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Critical approaches and methodologies for selecting backfill solutions and plant location for Sociedad Minera El Brocal's Marcapunta underground mine

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Abstract

Compañía de Minas Buenaventura S.A.A. retained Responsible Mining Solutions (RMS) to complete a feasibility level design for a paste backfill system for its subsidiary Sociedad Minera El Brocal S.A.A (SMEB or El Brocal). El Brocal is an underground copper mine that consists of 2 primary zones: North and South. Both mining zones are currently being mined by longhole stoping and have 77 Mt of copper ore reserves. A cemented backfill system will be implemented enabling continuous mining while primarily servicing the South mine.

A few challenges were encountered such as the underperformance of the paste thickener and inadequate hydraulic fill properties (the surface restrictions for the paste plant infrastructure and limited storage capacity at the tailings storage facility [TSF]).

An onsite thickener trial was carried out, showing that the paste thickener can produce thickened tailings at a concentration by weight (C_w) of >70%. Since upgrading the existing hydraulic fill plant was found to be an expensive solution, the approach has been revised: the plant will be modified to produce high-density fill with a C_w of 75% and a concentration by volume (C_v) of 45%. The testing campaign showed that high-density fill achieved lower strengths than slumpable paste while exceeding the targets required for mining.

To mitigate the negative environmental impacts, the paste backfill plant will be installed underground. The primary binder silos and auxiliaries will be installed on the surface at the decline entrance. To ensure a steady thickened tailings production at a C_w of 75%, a density boost circuit will be implemented with a single vacuum disc filter adjacent to the paste thickener. The agitated storage tank will blend a small portion of friable filter cake with the thickened tailings. Concurrently, this circuit alleviates density fluctuations, lowers the risk of pipeline blockage and reduces filtration requirements underground. This is inherently expensive due to underground plant excavation, ventilation, electrical supply, etc.

Keywords: *El Brocal, paste, backfill, hydraulic fill, high-density fill*

1 Introduction

Compañía de Minas Buenaventura S.A.A., through its wholly owned subsidiary Sociedad Minera El Brocal S.A.A (SMEB), is a polymetallic mining company, dedicated to the extraction, concentration and commercialisation of silver, lead, zinc and copper minerals. It carries out its operations in the Colquijirca Mining Unit and Huaraucaca Concentrator Plant, located in the district of Tinyahuarco (a province and department of Pasco) at an altitude of 4,300 metres above sea level (masl). The El Brocal Mining Complex layout is presented in Figure 1.

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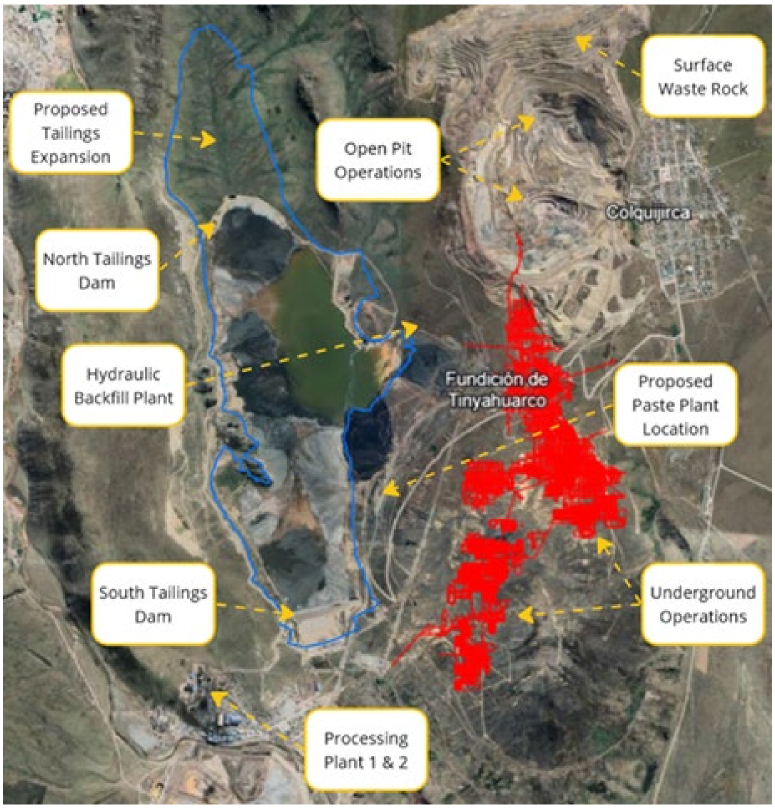

Figure 1 El Brocal mining infrastructure layout (Senis & Hall 2025)

The El Brocal Mining Complex consists of the following major components: underground mine (North and South zones), concentrator plant, tailings storage facility (TSF), hydraulic fill plant and open pit. The open pit has been exhausted; however, the southern edge of the open pit still contains a very small portion of ore that will be mined by modified sublevel caving. Once exhausted, the open pit may be used for tailings disposal (in-pit approach) in 2031 at the earliest. The hydraulic fill plant was initially introduced to primarily serve the North zone, enabling continuous mining and pillar recovery.

The North zone has 24 Mt of copper ore reserves and was historically mined by room and pillar, while current mining utilises longhole stoping. The remaining portions of the North and South zones have about 77 Mt of copper ore reserves left and are being mined by the longhole stoping method. Most of the ore is mined from the South Zone, where cemented paste backfill will be used to maintain ground stability and optimise production.

The concentrator plant processes a nominal ore throughput of 13,000 tpd, while the future production will be ramped up to 17,000 tpd of ore. The existing tailings arrangement will rely on a single paste type thickener and 2 centrifugal pumping trains (operating and standby). The paste thickener has a 40 m diameter, a 6.5 m sidewall height and a floor slope of 14°. Each pumping train is comprised of 4 centrifugal pumps installed in series where all pumps are 10 × 8 AHPP with 500 HP motors. Typically, the tailings are thickened to a concentration by weight (C_w) of about 55% and transported to the TSF via a tailings pipeline consisting of 300 mm Schedule 80 carbon steel pipes. The same pumping system was designed to supply tailings to the hydraulic fill plant.

