Backfill Technology of Mining under the Seafloor in China

——A Case of Seawater Hydraulic Filling with High Concentration of Total Tailings

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Abstract: As the first metal mine where mining is conducted under the seafloor in China, Xinli gold Mine is located at the side of Bohai Bay in Shandong Province. In order to prevent the displacement or collapse of host rock affected by mining activity, avoid mine flooding accident of seawater bursting into mine excavations, seawater hydraulic filling with high concentration of total tailings was conducted to control deformation and displacement of host rock around a stope, avoid surface subsidence, increase ore recovery, and improve safe working condition. Preferentially, cut-and-fill stoping is performed. A series of lab testing results show that total tailings (or cemented total tailings) can be placed in the mined domain. In practice, dilute slurry from mill plant are pumped directly and continuously to tailing silos and densified by tailings settling down naturally. A combined compressed air-and-seawater slurrying technique in filling station is optimized to increase pulp concentration. Dewatering facilities in stope pick up dewatering speed and the inclined-face filling method is implemented to restrain slime conglomerating on the surface of filling body. As results, the utilization factor of total tailings is up to 90% during test of unclassified tailings filing or cemented filing, the concentration of filling slurry that is transported by gravity is 73% to 75%, and later work in stope can be done in 3 days after filling.

Keywords: China; under seafloor mining; total tailings backfill; seawater hydraulic; technology

1. Introduction

The crucial issues of mining under the seafloor is how to prevent the displacement or collapse of host rock affected by mining activity, avoiding the mine flooding accident of seawater bursting into the interior mine excavations. Backfilling plays a main role in controlling deformation and displacement of host rock around a stope, and filling method is an effective method to avoid surface subsidence, increase ore recovery, and improve safe working condition. If the quality of filling body was poor and could not control the deformation or displacement of wallrock, mine flooding accident will occur likely, and the seawater bursting into the interior mine excavations will induce mine flooding accident with serious casualties and loss of property.

The development of mine backfill technology is to satisfy the requirements of mining industry. Back-filling method, as a kind of the artificially supported mining methods, could improve the safe working conditions, obtain the maximum ore recovery. The filling body could provide supporting power for the host rock of mined-out space, restrain the deformation of country rockmass and prevent the subsidence of ground surface. It is ideal if the mill tailings can be totally placed underground to produce a competent support for mining excavations and reduce the upper discharge of waste residue. Many investigators have reported the use of total tailings as a suitable materials for mine backfilling [1~6]. Optimization of mine backfill systems refers to the most cost-effective means of improving the operational efficiency of backfill-reliant mines. The optimizing practices carried out involve the processes of improving mine fill performance while reducing production cost [7~9]. An experimental study on technology and circuit of unclassified tailings paste filling, carried out in Nanjing Xixiashan Lead-zinc-silver Mine where mining is conducted under surface water body, building or railway [10, 11].

Xinli Gold Mine which is located at the side of Bohai Bay in Shandong Province, is one of the biggest gold mines and also the first metal mine in China where mining operation is carried out under the seafloor bedrock. The geological reserve of the deposit in this mine is very big, and the key commercial ore bodies lie in the bedrock stratum under the sea-bottom. The crucial issue is how these reserves could be safely and economically extracted from its special mining conditions during the total life of this mine.

This paper elaborated the results of tests and engineering practice on total tailings backfill at the condition of

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seawater hydraulic fill in mining under seafloor, and certain guidance is expected to mining operation of similar mines.

2. The effects of material properties on backfill behavior

2.1 Lab testing and experiment of unclassified tailings

(1) Size-consist determination of unclassified tailings

The effectiveness of any type of backfill for underground support depends on the inherent material properties, slurry concentration and conditions of placement. Particle sizes and gradation play important role in the mechanical properties and behaviour of solid-like materials including backfills [12].

Particle size analysis of the tailings is performed to estimate the fluidization effectiveness of tailings slurry. In order to research the backfilling properties of unclassified tailings, the particle gradation is needed to be analyzed first. The results of size compositions of a certain weight of unclassified tailings that were sieved by watering method are shown in Table 1.

Table 1. Size compositions of unclassified tailings

size grade (mm)	> 0.177	0.177 ~0.122	0.122 ~0.098	0.098 ~0.074	0.074 ~0.045	< 0.045
Proportion (%)	31.49	7.75	6.97	7.07	8.32	38.48

The results of griddling show that the proportion of fine size grades less than 0.074mm in unclassified tailings was 46.8%, compared with other gold mines, this ratio was bigger than that of them.

