

The Short-Processing Tailing-Storage-Free Filtration Backfilling Method

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ABSTRACT

In order to meet the need of efficient backfills in some low grade and hard-to-recover mines, a new backfilling method named short-processing tailing-storage-free filtration backfilling method was invented by studying on the quantity and concentration control of filtrated slurry, as well as optimizing of mine operating flowchart and cyclone clusters. No tailing storage is required for this system; as a result, tailings can be transported to cyclone clusters directly. Generally, the concentration and production rate of the downstream inside the cluster is between 68% to 72% and 69% to 72% respectively. This downstream then flow directly down to the continuous mixers for the mixing with cement, and ultimately, was filled into the voids through underground reticulation systems and boreholes. The installation time for this system has been reduced to 4 months, while the capital investment and operating cost are also reduced by 70% and 20% respectively. The strength of the filling body, with ratio of cement to sand 1:4, can reach up to 3.2Mpa in 28 days. Therefore, this system can be effectively integrated with the overall mining sequence, balance the mineral extraction rate and processing rate safely, hence to improve the profitability of the mine.

Filling method is particularly cater for the mines which are complicated and hard-to-recovery, associated with poor external conditions and having some special requirements (Zhou, 2015 and Liu, X.S., 2015). The filtrated tailing backfilling method is the most widely used nonferrous mine filling method in China, and many Chinese mines have built the filtrated tailings cemented backfill system. This system utilize the cyclone cluster for tailing filtration, vertical tailing storage (most Chinese mines have two tailing storage silos which have volume between 800 and 2500m³), high pressure (wind) water for paste making, gravity-driving tailing inputs, continuous mixers, and ultimately fill the paste back into underground stopes. This backfill method is maneuverable and capable to produce high-concentrated and controllable filling paste which can always become sound filling body with high strength when solidified. However, it demand large capital costs of tailing storages and mixing systems, as well as lots of labour force; besides, the whole process is complex. In addition, the paste making would become hard when there are many coarser particles, as those particles always sink to the bottom and often lead to pipe plugging (Zhou, 2015 and Zhou, 2013).

SYSTEM REQUIREMENTS FOR FILTRATION MINE FILL

Filtrated tailing backfilling method is associated with the filling system that fills the so called filtrated tailings (coarse) into stopes, while transports fine particles to tailing dam. The operation and management for this system is simple. It do not have strict requirement about tailing fraction distribution; but, it do have high and stable tailing utilization rate. On the premise of no segregation, this system has the same cement amount consumption, but produces higher strength filling body. However, in case of segregation, it may heavily wear the pipes, easily blocks pipes and lead to the filling body heterogeneity, pollutes of underground tunnels and increases water and slurry drainage (Peng, 1998, Yue, 2013 and Liu, X.S. 2015).

When utilizing the filtrated tailing cemented backfilling method, efforts must been made to amplify its advantages and avoid segregation, that the tailing fraction must be allocated reasonably and tailing particles should be mixed intentionally. Also, proper control of paste transportation velocity and paste concentration is vital as it ensures that paste inside pipes and stopes remains even and tailings are fully mixed with cement. Thus, guarantee this paste is quickly solidified and the fill body is stable and with sound strength.

When utilizing the filtrated tailing uncemented backfilling method, backfilling slurry transportation must remain at reasonable quantity speed, and keep full-pipe-flow. Efforts must been made to accelerate the dewatering of paste filled already into stopes, thereby reduce the overall processing time.

SHORT-PROCESSING TAILING-STORAGE-FREE FILTRATION BACKFILLING METHOD

An iron mine in Anhui province has successfully installed and operating with the short-processing tailing-storage-free backfilling method. The mine is located alongside of Huai River, and the mine surface is serving for farmland and village. The ore body is covered by about 260m thick formation of the Quaternary Period with water layer; and classification of the geological condition is from bad to middle. Sublevel open stoping with backfilling and upward sublevel room-and-pillar with backfilling are utilized for this mine. The production rate and mineral processing rate are both 1.5 million t/y. Processing plant is located at south-west side of the mine and its flow sheets include both dry and wet selective separation, in which result some coarse particles are mixed into tailings. Recovery of tails is around 40%, tailing concentration is around 10% and paste production rate is around 800 m³/h. The artificial tailing dam locates 1.2km south from infrastructure; and the dam elevation is 12m higher than it.

The last preliminary design combine the tailings cemented filling and uncemented filling, including of 3 sets of independent filling system with vertical tailings silo (3 tailings silos, 3 cement silos, 3 continuous mixers and 6 boreholes). Total capital investment accounts for about 45 million RMB.

