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Application of wet tailings pressure filtration for filtered tailings stack and co-disposal with mine waste at various sites including upstream and downstream of the tailings storage facility

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Abstract

The Martabe Gold Mine is located in the district of Batang Toru in the Province of North Sumatra, approximately 40 km southeast of the coastal town of Sibolga. The carbon in pulp plant was commissioned in 2011 with a nameplate capacity of 5.5 mtpa. With the recent upgrade in 2022, whereby a Verti-mill was installed in the comminution circuit, this has increased the annual plant capacity to 7.0 mtpa.

Given the significant increase in plant annual throughput, additional tailings capacity is required to sustain this increase for the life of mine. With challenging terrain and a lack of suitable valleys for construction of a tailings storage facility, this has prompted the application and adoption of a filtered tailings stack and co-disposal approach for containing tailings and mine waste as various sites at Martabe.

Preliminary laboratory testing using a pressure unit from Diemme–Aqseptence has shown that the tailings slurry can be filtered to attain the required critical moisture content of between 12–14% w/w with good cycle times at 12–13 minutes. Following from the laboratory test, a 0.3 t/h pilot plate and frame pressure unit was hired and tested on plant tailings slurry for over 12 months. The pilot plant with the blow and squeeze function included was able to replicate the moisture results attained from the laboratory test.

With the success of the pilot pressure filtration testing and its suitability to be used for tailings filtered stack and with mine waste for co-disposal, PT Agincourt Resources engaged Ausenco to complete the feasibility study, followed by the design, engineering, construction and installation of two plate and frame pressure filters. The preferred vendor chosen to supply the filter equipment was Diemme–Aqseptence. The plant consists of two vertical recessed pressure plate filters rated at 235 t/h for each unit. The GHT-2500 F26 filter plate and cloth are made of polypropylene capable of withstanding the high filter pressure rated at 16 bar. Each unit consists of 132 recessed plates with two end plates with a plate size of 2,640 mm in width and 3,050 mm in length with a 50 mm chamber thickness. The plant is expected to be ready for commission by June 2024.

Site selection was dominated by proximity to the planned disposal site, being adjacent to the haul road intended to transport the mine waste and filtered tailings for co-disposal, which improves the geotechnical strength of the placement structure and close to the process plant for ease of services extensions and slurry tailings delivery. The zone was also a low grade extension of the main Purnama pit, which provided some financial return on the costs of excavation of the proposed filter plant site.

Keywords: *gold processing, pressure plate and frame filter, tailings filtered stack, waste co-disposal, filtered cake moisture*

1 Introduction

The Martabe Gold Mine is located in the district of Batang Toru in the Province of North Sumatra, approximately 40 km southeast of the coastal town of Sibolga. Figure 1 shows the mining area contract of work. The mine is currently managed by PT Agincourt Resources (PTAR) which is part of PT Pamapersada Nusantara and PT United Tractors, a subsidiary of the Astra group.

The mine has been in operation since July 2012. The plant was designed by Ausenco with a design nameplate capacity of 4.5 Mtpa but with provision for an expansion of up to 6.6 Mtpa through the addition of secondary crushing, screening and pebble crushing. With the recent installation of the Verti-mill in 2022 to increase secondary milling capacity and attain target grind size, this has lifted the total milling capacity to nearly 7.0 Mtpa.