(2) Settlement test of unclassified tailings

In order to make an approach to the natural settling characteristics of tailings slurry and provide parameters to define the filling pulp concentration, the natural settling test of classified and unclassified tailings slurry with maximum concentration was conducted by the following steps: 1) getting a certain weight of tailings, adding enough seawater and stirring them uniformly; 2) settling the slurry for 24h; 3) draining off the clean water of upper layer, and the left settling body — water-saturated tailings achieved the maximal settling concentration. The maximal settling concentration could be calculated by the weights of water-saturated tailings pulp and dry tailings. The settling test of tailings was showed as Figure 1.

The test result showed that the maximal natural settling concentration of classified tailings slurry is 79.1%, and the unclassified tailings is 69.43%. So a reasonable filling slurry concentration of unclassified tailings could be determined at 70%.

(3) Dewatering properties of unclassified tailings slurry

In order to acquire the amount and the speed of dewatering of unclassified tailings slurry, a series of dewatering tests were carried out at different concentrations, such as 65%, 68%, 70% and 72%. The dewatering test results of unclassified tailings slurry are shown in Figure 2.

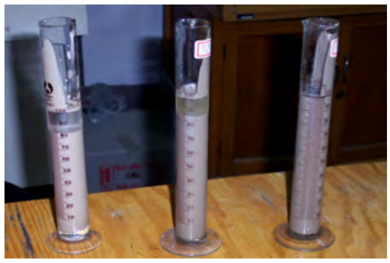

Figure 1. Settling test of tailings

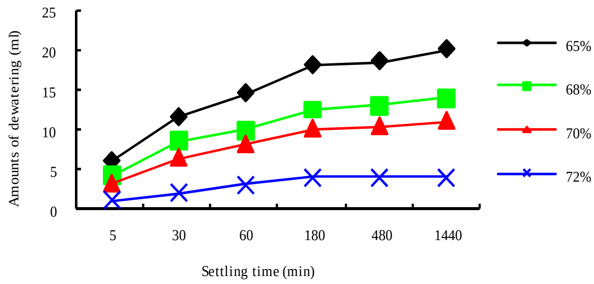

Figure 2 Relationship between time and dewatering content of unclassified tailings slurry at different concentrations

The test results show that no matter what kind of concentrations the unclassified tailings slurry is, it took about 3h to achieve the amount of more than 90% of final dewatering content, and the moisture content of slurry at each concentration settled finally was very close to that of the maximal settled concentration.

2.2 Consolidating properties of tailings cemented by different cements

(1) Consolidating test of Portland cement

In order to find the differences of cementation properties between unclassified and classified tailings, the Grade 32.5 Portland cement was used in the consolidating test. The slurry concentration was 65% and 70%, and the cement—tailings ratio was 1:10 and 1:8. The results are shown in Table 2.

Table 2. Strength test of tailings cemented by Portland cement

Specimen No	tailings	cement-tailings ratio	concentration, %	strength, MPa		
				3d	7d	28d
7	classified	1:10	65	0.351	0.43	0.772
8	unclassified	1:10	65	0.367	0.551	1.282
9	classified	1:10	70	0.53	0.822	1.737
10	unclassified	1:10	70	0.473	0.685	2.506
11	classified	1:8	65	0.405	0.767(10d)	1.001
12	unclassified	1:8	65	0.467	0.866(9d)	1.887
13	unclassified	1:8	70	0.476	0.953(9d)	2.639
14	classified	1:8	70	0.898	1.727(9d)	2.774

The conclusions drawn from the test results are as followings:

1) Under the same conditions, early curing-time strength of cemented classified tailings was as much as that of cemented unclassified tailings. No matter the cement—tailings ratio was 1:10 or 1:8, when the slurry concentration was 65%, the strength of unclassified tailings specimen was a little bigger than that of classified tailings' one, and, when the concentration was 70%, strength of classified tailings specimen was bigger. But the later curing-time strength was that the unclassified tailings specimen was bigger than classified tailings' one.

2) Compared with other mine, the strength of cemented unclassified tailings in Xinli mine is higher. So the unclassified tailings could be used in mining fill, the concentration of filling slurry might be about 70%, and the cement—tailings ratio might be about 1:10.