SMEB commissioned Responsible Mining Solutions (RMS) to complete a feasibility level study for paste backfill and to carry out a testing campaign to support the study. The feasibility study was executed in 2 phases.

- Phase 1: increase thickened tailings density to the TSF and determine any modifications to the hydraulic fill plant to meet targets.
- Phase 2: development of the paste backfill process.

The testing campaign was carried out to support the paste backfill plant design and to define the paste backfill recipes – to satisfy the required strengths. The tailings required for backfill will be sourced from the existing tailings thickener underflow. The feasibility study also included tailings transport to the paste backfill plant, the hydraulic fill plant and the TSF. Concurrently, the feasibility study was focused on an integrated process design and the tailings synergy between the paste backfill plant, the hydraulic fill plant and the TSF.

This paper outlines the key design characteristics, the general methodology and the approach for selecting the backfill solution and determining the paste backfill plant location.

2 Critical project constraints and drivers

2.1 Overview

The initial intent was to install the paste backfill plant on the surface at the portal area (Figure 1), which was identified as the most appropriate location for the paste backfill distribution as it will primarily be servicing the South zone. According to the initial assessment, this location will have a minimal social and environmental impact on the local community. This approach was considered only during the initial site visit and discussion with the El Brocal team.

During the site visit at the project onset, the following key issues were identified:

- The Santa Rosa and Colquijirca communities are requesting a reduction in the operational footprint of the TSF, which is a challenge for the environmental and permitting applications and overall project expansion.
- The tailings thickener underperforms and produces lower underflow densities.
- The TSF has a limited storage capacity and requires additional dam raises. This will require the footprint to be expanded towards the North zone. Also, the process of water storage is restricted and requires an integrated solution with the TSF.
- The hydraulic backfill has challenges reaching the proposed design densities. The existing plant was unable to meet the backfill demand and capacity, which negatively impacts underground operation and production.

To better understand the tailings characteristics, RMS reviewed historical reports and testing programs. The following major threats to the backfill process and the TSF geotechnical slope were identified:

- The existing tailings thickening circuit thickens the full plant tailings (FPT) at a C_w of about 55%. Concurrently, this low density affects the geotechnical slope of the TSF (storage capacity) and filtration rates that directly affect the paste plant design and operation.
- The hydraulic fill properties were inadequate in terms of low density (C_w of 58%) and fines content/permeability. The particle size distribution (PSD) is shown in Figure 2. Additionally, the hydraulic fill plant does not meet the hydraulic backfill flowrates and capacity.
- The hydrocyclone overflow stream (slimes) was produced at a C_w of about 10% which reports to the TSF and exacerbates challenges around water management in the TSF.

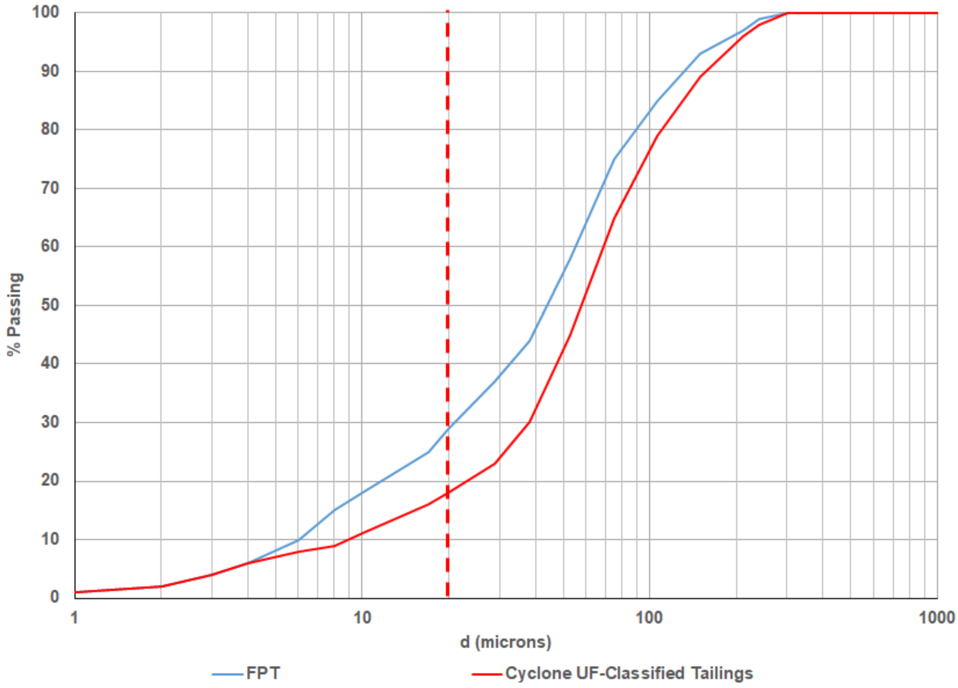

Figure 2 Particle size distribution (Pavlovic et al. 2024)

From a PSD perspective, a rule of thumb often utilised is that tailings have a minimum of 15% passing 20 microns to be suitable for paste production, while the maximum 8% passing 20 microns is required for the hydraulic fill production. The PSD analysis was performed on hydrocyclone feed and underflow samples provided by the client, with results summarised in Figure 2. It was found that the hydrocycloning process produces classified tailings in the underflow stream with cumulative passing of the sub 20 micron class of about 18%. This higher fines content reduces water bleeding (drainage), which affects the permeability. Based on the preliminary hydraulic fill plant analysis, conducted after commissioning and process start-up, it was found that the hydraulic backfill flow rate of 2,800 m^3/day is well below the targeted flow rate of 4,550 m^3/day (design value). This presents significant risk in terms of potential pipeline blockages and does not satisfy mining production targets. Also, the hydraulic backfill density at a C_w of 58% is low and contributes to the longer consolidation time and longer time needed for draining the underground stopes.

