Integrated Disposal of Paste Backfill and Surface High-concentration Tailings Stacking at Chambishi Copper Mine

Aixiang Wu[1], Zhuen Ruan[2*], Shenghua Yin[2], Yong Wang[2], Yiming Wang[2], Shaoyong Wang[2] and Bingheng Yan[2]

1. *Key Laboratory of High-Efficient Mining and Safety of Metal Mines of the Ministry of Education, University of Science and Technology Beijing, P.R. China*
2. *School of Civil and Resource Engineering, University of Science and Technology Beijing, P.R. China*

ABSTRACT

Inspired by the success of cemented paste backfill in the west orebody of Chambishi Copper Mine, integrated disposal of paste backfill and surface high-concentration tailings stacking was applied in the southeast orebody. This paper presents the integrated disposal system, including two deep cone thickeners, double-shaft horizontal mixer, two plunger pumps for underground backfill and three diaphragm pumps for surface stacking. The challenges of the integrated disposal system were deep backfilling (0.98 km) and long-distance discharging (15 km), so a combination of gravity flow and pumping was used in paste backfill and three diaphragm pumps with a preset pressure of 7 MPa were applied for surface stacking. The annual ore production in the southeast orebody is 3.3 Mt, which is 3.3 times larger than that of the west orebody. Therefore, the capacity of the integrated disposal system also needs to be expanded. The capacity of the paste backfill system and surface stacking system were 160 m^3/h with paste concentration of 75 wt.% and 265 m^3/h with slurry concentration of 55 wt.%, respectively. In the first phase, the cement to tailings ratios for primary and second stopes are 1/8 and 1/24 respectively. To meet the backfill strength and reduce the cost, waste rock will be added in paste backfill in the second phase, the waste rock to tailings ratio is 1/3, the cement to tailings and waste rock ratio for primary stopes are 1:12, and 1:30 for secondary stopes. As a result, the UCS after 28 days for primary and second stopes were 1.2 MPa and 0.5 MPa, respectively.

INTRODUCTION

The Chambishi Copper Mine is located in the central part of the Zambian copper belt, about 30 km from the border between Zambia and the Democratic Republic of Congo and 360 km from the capital Lusaka. The deposit was formed in low brown group sedimentary rock and it is one of the world's largest sedimentary deposits. It is made up of three ore bodies – the main, the west, and the southeast. The annual ore production in the southeast orebody is 3.3 Mt, which is 3.3 times larger than that of the west orebody. Led by University of Science and Technology Beijing, cooperated with China ENFI and equipment manufacturers, the first cemented paste backfill (CPB) system in Zambia was built up in the west ore body in 2013 (Li et al., 2017; Wu et al., 2015). Inspired by the success of CPB in the west orebody, integrated disposal of CPB and surface high-concentration tailings stacking was applied in the southeast orebody.

However, more restrictions were faced in the southeast: higher capacity, higher strength, and lower cost. High annual ore production calls for a higher capacity of CPB to achieve a short process cycle of intensive "excavation—stoping—backfilling—transportation". High ground stress and surrounding rock destabilization require higher strength. Low ore grade requires strict cost control to increase profit. To overcome the restrictions above, integrated disposal was applied.

MATERIAL CHARACTERISATIONS

2.1 Specific Gravity

The specific gravity (SG) of tailings and waste rock were measured to be 2.77 and 2.54, respectively.

2.2 Particle Size Distribution

The particle size distribution (PSD) of tailings is shown in Table 1. The waste rock was ground to under 10 mm, the PSD is shown in Table 2.

Table 1 PSD of the tailings

Particle size/micron	**+0.18**	**-0.18~ +0.125**	**-0.125~ +0.09**	**-0.09~ +0.074**	**-0.074~ +0.043**	**-0.043~ +0.038**	**-0.038~ +0.025**	**-0.025**
Content/%	19.24	8.90	3.63	5.40	12.93	4.24	10.27	36.39

Table 2 PSD of the waste rock

Particle size/mm	**-10~ +5.6**	**-5.6~ +2.8**	**-2.8~ +1**	**-1~ +0.5**	**-0.5~ +0.2**	**-0.2~ +0.1**	**-0.1~ +0.074**	**-0.074**
Content/%	17.53	23.33	14.83	10.59	12.20	12.88	3.10	5.53