3) Because the grade of fine size included in unclassified tailings was more than classified ones, slurry prepared by unclassified tailings took on much better uniformity and flow ability, which would be very favorable to deliver via pipeline.

4) Unclassified tailings fill could improve the utilization factor of tailings greatly, and reduce the amount of tailings discharge on the ground surface.

(2) Consolidating test of the TSSCM

The SSCM, a kind of Total Sand and Solid Cemented Materials, has a better consolidating effectiveness in cemented tailings fill in other mines nearby Xinli mine. In order to compare the cementation effectiveness of the TSSCM with Portland cement, specimens were separately prepared with classified and unclassified tailings cemented by the TSSCM and the test results are shown in Table 3.

Table 3. Strength test of tailings cemented by TSSCM

Specimen No	tailings	cement-tailings ratio	concentration, %	strength, MPa		
				3d	7d	28d
15	unclassified	1:10	65	0.642	1.174	2.726
16	unclassified	1:10	70	0.786	1.628	3.363
17	unclassified	1:15	65	0.512	0.912	1.246
18	classified	1:10	65	0.492	0.495	2.210
22	classified	1:15	70	0.612	0.94	1.275

The conclusions drawn from the test results are as followings:

1) Under the same conditions, the TSSCM provides more better consolidation performance, the strength of tailings cemented by TSSCM was nearly double than that of Portland cement.

2) To consolidate the tailings from Cangshang Milling Plant, compared to Portland cement, the TSSCM has a higher early hardening speed and a higher increasing speed of later strength.

3) Under the precondition of ensuring the fill effect, to use the TSSCM was capable of decreasing the cement consumption and reducing the filling cost.

2.3 Effects of seawater on backfill behavior

(1) Composition analysis of filling water

Due to the mine is located nearby the Bohai Sea, the seawater is very abundant. So, in order to save freshwater and reduce the filling cost, seawater was utilized to convey tailings and cement in backfilling technology. Hence, the composition of seawater was mensurated by Beijing General Research Institute of Mining and Metallurgy. The results are shown in Table 4.

Table 4. Test results of the seawater compositions

element	contents, (mg/l)	element	contents, (mg/l)	element	contents, (mg/l)	element	contents, (mg/l)
Al	<0.005	Co	<0.005	Mg	720	Se	<0.01
As	<0.001	Cr	0.093	Mn	0.01	Sr	9.37
Ba	0.02	Cu	0.04	Mo	0.015	Ti	<0.005
Be	<0.001	Fe	0.55	Na	7926	V	<0.005
Bi	<0.01	K	219	Ni	0.06	Zn	<0.005
Ca	413.6	Li	0.13	Pb	0.01	Sn	<0.005
Cd	<0.005	Cl^-	10000	Sb	<0.01	SO_4^{2-}	1430

According to the menstruating results, the main negative ions contained in the seawater were Cl^-, $SO4^{2-}$, and the main positive ones were Na^+, Mg^{2+}, Ca^{2+}, K^+.

(2) Test of classified and unclassified tailings cemented with seawater

Test on strength of cemented tailings affected by seawater was carried out, and the results are shown in Table 5.

Table 5. Test results of cemented tailings strength affected by seawater

Specimen No	Type of tailings	Type of cement	Cement-tailings ratio	Concentration, %	Strength, MPa		
					3d	7d	28d
19	unclassified	TSSCM	1:15	70	0.62	1.27	1.86
20	classified	Portland	1:10	70	0.42	0.566	1.49
21	unclassified	Portland	1:10	70	0.622	0.744	2.01
23	unclassified	TSSCM	1:10	70	2.01	3.78	4.97

Based on the test results, the TSSCM has a strong applicability while the seawater is used to cement the unclassified tailings. The 3d curing-time strength of specimen, with 70% slurry concentration, at the cement—tailings ratio of 1:10, achieved 2.01Mpa, and the 7d curing-time strength achieved 3.78Mpa.

2.4 Test of fine size content effects on cemented strength

It has been reported that fills containing high ratios of fine material, developed higher compressive strengths than backfill compounds containing medium or coarse materials [3, 13, 14].

In order to get better knowing of the influence of unclassified tailings on strength of filling body of cemented tailings, especially the fine size tailings, many groups of cemented-tailing specimens were prepared by adding

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more other fine size tailings of overflowing to test, the results are shown in Table 6.