Due to the low selling price of iron ore, low ore grade, complicated mineral extraction conditions and unsatisfied profits, the mine decided to make efforts in optimizing the backfilling system through avoiding surface subsidence and water penetration fracture from roof and achieving efficient filling. At

the same time, reducing system investments and operating costs are also essential for the improving of profit making. Needless to say, all those efforts should assure quality of filling body and mine safety.

The preliminary uncemented backfilling method, according to the mining conditions, is poor in dewatering and solidification. Thus, always lead to potential hazards and makes it not an ideal filling method for this mine. The cemented backfilling method, also, because of the large flow amount and low concentration of tailings (hard to sink, and especially, the tailings is transported to the Ø11m silo without any thickener and additives, the tailing utilization rate is always around 50%), cannot meet the demand of underground stope fills. After tailings are imported into the silo, the slurry making need the cooperation of highly compressed air and water, which is a complicated process with high cost. In addition, the coarse particles can easily sink to the bottom, which makes it difficult for stable tailings feeding. Moreover, this cemented filling exists some in slurry mixing and transportation, filling paste can easy segregate and block the pipe. Besides, with an uneven filling paste, the filling body is always uneven and with low strength. The most important is, the high investments and operation cost, are unaffordable for the mine.

Tailing fills need de-watering and thickening. Nowadays, the most common de-watering methods are associated with high investment; high operating cost; or the cycle water can be used by processing plant. Filtrated tailings can be de-watered and thickened by using cyclone clusters, which separates fine particles and most of water from paste. And the system investment is comparably low. This mine has built the tailings dam which is capable to store fine tailings (Liu, X.S. 2015, Liu, X.J. 2015 and He, 2005).

The key points of this filling method are the control of slurry flow rate and concentration, and then the particles ration. Because of high resistance of filling slurry and requirement of continuous filling, there are strict requirements on the pipeline diameter and flow rate. Slurry concentration is the key factor that ensures the filling body of filtrated cemented fills are not segregated and separated. The traditional tailing filtration process is start by tailing filtration by utilizing cyclone clusters; then coarse particles sink to the bottom, then continuous adding water and tailings, followed by paste making, then materials are mixed through the mixers and reach the ideal concentration and full pipeline volume for gravity flow. If the downstream of filtrated tailings can keep stable at the designed concentration and quantity flow rate, the materials can be sent into the mixer directly for mixing. In this way, the tailings silo can be canceled, so as to largely reduce the investment and production costs.

Through investigation and discussion, the management team decided to use the short-processing tailing-storage-free filtration backfilling method (see Figure 1). The tailings with 10% concentration from processing plant is fed to the top of mixing tower, blowing air with 0.15MPa pressure pushes the tailings into a cyclone cluster, which has the structure of cone angle 13°, upper diameter 350mm and bottom opening diameter 55mm for tailings filtration, and the tailings with 1-2% concentration from cyclones overflow is sent to tailings reservoir by gravity flowing for cycle use. The settling tailings concentration from cyclone cluster can reaches 68-72%, while coarse tailing production rate accounts for 69.44-72.44%. The downstream of filtrated tailings then be fed directly to intermediate chute (buffer tank) and flows down to the continuous mixer by gravity. In the mixer, a certain amount of cement is added. At