2.3 Tailings Flocculation and Sedimentation

On the basis of the flocculant selection experiment, Magnafloc 5250 from BASF is suitable for the tailings (quickly settling and relatively less dosage). The optimal concentration range of tailings slurry after diluted by the feedwells is 10 wt.%~15 wt.%, with the optimal flocculant dosage of 15g/t~20g/t. Under the optimal flocculation conditions, the concentration of underflow was 69.74 wt.% after sedimentation of 48 h in the settling cylinder. Inspired by the rake in deep cone thickener (DCT), a self-made rake was applied to enhance the tailings thickening. The concentration of underflow reached 75.53 wt.% after dynamic compaction of 4h, which is 9.04% higher than the limit concentration of static sedimentation.

2.4 Slump and Uniaxial Compressive Strength

2.4.1 *Tailings + Cement*

For the first phase, Ordinary Portland Cement 42.5 R was added to improve the strength. The slump and uniaxial compressive strength (UCS) were tested under a concentration of 74 wt.%, 75 wt.%, 76 wt.%, 78 wt.% and a cement to tailings ratio of 1/24, 1/20, 1/16, 1/12, 1/8. The slump results are shown in Figure 1, illustrating that the fluidity is satisfactory when the concentration is 74 wt.%~76 wt.%. However, it gets worse when the concentration increased to 78 wt.%.

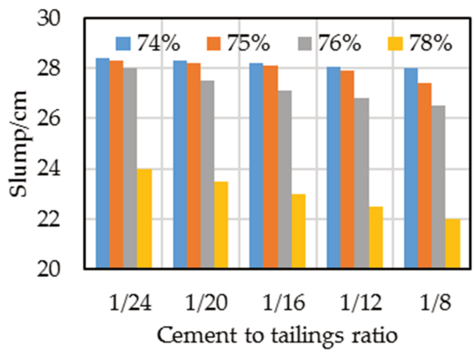

Figure 1 Slump of cemented tailings

The UCS results are shown in Figure 2. When the cement to tailings ratio is 1:24, the UCS after 7 days is greater than 0.3 MPa, and after 28 days is greater than 0.5 MPa, which meet the requirement of self-supporting. When the ratio is 1:8, the UCS after 28 days is about 1 MPa, which meets the requirements of the primary stope.

2.4.2 *Tailings + Waste Rock + Cement*

To meet the backfill strength and reduce the cost, the waste rock will be added to CPB in the second phase. When the cement to tailings and waste rock ratio is 1/12 and the waste rock to tailings ratio is

1/4, the slump and UCS results were tested as shown in Figure 3 and Figure 4, respectively. With the increase of concentration, the UCS increased while the slump decreased. Especially when the concentration increased to 82 wt.%, the slump dropped sharply to 16 cm, which could not meet the transportation requirements.

