluminate and hydrated aluminum sulfate, which solidified the sludge; the main components of fly ash are SiO₂ and Al₂O₃. The vitreous in fly ash has potential activity. Calcium hydroxide, one of the cement hydration products, can interact with active SiO₂ and Al₂O₃ in fly ash to generate calcium silicate hydrate and calcium aluminate hydrate gel. Therefore, cement is usually used as the active activator of fly ash; Desulfurized gypsum can interact with cement, fly ash and washing mud, forming needle-shaped ettringite, which can improve the strength and water stability of the solidified body; the Bayer red mud developed
hydrogel properties under the excitation of cement and desulfurized gypsum. At the same time, the alkalinity of the bayer red mud will further stimulate the activity of fly ash. Based on the above principles, a red mud-based curing agent is prepared.\[2,3]\n
In addition, after the solidified material is mixed with the sludge, the high-valent cations released by the hydration reaction, such as Ca$^{2+}$, Fe$^{2+}$, and Mn$^{2+}$, can enter the colloidal particle diffusion layer and adsorption layer of the soil, and neutralize the negative charge on the surface of the colloidal core. The zeta potential is lowered, the electric double layer is compressed, and the soil particles gather into larger aggregates, which are denser. The free water is used for further hydration reaction, so that the water content of the mud decreases, achieving the effect of settlement and solidification.\[4]\n
The liquid limit index is an index for judging the soft and hard state of soil. According to the size of the liquidity index, the state of the soil is classified as follows, liquid limit index $\leq$ 0 is hard; 0 $<$ liquid limit index $\leq$ 0.25 is hard plastic; 0.25 $<$ liquid limit index $\leq$ 0.75 is plastic; 0.75 $<$ liquid limit index $\leq$ 1 is soft plastic; liquid limit index $>$ 1 is flow plastic.

According to the content of clay particles, the texture of soil is divided into three categories: less than 15% is sandy soil and loam; 15%-25% is clay loam; and clay content greater than 25% is clay.

(2) Test method

After consulting relevant information, for economic considerations, the amount of curing agent added is set to 10% of the total dry mass of washed mud, that is, 500g of washed mud and 50g of curing agent. Selected bayer red mud, fly ash, cement, and desulfurized gypsum as ingredients, the curing agent ratio scheme is shown in Table 1.

Weighing 500g dry-bauxite washing mud, and prepare it into washing slurry with a weight moisture content of 40%, then added fly ash, cement, gypsum, and red mud, stirred uniformly and stand for solidification, and determine the moisture content, liquid limit, plastic limit, liquid limit index, clay content of the solidified body after 48 hours.

| Test number | Fly ash Proportion % | cement Proportion % | desulfurization gypsum Proportion % | bayer red mud Proportion % |
|-------------|----------------------|---------------------|-----------------------------------|---------------------------|
| 0           | 0                    | 0                   | 0                                 | 0                         |
| A           | 10                   | 10                  | 10                                | 70                        |
| B           | 15                   | 25                  | 15                                | 45                        |
| C           | 15                   | 10                  | 15                                | 65                        |
| D           | 10                   | 15                  | 15                                | 60                        |
| E           | 15                   | 20                  | 15                                | 50                        |
| F           | 20                   | 15                  | 10                                | 55                        |

3. Test results and discussion

3.1 Test results and analysis

The curing test results and analysis are shown in Table 2 and Figure 3.

It can be seen that without curing agent, the liquid limit index of the washing mud is 0.42, which is in a plastic state. After the curing agent is added, the water content of the filter cake is further reduced due to the chemical reaction, and the liquid limit and plastic limit are increased. After curing, The liquid limit index is reduced to less than 0, which means that the fluidity of the washing mud is reduced and it is in a hard state, the volume does not change with external force, which greatly reduces the potential safety hazards, and the content of clay particles decreases, which means that the particles increase.