Table 6. Results on cemented strength affected by fine size content

Over flowed tailings content, %	compressive strength at 12℃, MPa				compressive strength at 20℃, MPa				compressive strength at 25℃, MPa			
	1d	3d	7d	28d	1d	3d	7d	28d	1d	3d	7d	28d
0	0.10	0.18	0.22	0.4	0.10	0.18	0.34	0.48	0.2	0.28	0.46	0.52
10	0.12	0.24	0.30	0.48	0.14	0.34	0.64	1.02	0.23	0.46	0.64	0.86
15	0.15	0.2	0.34	0.52	0.20	0.36	0.68	1.08	0.26	0.44	0.72	0.92
20	0.15	0.24	0.32	0.56	0.16	0.41	0.80	1.12	0.30	0.50	0.76	1.00
25	0.12	0.24	0.3	0.60	0.19	0.41	0.82	1.12	0.25	0.50	0.76	0.94
30	0.10	0.22	0.26	0.64	0.18	0.40	0.64	1.00	0.24	0.54	0.76	0.88
35	0.10	0.2	0.24	0.62	0.20	0.42	0.74	1.10	0.16	0.60	0.72	0.88
40	0.10	0.18	0.22	0.62	0.14	0.40	0.66	1.00	0.16	0.60	0.72	0.88
45	0.10	0.18	0.20	0.58	0.16	0.38	0.70	0.94	0.18	0.54	0.72	0.82

Different cementing materials provide prodigious influence on strength of consolidated tailings. In order to research in the effects of cemented classified and unclassified tailings on the strength under conditions of different cementing materials, many groups of specimens were tested and the results are shown in Table 7.

Table 7. Results of consolidation material type effect on strength of cemented tailings

Type of consolidating materials	Content of consolidating material, %	Compressive strength of cemented classified tailings, MPa			Compressive strength of cemented unclassified tailings, MPa		
		3d	7d	28d	3d	7d	28d
Portland cement of grade 32.5	3	0.06	0.10	0.20	0.06	0.10	0.24
	5	0.08	0.10	0.25	0.08	0.16	0.30
	8	0.12	0.20	0.60	0.12	0.30	0.68
	10	0.14	0.32	0.80	0.14	0.50	0.84
the SSCM	3	0.22	0.22	0.22	0.34	0.74	1.10
	5	0.80	0.80	0.80	0.66	1.28	1.82
	8	1.00	1.00	1.00	1.24	2.28	3.24
	10	1.35	1.35	1.35	2.00	3.80	5.00

Note: At the conditions that slurry concentration is 70% and curing temperature is 20℃ in testing.

The conclusions drawn from the test results are as followings:

1) The content of fine size tailings in filling materials plays an important part in the strength of filling body. Under the same conditions, the strength of filling body is getting higher as increasing of fine size tailings content.

2) The finer size consolidation materials (cement) have very strong ability of cementing the unclassified or fine size tailings.

3) There is a suitable content range of overflowing tailings that the strength of specimen with fine size tailings in this range has a higher early and final strength. Only in the view of strength, under the conditions of the slurry concentration at 75.7% and the curing temperature at 12℃~30℃, the appropriate content of overflowing tailings added in the slurry was at a range of 10~45% and the maximal strength obtained when the fine size tailings content was in the range of 20~25%.

2.5 Summarization of test

Based on a series of lab testing and the analysis of the test data, the properties of tailings from Cangshang milling plant was discovered as following:

1) Unclassified tailings of this mine have much more fine size content. It expressed that if the classified tailings were used in mining backfill, a majority of tailings in fine size reduced the tailing utilization ratio and increased the discharge content of tailings, also, the cost increased.

2) Great difference of maximal settling concentration exists between classified and unclassified tailings. For a very small content of fine size, the maximal settling concentration of classified tailings can achieve 79%, but for unclassified tailings, it only attains 69%. Therefore, when the unclassified tailings were selected to backfill, a reasonable concentration of cemented filling is 70%.

3) Both classified and unclassified tailings have better dewatering properties, and after dewatering, the final settling concentrations of slurry at different original concentrations are extraordinary closed to each other.