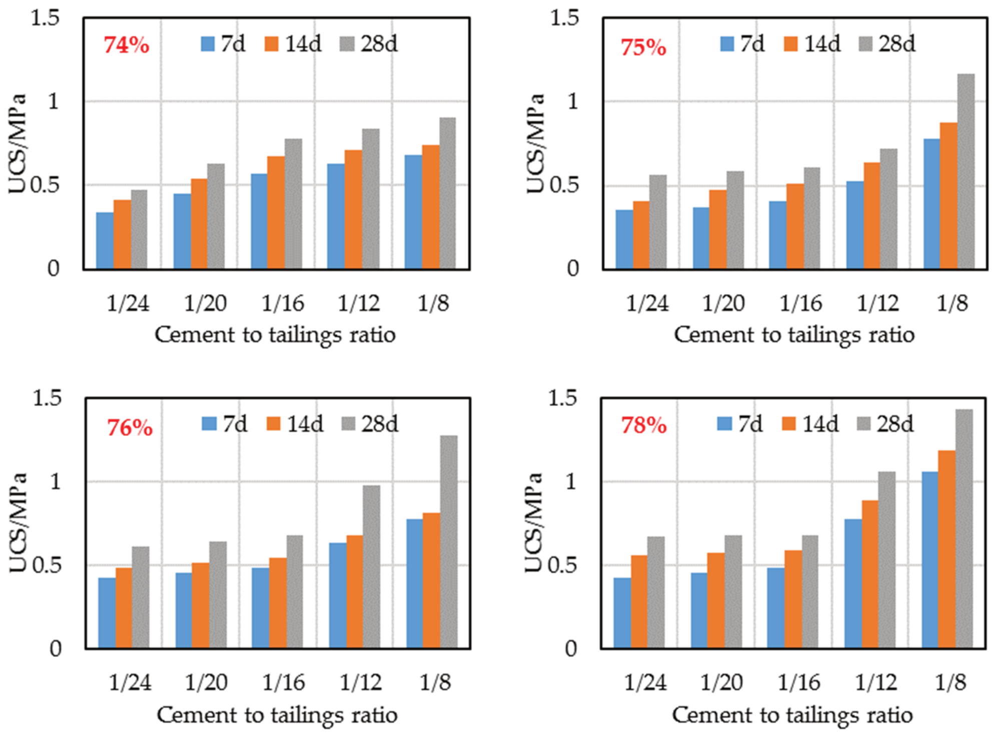

Figure 2 UCS of cemented tailings

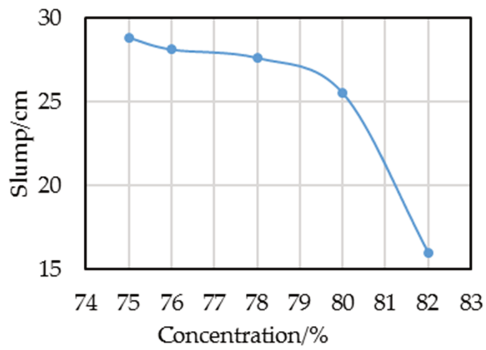

Figure 3 Slump of cemented tailings and waste rock

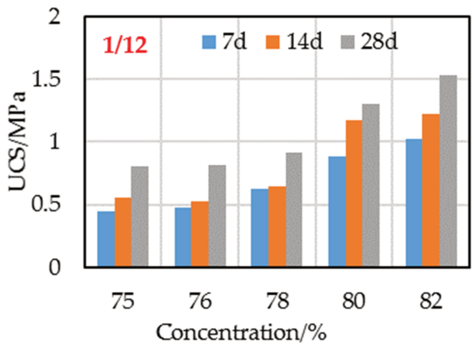

Figure 4 UCS of cemented tailings and waste rock

To improve the fluidity, the waste rock to tailings ratio was increased from 1/4 to 1/3. The slump of paste with a concentration of 78 wt.% and 80 wt.% increased from 27.6 cm to 28.1 cm, and from 25.5 cm to 27.2 cm, respectively. The UCS of paste with a concentration of 78 wt.% and 80 wt.% and a waste rock to tailings ratio of 1/4 and 1/3 is shown in Figure 5. When the waste rock to tailings ratio increased, the UCS increased.

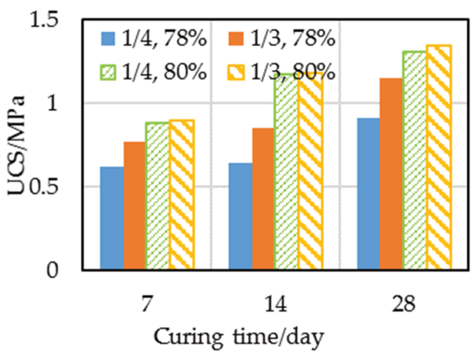

Figure 5 UCS of paste with different cement to tailings and waste rock ratios

Therefore, when the concentration is 78 wt.%~80 wt.%, the waste rock to tailings ratio is 1/4 to 1/3, the cement to tailings and waste rock ratio is 1/12, the UCS and slump can meet the requirement of the primary stope.

When the concentration is 80 wt.%, the waste rock to tailings ratio is 1/3, the cement to tailings and waste rock ratio was decreased to 1/30 for the second stope. The UCS after 28 days and slump were 0.56 MPa and 27 cm.

INTEGRATED DISPOSAL SYSTEM

The integrated disposal system is made up of two DCT, double-shaft horizontal mixer, two plunger pumps for CPB and three diaphragm pumps for surface stacking. The sketch of the system is shown in Figure 6. The capacity of the CPB and surface stacking are 160 m^3/h with a paste concentration of 75 wt.% and 265 m^3/h with a slurry concentration of 55 wt.%, respectively.