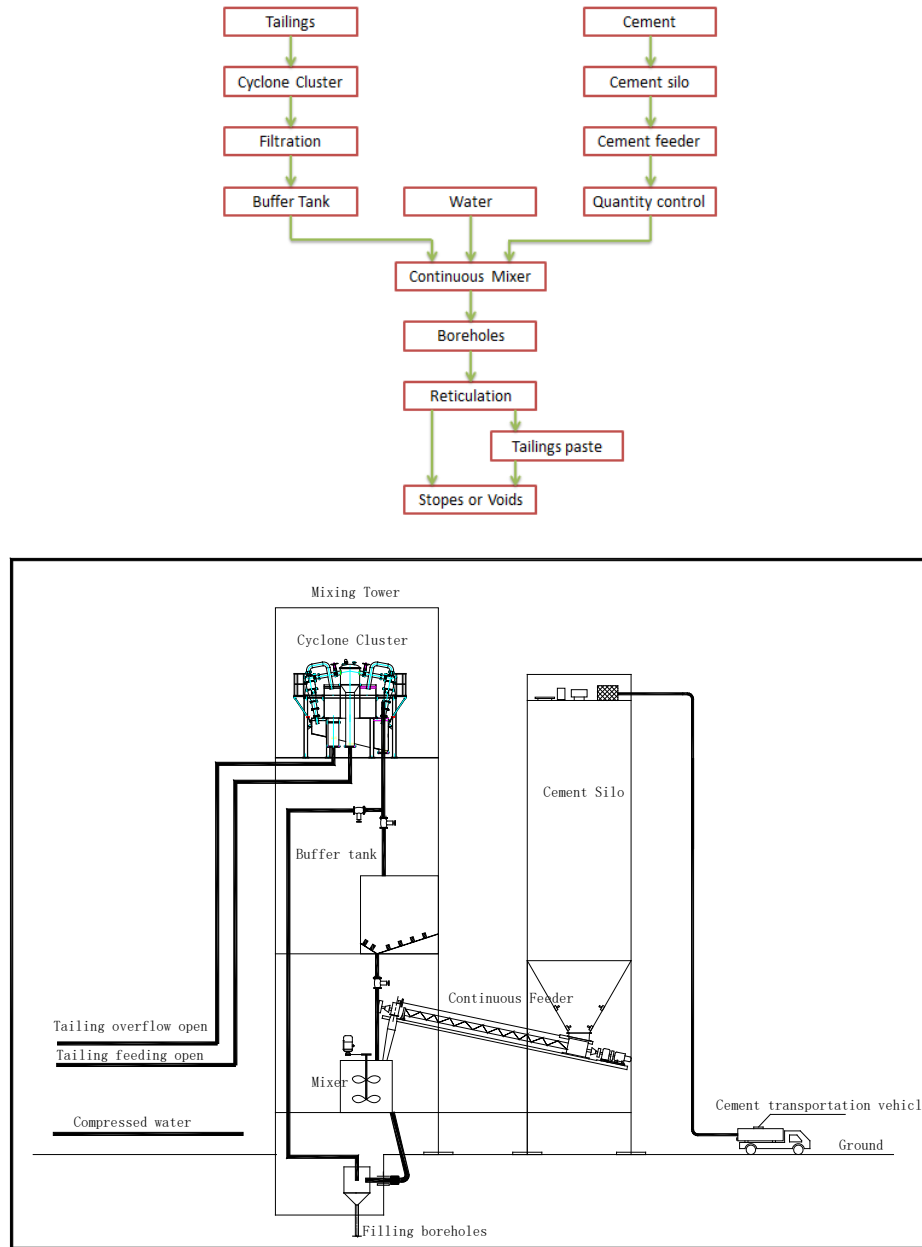


Figure 1. Flow chart of short-processing tailing-storage-free filtration backfilling and filling station

the same time, there always need to add some water (flow rate 0~5m³/h) for concentration adjustment. After high effective activation mixing, the filling paste can eventually reach a stable state with concentration 70-72% and flow rate 55-70m³/h. The prepared filling material slurry then flows through the metering pipe and nearby filling borehole, and finely reaches underground empty stope for filling. The transportation of slurry is driving by gravity or parts by pumping. In this way, the continuous filtrated tailing cemented filling is realized without the tailings silo, tailing storage and slurry preparation.

In order to ensure the high concentration, stable flow rate and stability of downstream from filling station, the properties of filling blinding and pattern of cyclone separation have been researched. It has been recommended a complex cone cyclone, which has the optimized material input opening, overflow opening and settling opening. With using this new cyclone cluster, the high concentration tailing downstream can be produced stably and satisfy the requirements of high concentration tailing filling can be satisfied.

For the purpose of preventing downstream in cyclone clusters from flow rate and concentration fluctuation due to ore grade variation and so does this on backfilling paste, a $\phi 3.0 \times 3.1$ m intermediate chute (buffer tank) is installed under the cyclone to adjust filling flow rate. In case of some filling operation problems occur, this intermediate chute (buffer tank) could help for troubleshooting within 0.5 - 2 hours, together with an emergence pond of filling borehole. Meantime, the base of cyclone is 5m higher than tailing dam and the tailings can flow down to tailing dam by gravity when there is no appropriate condition for backfilling.

The key aspects of the realization of this backfill method are the precise control of production rate combined with proper optimization of the cyclone cluster. It is because there is no tailing silo for buffers and adjustments (only need a buffer tank accounts for 10 m^3). The tailings from processing plant, however, are handled to filling station for paste making when there is a need for backfill; the other tailings, are transported to the stockpiles if no void is available for the fills. As a sequence, this method is poor in controlling and adjusting the backfill time and capacity, which requesting better mine planning and production management to balance the continuous mineral processing rate on the surface and discontinuous ore extraction and backfilling rate underground. Through optimization of mine production and management, the orderly cohesion of mining, mineral processing, backfilling and tailing treatment can be realized. The flowchart of mining using this new backfilling system can be seen in Figure 2.