4) Under the same condition of cement-tailings ratio, discovered in the consolidating test, there was a certain difference between the early strength of cemented classified and unclassified tailings. When at a lower concentration, the early strength of cemented unclassified tailings was higher, and at a higher concentration, that of cemented classified tailings was higher. But no matter the slurry concentration higher or lower, the lateral strength of cemented unclassified tailings was higher than that of cemented classified tailings. Compared with other mine nearby Xinli mine, the strength of cemented unclassified tailings of Cangshang mill plant was higher. When seawater was used to cement the tailings and the slurry concentration was 70% with the cement—tailings ratio of 1:10, the filling body cemented by TSSCM acquired a higher 3d curing-time cemented strength of 2.01MPa.

5) The unclassified tailings from Cangshang mill plant was a suitable fill material in mining backfill of Xinli mine. Cemented by the TSSCM with the seawater medium, under the conditions of the slurry concentration being 70% and the cement—tailings ratio being 1:10, better effectiveness would be achieved.

3 Optimization of backfill and dewatering system

3.1 Optimization of the tailings filling system

The designed capacity of Xinli mine is 1500t/d. By the end of 2007, the actual ore productive capacity achieved

2500t/d. Based on the mining condition of the ore bodies, the central main-and-auxiliary shafts development program and the back cut-and-fill stoping were performed in the mine project. During the early days of the mine testing production, backfill was carried out by classified tailings as the original design.

It was very intricate in production control that the classified tailings needed for filling must be transported by trucks from classification station in Cangshang milling plant, which is 6km away to Xinli mine. Then, it was slurried and feeding to tailings silos in filling station. In order to simplify the production process, developing a total tailings backfilling method is very significant. So, the filling system was optimized as follows:

1) The tailings are transformed to unclassified tailings via pipeline instead of classified ones by trucks. Thus, the unclassified tailings could be delivered to the silos directly and continuously by a pump from the tailings slurry in Cangshang milling plant, and the dilute slurry, generally with a concentration of 35% to 40%, was dewatered and densified by natural sedimentation or flocculation process in the silos.

2) Another vertical steel tailings silo with a cubage of $1000m^3$ was constructed to increase the storage capacity of tailings to meet the going up of mining productive capacity. Before this, only a vertical concrete tailings silo of $1000m^3$ in cubage and a vertical concrete cement silo of $145m^3$ in cubage were constructed as the primal design in the filling station.

3) Measures of speeding-up the settlement of fine size tailings are conducted inside the tailing silos. In order to improve the utilization factor of tailings, speeding-up the settlement of fine size tailings, by using the method of installing baffles at the top of the tailings silos, was selected to reduce the overflowing speed of fine size tailings, as shown in Figure 3.

Figure 3. Placement and structure of baffles installed at op of the tailings silos to control fine size tailings overflowing

4) The fluidization technology on settled tailings in the silos are transformed. Before backfilling, tailings settled in the silos were fluidized by compressed-air and compressed-seawater with took place of compressed- freshwater.

Through reforms as described above, the filling circuit used at present in this mine is shown in Figure 4.

3.2 Optimization of the dewatering system in stope

Drainage plays an important role in influence on the strength of fill body and effect of stope support. Especially, the buoyancy of seawater is more than general freshwater, which caused the very fine size of tailings conglomerated on the surface of the fill body and affected the filling or mining work. Under the condition of increasing the concentration of filling slurry maximally, speeding up the dehydration of stope filling would be very favorable to shorten the hardening time of cemented unclassified tailings slurry, enhance the early strength of filling body, simultaneously, the time waiting of mining was shortened effectively, and the utilization factor of stope was increased.

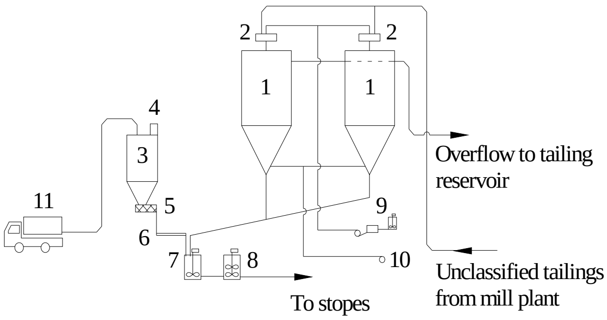

Figure 4 Unclassified tailings cemented filling system in Xinli mine

1—tailings silo (1000m3) 2—flocculating agent and unclassified tailings mixer 3—cement silo (145m3) 4—dust collector 5—double–pipe spiral feeder 6—electronic spiral weigher 7—stage agitation vat 8—high-effect activation agitator 9—adding device for flocculatingagent agitation 10—compressed-air and compressed-seawater slurrying device 11—cement tank car

For stope filling in Xinli mine, the quality concentration of slurry achieved more than 73%, if the minimal concentration of the water-saturated filling materials was 80%, 0.12t of water must be drained out for each ton of dry tailing's filling. The fill volume of one stope cuts in this mine was calculated as length × width × height = 50m×20m×2m, and the volume-weight of tailings as 1.6t/m3, 3200t of tailings were needed to fill one horizontal slice of a whole stope, and 384t of water to be drained out, this increased 768Yuan (RMB) of the drainage cost.