Plan B has the most significant effect. Compared with the blank sample without curing agent, the water content reduction rate is 13.93%, reaching 24.10%, the liquid limit increasing rate is 27.57%, reaching 54.27%, and the plastic limit increasing rate is 67.03%. Reaching 30.48%, the liquid limit index reduction rate is 164.29%, reaching -0.27, which is a hard state, and the clay content reduction rate is 36.63%, reaching 24.6%, which becomes clay loam, which meets the requirements of dry tailings
Therefore, it is determined that the best ratio of washing mud curing agent is Option B, namely 15% fly ash, 25% cement, 15% gypsum, and 45% red mud.

![Figure 3. Curing test results graph](image)

### Table 2. Analysis of curing test results

| Test number | 0   | A     | B     | C     | D     | E     | F     |
|-------------|-----|-------|-------|-------|-------|-------|-------|
| Water content % | 28  | 24.34 | 24.1  | 25.15 | 24.48 | 24.14 | 24.19 |
| moisture content reduction rate compared to the blank test | /   | 13.07%| 13.93%| 10.18%| 12.57%| 13.79%| 13.61%|
| Liquid limit | 42.54| 49.35 | 54.27 | 49.55 | 49.7  | 48.32 | 48.43 |
| Liquid limit increase rate compared to the blank test | /   | 16.01 | 27.57%| 16.48%| 16.83%| 13.59%| 13.85%|
| Plastic limit % | 17.65| 27.83 | 30.48 | 26.84 | 27.1  | 24.58 | 26.19 |
| plastic limit increase rate compared to the blank test | /   | 57.68%| 67.03%| 52.07%| 53.54%| 39.26%| 48.39%|
| Liquid limit index | 0.42 | -0.16 | -0.27 | -0.07 | -0.12 | -0.02 | -0.09 |
| Liquid limit reduction rate compared to the blank test | /   | 139.00%| 164.29%| 117.90%| 127.88%| 104.46%| 121.63%|
| Status | plastic | hard | hard | hard | hard | hard | hard |
| Clay content % | 40.4 | 38.8  | 24.6  | 26.6  | 25.2  | 30.4  | 30.6  |
| Reduction rate of clay content compared to the blank test | /   | 3.96% | 36.63%| 34.16%| 37.62%| 24.75%| 24.26%|

### 3.2 Characterization of performance before and after curing

Scanning electron microscopy was used to analyze the original washing mud and the solidified body of Scheme B.

According to the scanning electron microscope observation, the original microstructure of the washing mud is shown in Figure 4.
Figure 4. SEM of washing mud before and after solidification

It can be seen from Figure 4 that the original microstructure of the washing mud is open and loose, so it can be regarded as an "overhead structure". After solidification, the crystal morphology is mainly fibrous and needle-like, and the structure between the crystals is denser than the original, and the porosity is low, which confirms the hydration products of calcium silicate hydrate, calcium aluminate hydrate, and ettringite, which cement the particles in the soil, resulting in a dense and hard solidified body.

4. Conclusions
The solidification test was carried out for Pingguo bauxite washing mud. When the water content of the washing mud is less than 40%, mixing the curing agent at a weight ratio of 10% of the dry amount of the washing mud, and the curing agent is compounded of bayer red mud, fly ash, cement, and desulfurized gypsum. Through the screening test of curing agent, it is found that the best formula of reasonable and effective curing agent is: 15% fly ash, 25% cement, 15% gypsum, and 45% red mud. Compared with the blank sample without curing agent, the water content reduction rate is 13.93%, reaching 24.10%, the liquid limit increasing rate is 27.57%, reaching 54.27%, the plastic limit increasing rate is 67.03%, reaching 30.48%, and the liquid limit index is reduced, the rate is 164.29%, reaching -0.27, which is a hard state, and the reduction rate of clay content is 36.63%, reaching 24.6%, which becomes clay loam, which meets the requirements of dry tailings storage. Although this solidification scheme greatly reduces the fluidity of the ore-washing mud and reduces the potential safety hazard of washing mud pond, because the curing agent is made up of alkaline substances, the pH of the solidified washing mud increases. How to deal with this problem is the next step research direction.

Acknowledgement
National Natural Science Foundation of China –Key projects: In-situ remediation and mechanism study of complex multi-pollutants in groundwater of metal mine tailings pond (0102-1901)

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