2.1.1 Initial concept

Based on the initial assessment and preliminary paste backfill system design, the portal area was unable to accommodate the complete paste backfill infrastructure due to the limited footprint area, social impact and permitting process. To mitigate the social and environmental impacts, the paste backfill system and supporting infrastructure was envisioned to be installed underground (Ansah-Sam et al. 2008). This approach would facilitate the permitting process and avoid conflicts and interferences on the surface. Minsur's San Rafael underground tin mine in southeastern Peru currently operates at an altitude of 4,500 masl and was benchmarked in support of this study. Some details of San Rafael's backfill plant are illustrated in Figure 3.

(a)

(b)

Figure 3 San Rafael backfill plant. (a) Vacuum disc filters; (b) Paste (piston) pump (Palkovits 2003)

According to the initial life of mine plan, the underground mine would produce about 4.38 million t/y of ore and approximately 1.92 million m^3/y of voids in the southern orebody. The tailings dewatering circuit and paste backfill plant would be designed for a tailings solids throughput of about 516 t/h. The paste backfill plant underground location and underground distribution system (UDS) are presented in Figure 4.

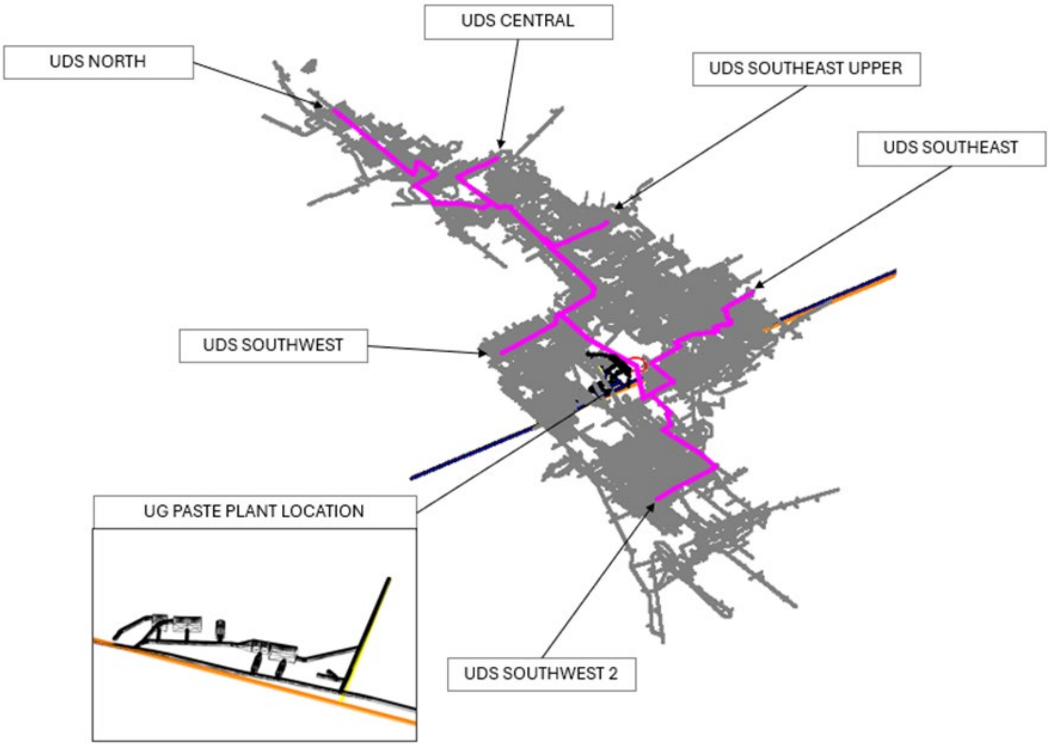

Figure 4 Underground (UG) paste backfill plant location and underground distribution system (UDS) (Senis & Hall 2025)

An onsite thickener trial test showed that the existing paste thickener can produce thickened tailings at a density of a C_w from 72–77%. The hydraulic transport analysis showed that the existing pumping arrangement can be utilised for delivering the thickened tailings at a C_w of 75%; however, the existing overland piping arrangement with 300 mm Schedule 80 pipes should be replaced by 250 mm diameter Schedule 80 pipes with a 12.5 mm liner. The existing tailings thickener underperforms and produces the low-density thickened tailings at a C_w of 55% (flow rate of 566 m^3/h) to enable the safe hydraulic transport from the thickening plant to the TSF disposal points. According to the initial analysis using filtration testing results (Table 3), the low thickened tailings density at a C_w of 55% calls for 5 operating and one standby disc filter which results in the larger paste plant footprint area. By improving the thickener underflow density to a C_w of 75%, the quantity of disc filter units would be reduced to 2 operating and one standby. The selected filters have 3.8 m diameter discs, where each disc has 20.4 m^2 of available filtration area. The total number of discs per filter unit is 15. To improve the tailings thickener performance, the following options were investigated:

- Option 1: utilising the existing thickener and drive mechanism.
- Option 2: upgrading the existing thickener with a new drive mechanism.
- Option 3: installing a new paste thickener with 40 m Ø × 8 m sidewall and floor slope of 30°.
- Option 4: constructing a density boost circuit.

Option 1 was identified as the simplest approach to achieve density targets. After the onsite trial test, it was decided to calibrate the existing instrumentation and to create a trigger criteria for the monitored process parameters that would alarm any deviation from the targeted set point. Additionally, an ongoing maintenance schedule for maintaining the instrument accuracy would be established. The flocculant aging would also be improved to produce more viscous flocculant solution suitable to efficiently bond the tailings particles.

Option 2 demands longer process interruption for installation of the new rakes and drive mechanism. Additionally, Option 3 resulted in a high capital cost and longer procurement time and implementation. Lastly, Option 4 offers a thickened tailings product with a steady density and it would largely mitigate any fluctuations in underflow density. Option 4 also resulted in the smallest footprint area and lower capital cost.

With reference to the hydraulic fill plant improvement, the key focus was to improve the hydraulic fill properties by providing a PSD targeting from 4–8% passing 20 microns and a density at a C_w from 70–75% solids. It would consequently increase permeability to be more in line with typical targets (100 cm/h) (Shailesh et al. 2008). Investigated options to improve plant performance included the possible addition of agitated storage tanks and/or settle storage tanks, and the use of a dewatering screen to support stockpiling.