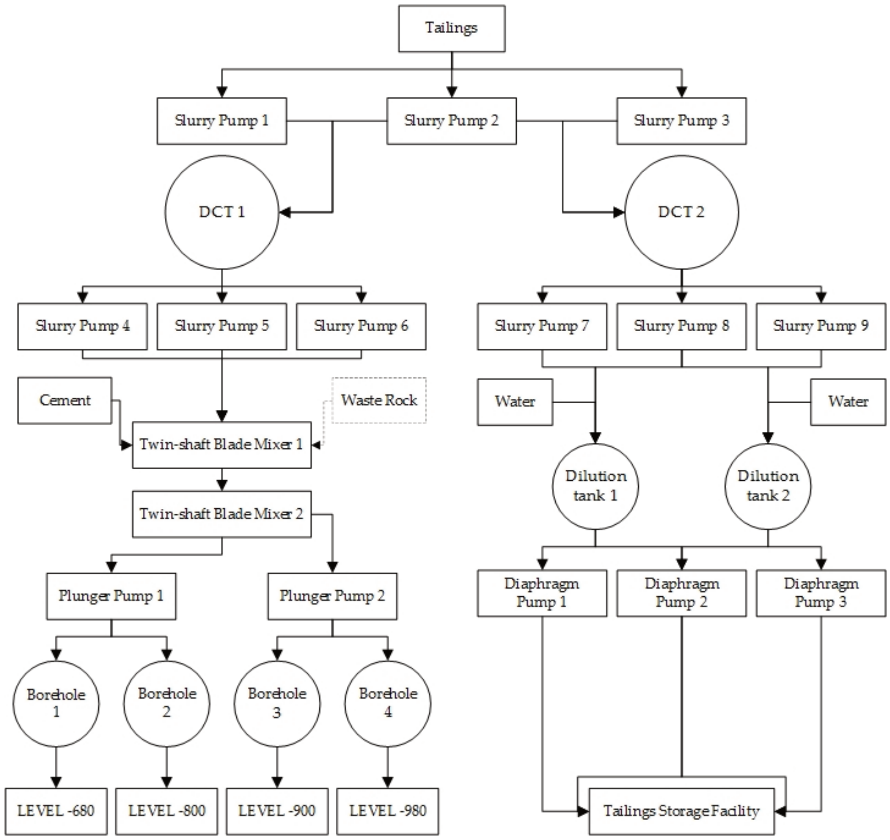

Figure 6 Sketch of the integrated disposal system

3.1 Thickening System

The thickening system is made up of two Φ 18 m DCT from FLSmidth, flocculant dissolving and dosing apparatus, and other auxiliary equipment. The capacity of the DCT is 5000 t dry tailings/d. The underflow of DCT for CPB and surface stacking are 72.8 wt.% and 72 wt.%, respectively.

3.2 Mixing System

The mixing system is made up of two-stages double-shaft horizontal mixers from FENY, cement addition system, and waste rock addition system (for the second phase). The volume and capacity of the mixer are 10 m^3 and 180 m^3/h. The cement to tailings ratio was controlled by new cement feeding with an anti-blocking structure.

For surface stacking, two dilution tanks are applied for diluting the underflow to 55 wt.%.

3.3 Reticulation system

3.3.1 *Reticulation system for CPB*

Because of two mining areas in the southeast orebody, the reticulation system for CPB is divided into two parts, as shown in Figure 7.