The old dewatering system in stope, as shown in Figure 5, only consists of a cylinder drainage tower made of steel plat of 8 to 10mm in thickness. The cylinder is 1.0 to 1.2m in diameter and 1.0 to 1.1m in height. When a stope was prepared to be filled, the drainage tower was extended by two cylinders welded discontinuously one after another to its upper edge. It is very poor in dewatering effectiveness that there is no other passage to enable the

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water contained in the slurry filled in stope to flow out, except the discontinuous cracks between the edges of two cylinders.

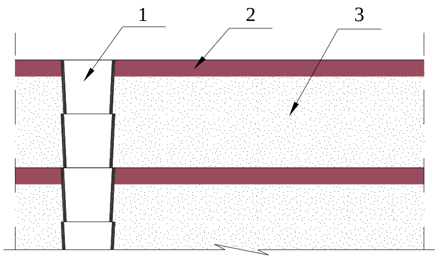

Figure 5. Old dewatering facilities in stope
1—drainage tower, 2—hard floor, 3— filling body

In order to pick up dewatering speed in a filling stope, a new dewatering system, which include a cylinder drainage tower with many small holes or cracks distributed in the cylinder plat, 3 to 4 dewatering cages linked to the drainage tower by rigid plastic pipelines, as shown in Figure 6, was designed and used to drain water away from the hydraulic fill after placement. The dewatering cage, which was wrapped completely by one lap of sack cloth, was made of steel bars of 6 to 8mm in diameter. The diameter of the cage is 500mm, and its height is 800mm to 1000mm. During the early period of filling, discovered in the engineering experimental process, water of large quantity that was contained in the backfilling pulp was filtrated and discharged out from the filled body in stope by drainage tower, dewatering cages and them drainage pipeline rapidly in a short time, and the filling quality and the mechanical properties of the fill body was improved in a high speed. In general terms, better dewatering functions could be gained by this kind of dewatering system in stope. But when the filter cloth was blocked later by the very fine size tailings, the dewatering efficiency would be affected.

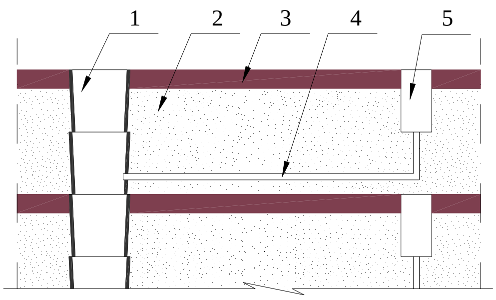

Figure 6. New dewatering facilities in stope
1—drainage tower 2—filling body 3— hard floor 4—drainage pipe 5—dewatering cage

4 Practice on stope backfill

4.1 Stope backfilling

The long transportation of the dilute unclassified tailings from Cangshang mill plant was conducted directly and continuously by use of oil isolation pumps to the tailings silos, where the tailings settled naturally and free water containing solids (mainly the slime) whose content was not more than 10% overflowed to tailings reservoir. Solids content in the slurry of more than 90% were settled down in the silos prepared to filling.

When a stope was prepared to fill, the sediment of solids in tailings silo was suffered from the compressed-air and compressed-seawater slurrying. In sequence, opening the discharging valve so as to directly add the uniformly stirred unclassified tailings slurry, via the pipe, to the continuous agitator with double horizontal shafts; At the same time, when cemented filling was needed, the double-pipe spiral feeder and the spiral electronic weigher fed cement to the agitator, and then the cement and unclassified tailings material suffered from the primary agitation, by the connector again, came into the high-speed agitator for activating agitation. Finally, the prepared filling slurry entered into the filling pipeline network, where the filling slurry flowed by gravity to the stope for backfilling.