Each option required hydraulic backfill plant optimisation and still had challenges in terms of water management, stope drainage, greater binder losses, etc. All options had higher cost and complexity versus the ultimate direction, as well as additional permitting requirements. To simplify the process design and permitting, it was decided to repurpose the plant for high-density backfill (unclassified) at a C_w of 75%.

3 Key testing data

The sample (denoted FPT for full plant tailings) was subjected to a testing campaign including material characterisation, rheology, thickening (settling testing), vacuum filtration and unconfined strength (UCS) testing. The key testing program that was crucial for the backfill process selection will be outlined in this paper.

3.1 Mineralogy

The major mineral constituents identified by x-ray diffraction analysis were quartz, pyrite and amorphous minerals. A minor amount of minerals with colloidal properties specifically kaolinite, alunite and gypsum were also detected.

3.2 Particle size distribution

The PSD is illustrated in Figure 5.

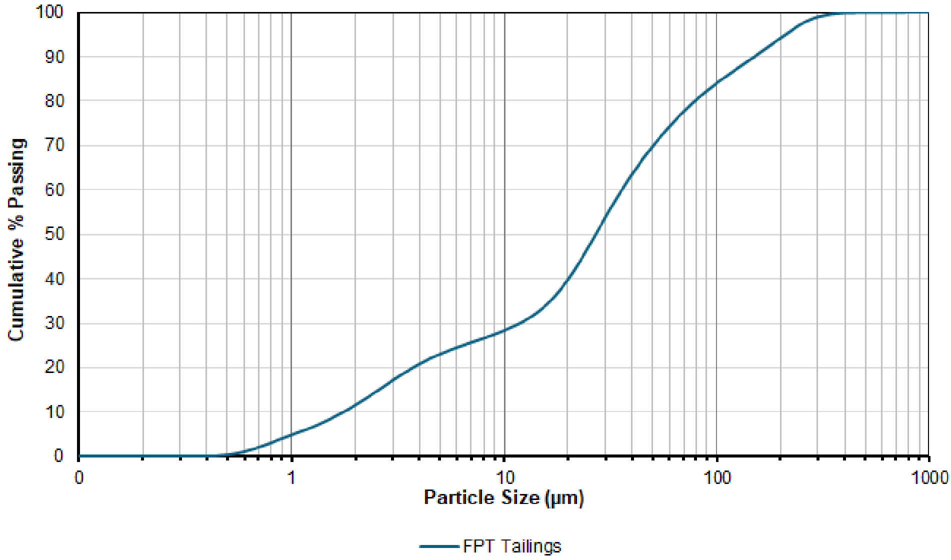

Figure 5 Particle size distribution of the full plant tailings (FPT) samples

3.3 Rheology

The paste concentrations by weight were determined by using Abrams 300 mm cone testing (ASTM International 2015). The results are provided in Table 1.

Table 1 Paste densities and static yield stress

Cemented/uncemented	Slump (mm)	C_w (%)
Uncemented	175	83.7
	250	82.2
5% Type 1 cement	175	83.4
	250	81.8

Static yield stress and viscosity results for the FPT samples (cemented and uncemented) are illustrated in Figures 6 and 7, respectively.