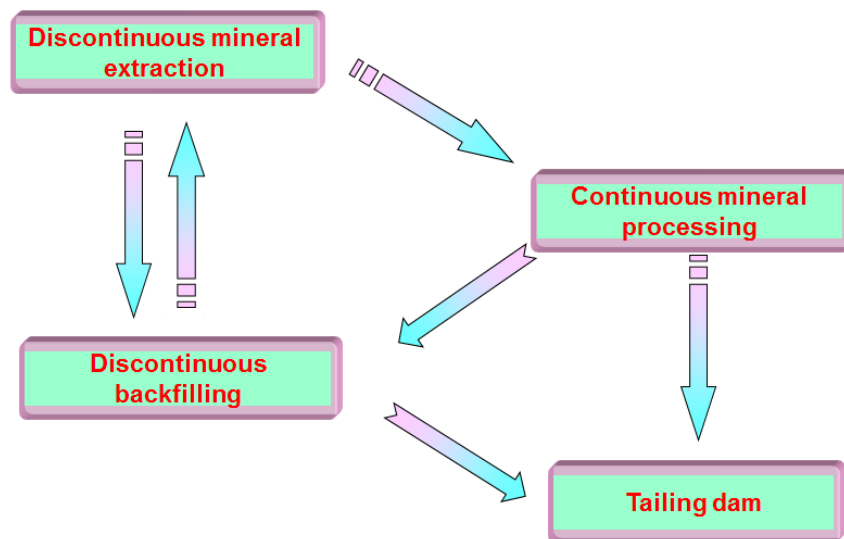


Figure 2. Mining circle with new backfilling method

Filling system configurations:

- Filling slurry concentration: 70%±1% (could be lower in uncemented filling)
- Capability of filling slurry preparation and transportation: 65m³/h
- Annual filling capability: 440,000m³/a
- Transportation Method: gravity flow
- Operation time: depends on the requirements of mineral extraction rate and processing rate
- Ratio of cement to sand: 1:4 (uncemented filling)

OPERATING PERFORMANCE

Generally, the new filling station could be constructed within 4 months after the mine fill system is designed. Then, the priority is to optimize each components of operating process. First, mineral production rate can be increased. The mining method for the mine are changed from open stoping method to cut-and-fill stoping method; with less concern about stope stability, the mineral extraction rate can be improved and the mine planning can also be optimized through adding some planned stopes and planned filling stops. Second, water adding to the process can be reduced. This new system require new balance between processing rate and water adding rate, so as to making each operating point consumes minimum and stable water, and making the downstream with high quantity speed and stable concentration. Third, monitoring system on filling station should be installed and integrate to the overall mine monitoring system, which comprehensively control the ore production, mineral processing and waste dumping.

After adjustment and operation, the filling slurry concentration rate can reach 70% ~ 72%; the capacity of preparation and conveying filling paste is 60 ~ 65 m³/h, the annual filling capacity is 440,000 m³; the strength of the filling body, with ratio of cement to sand 1:4, is 1 MPa after solidified, and can increased up to 3.2 MPa on the 28th day. The whole filling system is capable to operate at 330 d/y and 24 h/d, realizing continuous short-processing tailing-storage-free filtrated backfilling.

The capital cost of this backfilling system is around 7 million RMB (including filling pipes and borehole drillings), that only accounts for 30% of the investment of general backfill system with the same filling production rates. Labor force for the filling station accounts for 14 people, 4 per shift, totally 3 shifts plus 2 administrators. The cost for paste (cement to sand 1:4) making is about 93 RMB/m³, which is only 80% of those in similar mines (Lian, 2014).



Figure 3. Flow chart of short-processing tailing-storage-free filtration backfilling and filling station



Figure 4. Filling paste inside boreholes (already added cement and fully mixed)



Figure 5. Solidified filling body with underground stopes

CONCLUSIONS

Recently when the mineral extraction goes down deeper underground and becomes more complex in exploitation conditions, and the proportion of low grade and hard-to-recovery ore are increasing, many mines have to raise their producing expenditures accordingly, making the profit earning more challenge. The short-processing tailing-storage-free filtration backfilling method have cancelled the large vertical tailing silo and thickener, this have consequently reduced many land and space usage, as well as the capital cost. Besides, the overall construction time is quite short. All devices are integrated vertically in the mixing tower, while the operation, management and maintenance are safe and convenient with less additional work. This new backfilling system have avoided some complex processes including the traditional tailing input, settlement, overflow and output in tailing storage, but simplify the overall process. No air compression device is required for slurry making; hence the energy consumption can be reduced. The success of using this new backfilling method in this iron mine indicates a technical and engineering demonstration for the similar mines and offers the hard-to-recover mines more economic choice. Currently this method has been applied for patents (Lian, 2014) and promoted in China.

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