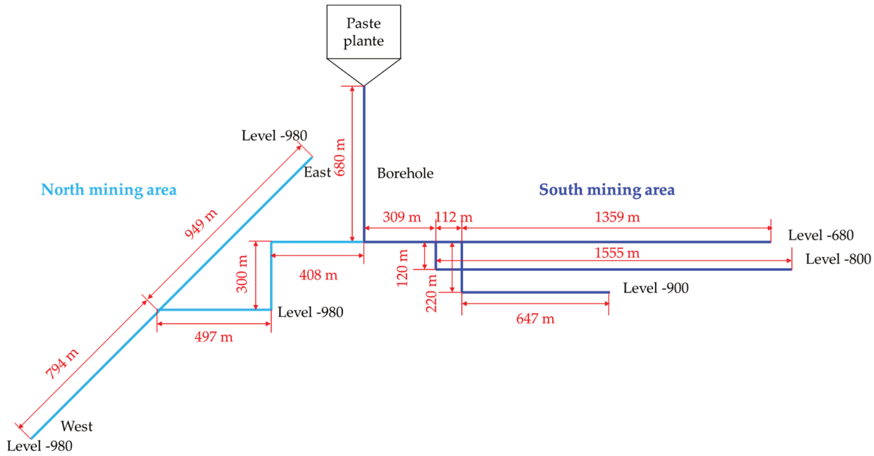

Figure 7 Reticulation system for CPB

The inside diameter of the pipe is 175 mm with a flow velocity of 1.85 m/s. When the concentration is 75 wt.% and cement to tailings ratio is 1/8, the yield stress and plastic viscosity of the paste are 158.188 Pa and 0.416 Pa·s. Based on Buckingham rheological equation, the friction losses calculated by equation (1) is 5624.57 Pa/m. The safety factor was set as 1.2, resulting in the friction losses increasing to 6749.48 Pa/m.

$$\frac{\Delta P}{L} = \frac{16}{3D}\tau_0 + \frac{32v}{D^2}\eta \tag{1}$$

where:

$\Delta P / L$ = friction losses, Pa/m.

v = velocity of the slurry, m/s.

τ_0 = yield stress, Pa.

η= plastic viscosity, Pa·s.

As for the south mining area, the outlet pressure was set as 0.5 MPa, the minimum inlet pressure for level -680, level -800, level -900 are calculated as 4.19 MPa, 3.28 MPa, and 0 MPa, respectively. As for the north mining area, the minimum inlet pressure for level -980 is 1 MPa. Consequently, gravity flow is suitable for level -900 while pumping transportation is required for level -680, level -800, and level -980. Two plunger pumps (one for use and one standby) with a pressure of 5 MPa from FENY are applied in the reticulation system for CPB.

3.3.2 *Reticulation system for Surface Stacking*

Three diaphragm pumps (two for use and one standby) with a capacity of 265 m^3/h from NSPI were applied for surface stacking. The pump pressure is 7 MPa with a rated power of 630kW. The distance of the discharge pipeline is about 15 km.

CONCLUSION

An integrated disposal system of CPB and surface stacking was applied in the southeast orebody of Chambishi Copper Mine.

- The capacity of CPB and surface stacking system are 160 m^3/h with paste concentration of 75 wt.% and 265 m3/h with slurry concentration of 55 wt.%, respectively.
- In the first phase, the cement to tailings ratios for primary and second stopes are 1/8 and 1/24, with UCS after 28 days of 1.2 MPa and 0.5 MPa, respectively.
- Two Φ 18 m DCT with a capacity of 5000 t dry tailings/d are applied. The underflow for CPB and surface stacking are 72.8 wt.% and 72 wt.%, respectively.
- Two-stages double-shaft horizontal mixers with a capacity of 180 m^3/h are applied for mixing in CPB. Two dilution tanks are applied for diluting the underflow from 72 wt.% to 55 wt.% in surface stacking.
- Two plunger pumps with a pressure of 5 MPa and three diaphragm pumps with a pressure of 7 MPa are applied for CPB and surface stacking, respectively. The biggest distance of the backfill pipeline is about 2.8 km. The distance of the discharge pipeline is about 15 km.

ACKNOWLEDGEMENTS

This research was funded by the National Natural Science Foundation of China (No. 51834001, 51804015).

REFERENCES

Li, H., Zhang, J., Zhang, D., Li, Z. & Hu, G. (2017) 'Paste pipeline transportation for Chambishi Copper Mine', *Proceedings of 20th International Seminar on Paste and Thickened Tailings*, Australian Centre for Geomechanics, Beijing, pp.393-401.

Wu, A., Miao, X., Liu, X., Wang, Y., Wang, C. & Zhang, J. (2015) 'Paste backfill system design and commissioning at Chambishi Copper Mine', *Proceedings of 18th International Seminar on Paste and Thickened Tailings*, Australian Centre for Geomechanics, Perth, pp. 301-308.