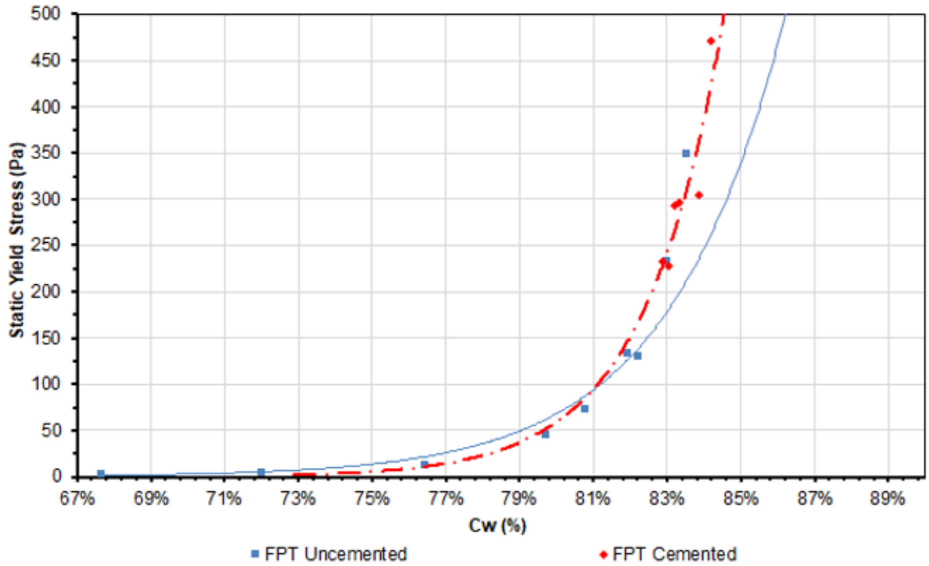

Figure 6 Static yield stress

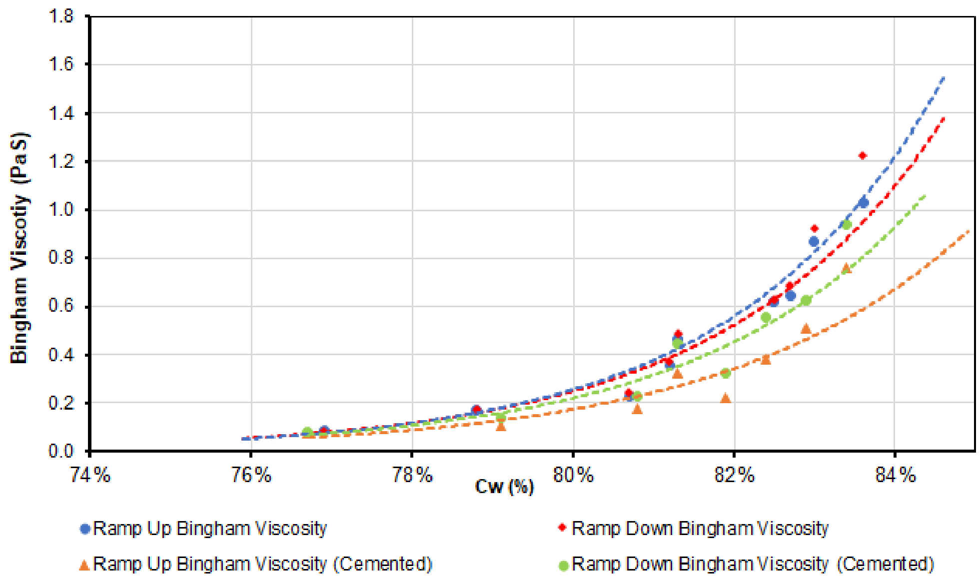

Figure 7 Dynamic viscosity

3.4 Thickening settling test

Thickening testing, including flocculant type and dosage, feed density screening, and static and dynamic thickening, was completed on the sample. It was found that the tailings settle rapidly with 945 VHM flocculant at a dosing rate of 20 g/t and thickener feed C_w of 15%. Dynamic settling tests showed that the sample settles well at a flux rate of 0.5 t/m^2/h. The current paste thickener operates in the flux range from 0.4 to 0.55 t/m^2/h when the mill operates from 13,000–17,000 tpd.

The dynamic thickening at a flux rate of 0.5 t/m^2/h is likely a good indication of possible thickener operation with expectation to produce the thickened tailings at a C_w from 75–77%. Dynamic thickening test results are tabulated in Table 2.

Table 2 Dynamic thickening test results

Flux rate (t/m^2/h)	Flocculant dose (g/t)	Underflow C_w (%)	Overflow clarity (ppm)	Unsheared yield stress (Pa)
0.5	10	68	264	8
0.5	20	74	72	43
0.7	20	73	50	42

3.5 Vacuum disc filtration test

A vacuum disc filtration test was completed for a maximum vacuum pressure of 0.47 bar using 3 filter feed consistencies at a C_w of 60, 65 and 76%. The standard cycle times of 60, 90 and 150 s were applied. These parameters enable the vacuum filtration operating envelop to be created. As the filter aid, a selected flocculant (945 VHM) was investigated with the same dosing rate of 20 g/t. This enhanced testing provides a wide spectrum of results; however, only those results that are critical for the vacuum filtration operation are outlined in Table 3.

Table 3 Vacuum disc filtration results

Sample/stream	Feed C_w (%)	Vacuum pressure (bar)	Cycle time (s)	Cake thickness (mm)	Filter cake C_w (%)	Filtration rate (kg/m²/h)
FPT unflocculated	60	0.47	60	4	86	353
			90	4	86	260
			150	6	85	210
	65		60	11	88	1,100
			90	9	87	498
			150	7	86	253
	72		60	9	87	963
			90	8	87	683
			150	14	87	565
	76		60	11	87	1,314
			90	15	87	964
			150	16	88	813
FPT-flocculated	65		90	13	85	768
	72		90	17	86	993

3.6 Unconfined strength test

UCS testing was carried out using 75 × 150 mm cylinders. Locally sourced binder (Type 1 and Forte) was used in this testing as well as a 90:10 binder blend. The 90:10 is an Ontario-sourced Lafarge cement blend of 90% ground granulated iron blast furnace slag and 10% general use cement. Binder dosing rates of 2, 3, 5, 7 and 10 were used for paste backfill ranging from 175–250 mm slump. Additionally, high-density backfill at a C_w from 72–77% was tested. A nominal backfill strength of 0.8 MPa was targeted. Selected UCS results that are relevant for the anticipated backfill recipe are shown in Figures 8, 9 and 10.

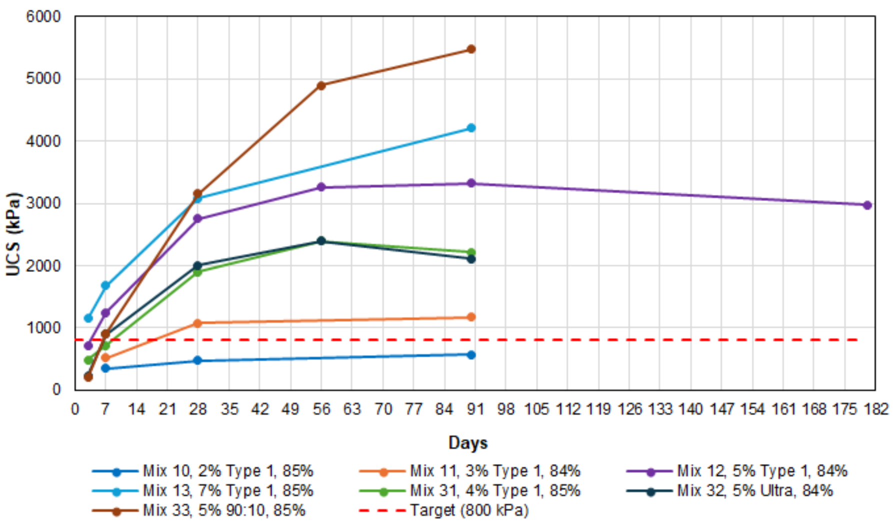

Figure 8 Unconfined strength testing (UCS) results for paste backfill (175 mm slump)

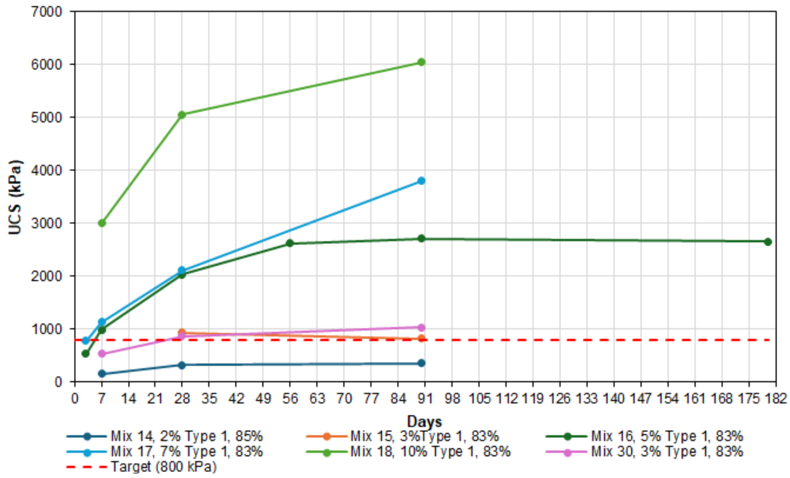

Figure 9 Unconfined strength testing (UCS) results for paste backfill (250 mm slump)