In order to reduce the consumption of cementing material, two kinds of filling forms were used in one slice backfilling of a stope. The unclassified tailings were filled in the lower space of the slice with a height of 1.7m, and the cemented unclassified tailings in the top to form a hard floor with cement to tailings ratio of 1:8. The hard floor was 0.3 ~0.4m thick with a strength of 2~3 MPa.

4.2 Restraint of slime in stope filling process

Because of the ununiformity of the tailings particles, the slurry of total tailings, when delivered to stope by pipeline, befell a non-uniform settlement, a layer of 30mm to 100mm in thickness of slime (very fine size tailings), as shown in Figure 7, conglomerated on the surface of filling body to respond to the action of the buoyancy of seawater. This influences on the quality of cemented tailings and the integrality of filling body.

Figure 7. Slime conglomerating on the surface of filling body in stope

Generally, when the filling slurry is discharged and flows in the volume of backfilling stope, the coarse and fine particles of tailings will settle down at different places. The coarse particles are nearer and the fines are further away from the slurry discharge mouth of pipe due to different weight of them. Based on this theory, an inclined-face filling method as shown in Figure 8 was carried out in the industrial testing. This method, consequently, could make coarse tailings being deposited a majority area of the surface of fill body, a large amount of fines imbedded in the fill body, and only a few of them deposited a small part of area of the surface where was less disadvantage to stope working later.

It is ideal if the coarse and fine particles of tailings are mixed together and distributed uniformly in the filling body. To run up the dewatering speed in the filling process and increase the pulp density, discovered in the laboratory and industrial testing, were also more helpful in restraining slime on the surface of filling body. The reason of those was that the filling slurry with lower moisture content and higher dewatering speed were propitious to the coarse and fine particles settled uniformly.

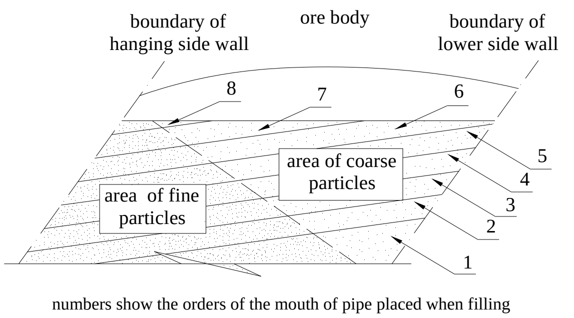

Figure 8. The inclined-face filling method on restraining slime conglomerated on surface of filling body

4.3 Effectiveness of stope backfill

Up to now, the unclassified tailings of about 900,000m^3 were placed in underground mined excavation in this mine. It plays a more important role in increasing the working safety in mining under the seafloor. The practice proves that the effectiveness of stope backfilling can be summarized as following:

1) The slurry at 75% concentration with the pipeline length—height ratio of 3.5 is easy to achieve the flow-gravity transportation, and the more ideal gravity flow transportation can be achieved and the flow rate is up to 80~100m^3/h.

2) Better fill quality and less drainage from the fill in stopes are achieved at the condition of the filling concentration is kept within 72% to 75%.

3) Working conditions of stope are improved greatly and production in the next lift can be started after the hard floor has been cured for 3 days.

5 Conclusions

As an effective tool, mining backfill is capable of making mine solid waste become resources, reducing the discharge of solid waste, increasing the utilization factor of resources and protecting the surface environment. The experimental study and practice on technology of high-concentration unclassified tailings fill in Xinli gold mine, can prevent the mine flooding accident of seawater due to displacement or collapse of wall rock affected by the mining, which will provide technological safeguard for the production safety of mining under the seafloor.

The utilization factor of tailings was up to 90% during the test of unclassified tailings filing or cemented filing, and the concentration that the fill was transported by gravity was 73% to 75%.

Under the same conditions, increasing concentration of the total tailings backfill and activating agitator were used to prepare the cement mortar, which was very helpful for improving the strength of cemented filling body and reducing the consumption of cement to lower the cost of filling.

It is ideal in total tailings fill that the coarse and fine particles of tailings are mixed together and distributed uniformly in the filling body. These are able to be actualized by increasing the concentration of filling slurry, reducing the moisture content of backfilling pulp and picking up dewatering speed in filling process.

The inclined-face filling method is propitious to restrain the slime conglomerated on the surface of filling body. Under the precondition that the slime was restrained, the strength of the hard floor formed by cemented unclassified tailing with cement—tailings ratio of 1:10 achieved that production on the next lift could be started after the hard floor had been cured for 3 days.

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