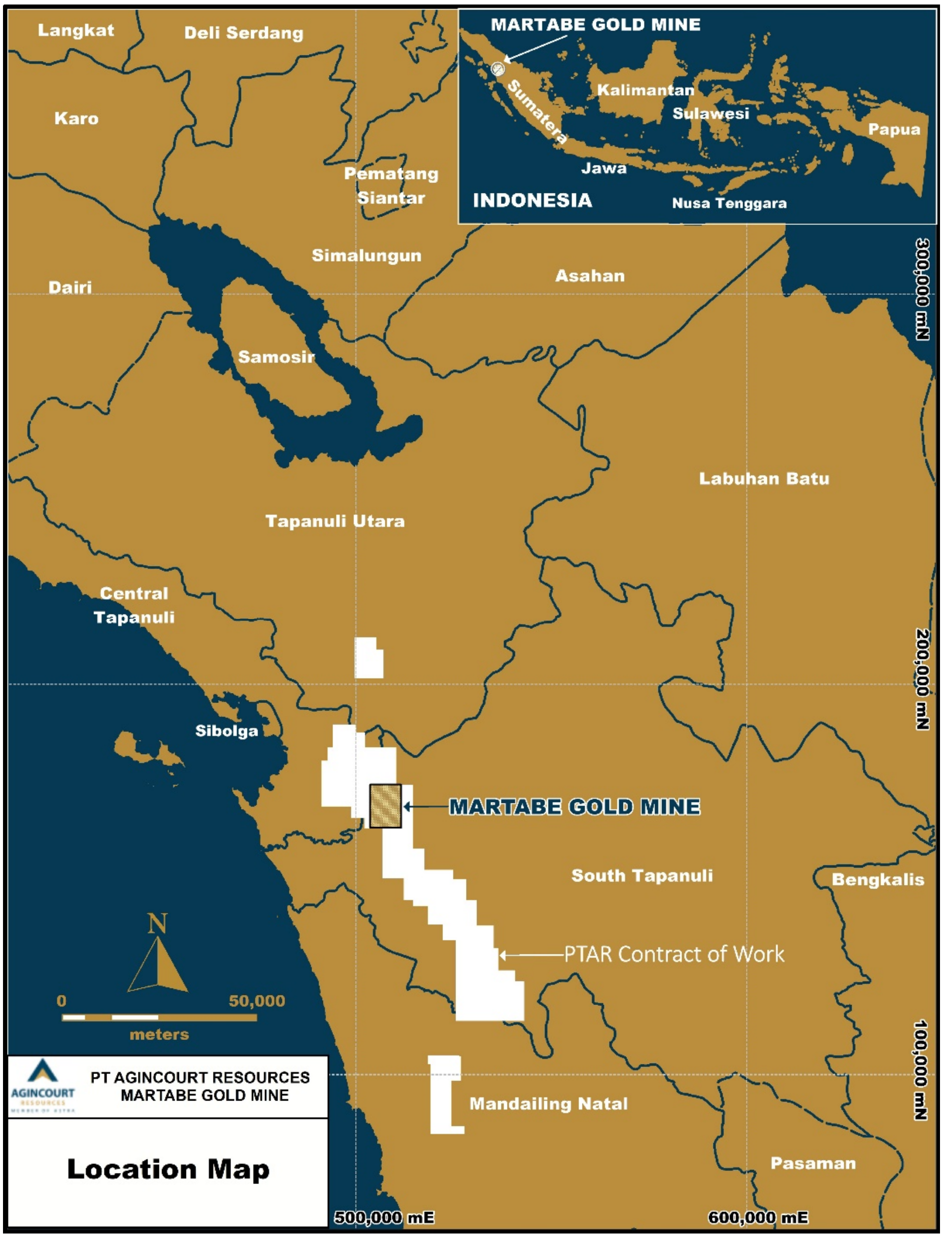


Figure 1 Location of Martabe Gold Mine

1.1 Overview of Martabe carbon in pulp plant

Run of mine ore enters the plant in the dump hopper and then travels over a vibrating grizzly to scalp fines. The grizzly oversize is crushed by a Metso C200 jaw crusher. The original design capacity for the crusher was 675 t/h with a closed side setting of 150 mm. Crushed material is then sent either to the coarse ore stockpile or to the secondary crushing station. Material is then reclaimed from the stockpile and fed to a SABC (SAG, ball mill, pebble crusher) and Verti-mill circuit to generate a final secondary mill hydrocyclone overflow product of 80% passing 150 µm. A schematic diagram of the Martabe comminution circuit is shown in Figure 2.