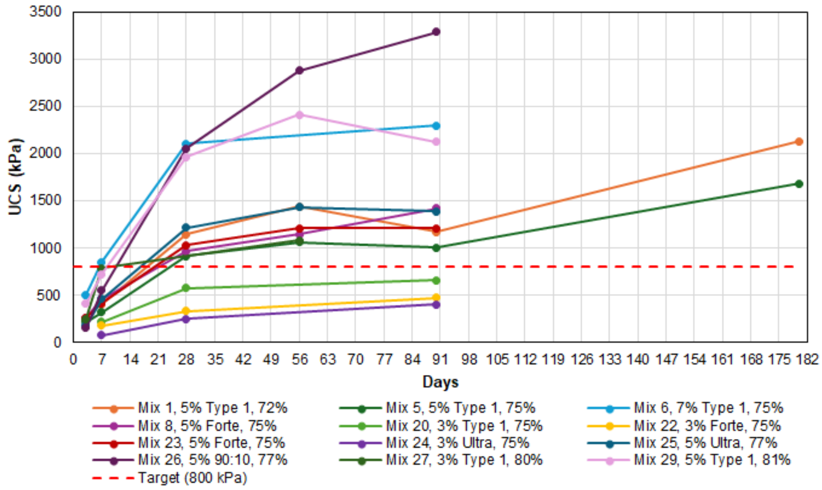

Figure 10 Unconfined strength testing (UCS) results for high-density slurry backfill

4 Integrated process design

The future of the overall paste backfill project and the life of mine plan were critical to understand the design considerations, permitting and risk. It is important to understand the integrated process operation from the tie-in point to final paste backfill product, including placement into the stope. Based on discussions at the beginning of the project, paste backfill implementation will be executed in 2 phases. Phase 1 would rely on the high-density slurry backfill at a C_w of about 75%. In Phase 2 a pair of vacuum disc filters and a filter cake weigh conveyor would be installed in the underground paste backfill plant to enable slumpable paste backfill production. According to the underground mine layout, the high-density slurry backfill (Phase 1) would be distributed by 4 centrifugal pumps installed in series. Along with the vacuum disc filters in the Phase 2, a pair of the piston diaphragm (PD) pumps would be installed to distribute the 250 mm slump paste backfill within the South mine.

The backfill process preparation was divided into 3 locations: the thickening plant located at the mill, the binder storage system located at the portal area, and the underground backfill plant. The thickening plant incorporates tailings storage and transport systems, and the portal area incorporates only the binder storage and pneumatic transport system, while the underground backfill plant includes vacuum filtration, binder storage, and mixing.

4.1 Density boost circuit

To ensure steady production of high-density slurry at a C_w of 75% (C_v of 45%) a density boost circuit would be constructed at the thickening plant. The density boost circuit would rely on a single vacuum disc filter that would be installed on top of the agitated storage tank to filter a smaller portion of the thickened tailings to filter cake consistency at a C_w of about 85%. The filter cake would be friable and easily mixed. To maintain this filter cake consistency, the vacuum disc filter could operate at lower vacuum pressures, if required. Based on the vacuum filtration testing results, the vacuum disc filter would be comprised of 15 discs with a 3.8 m diameter, where each disc has 20.4 m^2 of available filtration area. The filter cake would be discharged by gravity into the agitated storage tank and mixed with the remaining (larger) portion of the thickened tailings.

The thickened tailings at a C_w of 75% (C_v of 45%) would have non-segregating (non-settling) properties. The thickened tailings with this consistency (non-Newtonian fluid) could be transported at a lower velocity (i.e. 2.0 to 2.3 m/s), which is above the critical settling velocity (V_{sm}) of about 1.7 m/s. Transporting the thickened tailings at lower velocities calls for less power draw and results in less power consumption (Wilson & Thomas 2006). Additionally, due to their non-segregating properties, the thickened tailings have inherently less risk in terms of settling and pipeline blockages and managing of the transport velocity is less critical. In accordance with this, the high-density tailings transport was designed by applying the non-Newtonian (Bingham) approach (Slatter 2005).

Should the paste thickener continuously produce the thickened tailings at a C_w from 75–77%, the density boost circuit would be in standby mode. This system would allow constant filter feed density in Phase 2, enabling only 2 operating vacuum disc filters to be used only. Concurrently, this approach would improve filtration performance and reduce the underground paste backfill plant footprint (less excavation). The density boost circuit is presented in Figure 11.

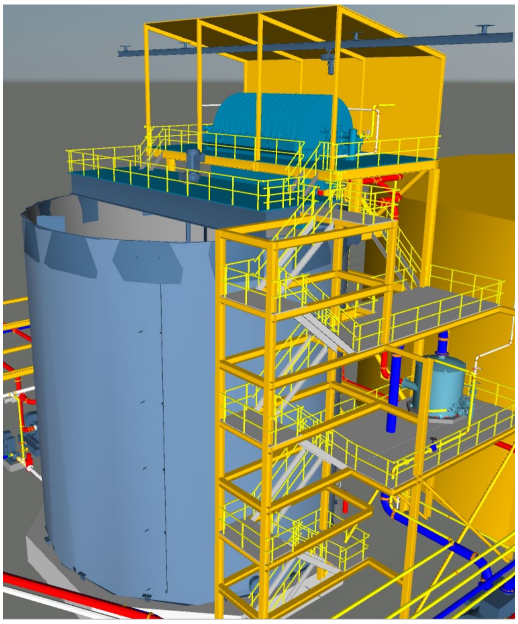

Figure 11 Density boost circuit

4.2 Paste thickener (tailings tie-in) and tailings storage

The existing thickening plant consists of the paste thickener, thickener underflow pumps and 2 pumping trains (one operating, one standby). Each train consists of 3 centrifugal pumps in series where each train is directly fed by a thickener underflow pump. Based on this, the entire pumping circuit consists of 2 pumping trains (operating and standby) where each train consists of 4 pumps installed in series. The optimisation process of the existing paste thickener would be executed at the project’s onset to enable the high-density slurry production at a C_w of 75%. This also includes improving the existing flocculant system.

An agitated storage tank with ~4 hours of live storage capacity would be installed along with a single vacuum disc filter (density boost circuit) to mitigate density fluctuations and improve backfill production. This tank would receive the thickened tailings via thickener underflow pumps and serves to decouple the mill from the surface transport, enabling continual pumping even if there are interruptions in mill and/or thickener operation. From this tank, 2 tailings transfer pumps would be implemented (operating and standby) to feed the existing tailings pumping trains which pump the thickened tailings to the TSF, the hydraulic fill plant and the underground paste backfill plant. In Phase 2, when the mill processes 17,000 tpd, additional pumping trains with 4 pumps in series would be installed at the agitated storage tank to transport excess tailings of about 4,000 tpd to the TSF or the hydraulic fill plant.

4.3 Overland thickened tailings transport

The current pipeline arrangement comprises of 300 mm Schedule 80 carbon steel pipe, and 350 mm high-density polyethylene (HDPE) DR 11 pipe. For this arrangement, the V_{sm} range from 1.8–2.1 m/s was calculated for a solid tailings throughput of 516 t/h and a C_w of 55%. According to this, the existing arrangement is suitable for the current plant operation and tailings density at a C_w of 55% (flow rate of 566 m^3/h and transport velocity of 2.4 m/s); however, the line velocity would fall too low once the thickened tailings density is increased to a C_w of 75% (flow rate of 316 m^3/h and transport velocity of 1.3 m/s), which makes these pipelines unsuitable for conveying the high-density thickened tailings.

To be able to safely convey the high-density thickened tailings at a C_w of 75% (C_v of 45%), the existing pipeline would be replaced with 250 mm Schedule 80 steel pipe with a 12.5 mm liner of either rubber or HDPE. The liners will be applied to ensure a long line life, minimising the need for replacement and servicing in the field, and reducing the potential for line failures. Additionally, dual wall pipes with 300 mm HDPE DR 7.3/400 mm HDPE DR 11 would be used in low-pressure areas. The dual wall pipes would ensure long life of the pipes and minimise the risk of environmental spillages. For this piping arrangement, a V_{sm} of about 1.7 m/s was calculated for a solid tailings throughput of 516 t/h and a C_w of 75% (flow rate of 316 m^3/h). The high-density thickened tailings at a C_w of 75% would be transported at the pipeline velocity of about 2.3 m/s, which is well above the V_{sm} of 1.7 m/s.

In Phase 2, new 150 mm steel pipes with a 12.5 mm liner (either rubber or an HDPE) would be implemented along with 2 smaller pumping trains with 4 pumps installed in series. This arrangement would convey the excess tailings to support the future ore throughput increase to 17,000 tpd. Similarly, dual wall pipes with 150 mm HDPE DR 9.0/ 200 mm HDPE DR 11 would be utilised in the low-pressure sections.

4.4 Portal pad

Based on the solid backfill throughput and the UCS testing campaign, a higher binder consumption would likely be expected. To meet the design capacity and to decouple the binder supply chain for about 96 hours, 2 surface binder silos, each with an approximate capacity of 2,000 t would be located at the portal pad. A single silo would be installed at the project onset, while a footprint is reserved for a second silo to be installed if required.

Along with the binder silo the binder pneumatic conveying system that consists of the Fuller-Kinyon (FK) pneumatic screw pump, conveying compressors and 300 mm Schedule 80 pipeline would be implemented. The binder from the silo would be delivered to the FK Pump via screw conveyor, while the compressed air from the conveying compressors would be used to dilute the binder into the FK Pump, ensuring safe operating velocities. The binder transfer pipeline would span from the portal pad to the underground day silo at the underground backfill plant via underground decline.

4.5 Underground backfill plant

The layout of the underground paste backfill plant is illustrated in Figure 12. The thickened tailings would be received in 2 agitated storage tanks. These tanks have roughly 5 hours of combined residence time. One tank would be installed in Phase 1, while a second tank would be added in Phase 2.

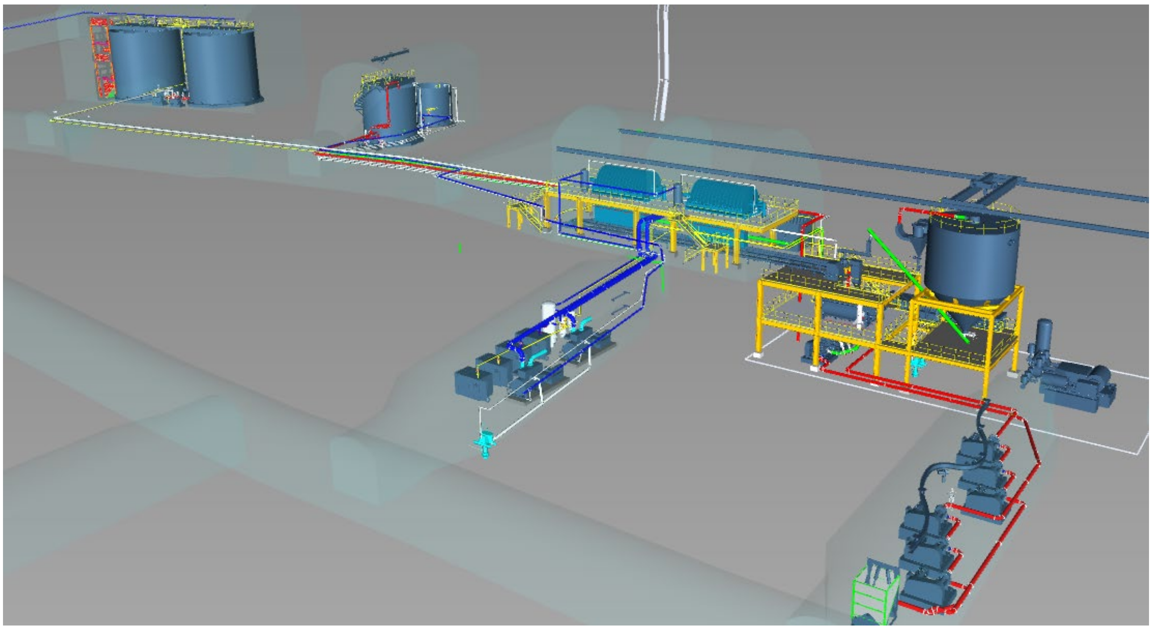

Figure 12 Underground paste plant

4.5.1 Phase 1

A pair of centrifugal pumps (operating and standby) would be used to pump a smaller portion of the thickened tailings stream to the vortex mixer to be pre-blended with dry binder, hence the mixture would be dropped into the continuous mixer. A larger portion of the thickened tailings would be directly supplied to the continuous mixer and blended with a pre-blended mixture. The current expectations around the backfill recipe for Phase 1 is that binder content might be as high as 10%, and closer to 5% on average.

The prepared high-density backfill at a C_w of 75% would be distributed by 2 centrifugal pumping trains across the South zone. Each centrifugal pumping train comprises of 4 centrifugal 10 × 8 AHPP pumps installed in series with 500 HP motors.

4.5.2 Phase 2

During Phase 2 of the backfill system, one agitated storage tank would be installed, along with 2 operating vacuum disc filters and a filter cake weigh conveyor. The selected vacuum disc filters are the same size as those installed in the density boost circuit. The standby vacuum disc filter was not envisioned, as the backfill plant could switch to Phase 1 operating mode producing the high-density backfill. The vacuum disc filtration circuit would consist of 2 operating vacuum disc filters, where each filter unit features 15 discs with a disc diameter of 3.8 m. Feeding vacuum disc filters with the thickened tailings at a C_w of 75% or higher improves filtration performance, which calls for 2 vacuum disc filter units to be used continuously.

The overall approach, with producing and conveying the thickened tailings from the thickening plant at the mill to the underground paste backfill plant, results in a smaller number of vacuum disc filter units and reduces the overall paste backfill plant footprint and underground excavation.

From agitated storage tanks, a smaller portion of the thickened tailings would be delivered to the continuous mixer via a vortex mixer. The remaining portion of the thickened tailings would be delivered to both the vacuum disc filters to produce the filter cake at a C_w of 85%. The filter cake would be delivered to the continuous mixer via the filter cake weigh conveyor and combined with a pre-blended mixture of thickened tailings and binder. According to the UCS testing results, the low-density paste backfill at a C_w of 81.8%, that refers to 250 mm slump, satisfies backfill strength. As such, the paste backfill would be produced and distributed across the South mine via a PD pump rated for 150 bar.

4.6 Hydraulic fill plant

The hydraulic fill plant would be modified to produce a high-density backfill at a C_w of 75%. The thickened tailings would be transported from the agitated storage tank at the mill to an agitated storage tank at the hydraulic fill plant. A pair of centrifugal pumps (operating and standby) would be used to transfer the tailings from the agitated storage tank to the mixing tank to blend with the binder. Once blended, the high-density backfill would be distributed across the North zone via 2 centrifugal pumping trains. Each train would consist of 6 × 4 AHPP pumps with motor rated for 150 HP. The initial hydraulic fill plant included 2 pumping trains with 3 pumps in series each; however, those trains would be upgraded with a fourth pump in series to allow high-density backfill to be transported to the furthest stope.

Concurrently, this approach results in eliminating hydrocycloning and the production of the low-density overflow stream that impacts TSF storage capacity and water management.

5 Conclusion

Project considerations such as the operational footprint of the TSF affected by the Santa Rosa and Colquijirca communities, the tailings thickener underperformance and the hydraulic fill plant challenges to meet capacity were identified at the project's onset. Additionally, the diluted slimes stream from the hydrocyclone overflow negatively impacted the TSF storage and water management.

Installing an underground paste backfill plant instead of on surface would concurrently mitigate the social impact to the local community and facilitate the permitting process.

The optimisation of the existing paste thickener would be required at the project's onset including the flocculant system. The optimisation process would rely on the updated instrumentation and trigger criteria to monitor the possible deviations of the process parameters from the targeted values, as well as the maintenance procedure and schedule. Along with the paste thickener optimisation, the existing tailings transfer pipeline with 300 mm Schedule 80 pipes would be replaced with smaller pipe diameter of 250 mm Schedule 80 pipe with 12.5 mm liner to enable the safe thickened tailings transport at a C_w of about 75%. Additionally, to ensure a steady high-density thickened tailings production at a C_w of 75% (C_v of 45%), a density boost circuit would be implemented with a single vacuum disc filter installed on top of the agitated storage tank at the mill. Blending the smaller portion of the friable filter cake with the larger portion of the thickened tailings would alleviate variability of the thickened tailings density allowing steady thickened tailings transport and improve the performance of filtration for backfill production.

The high-density thickened tailings production would primarily rely on the paste thickener operation, while the density boost circuit would be in standby mode and used if the thickener produces lower thickened tailing densities than the targeted value. Lastly, this approach would reduce the number of vacuum disc filters in the backfill plant to 2, which reduces the underground backfill plant footprint and minimises the required excavation. Consequently, it also decreases demand for the electrical supply and ventilation requirement. The steady thickened tailings density at a C_w of 75% (C_v of 45%) has non-segregating properties (non-settling properties/non-Newtonian fluid). The thickened tailings as such would be transported at a lower velocity (i.e. 2.0 to 2.3 m/s), which results in less power consumption. Also, in terms of the material settling along the pipeline and pipeline blockages, the thickened tailings at this consistency would have less risk and managing of the transport velocity would be less critical.

Modifying the hydraulic fill plant to produce high-density backfill at a C_w of 75% would simplify the backfilling process without using a tailings classification system (hydrocyclones). Once the hydrocycloning process is decommissioned, the TSF capacity would be improved. This approach also enables uniform backfill production that relies on the full plant tailings stream only to backfill the North mine.

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