Given the significant increase in plant annual throughput, additional tailings capacity is required to sustain this increase for the life of mine. Part of the future alternate tailings disposal method at Martabe will involve placement of filtered tailings solids within a tailings management facility (TMF). With challenging terrains and the lack of suitable valleys for construction of a tailings storage facility, this has prompted the application and adoption of a filtered stack and co-disposal approach for containing tailings and mine waste. With such an application it will require installation of a filtration plant where the use of plate and frame pressure filters will dewater tailings from the process plant. Filter tailings will be subsequently loaded and hauled to tailings storage facility (TSF) upstream and various other suitable co-disposal sites including a dedicated TMF, mined out voids and TSF downstream low angle embankment thickening providing additional stabilisation benefit.

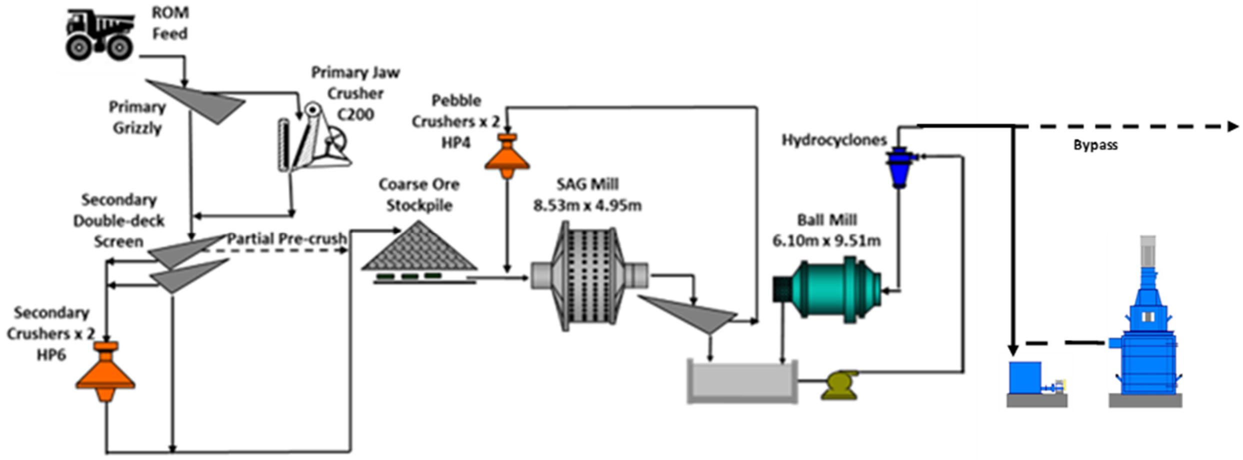


Figure 2 Schematic of Martabe comminution circuit

2 Filtration plant: laboratory and pilot plant testing

Selection criteria for the filtration plant was based on acceptable moisture content which had to be compliant with the requirement of under 18% w/w optimum moisture content (OMC) in order to allow application of a filtered tailings stack with co-disposal of mine waste. Using the standard proctor compaction laboratory testing, OMC of the filtered tailings in range of ~13% which with some tolerance the moisture content targeted from the filtration plant considered still achievable to meet the construction standard of compaction referring to the OMC values.

Two main and common filtration mechanisms were examined. Vacuum filtration despite its versatility and lower capital and operating cost was not considered suitable as the lowest possible attainable moisture content reported from laboratory testing was 20%, inclusive of using filtration aid (flocculants). Pressure filtration being the next available filtration mechanism was tested.

Table 1 shows an example of vacuum filtration testwork on a standard tailings sample which reported moisture content of over 20% at varying cake thickness.

Table 1 Lab vacuum filtration test work

Vacuum from start (-kPa)					80				
Feed density (%)					50				
Vacuum during air dry (-kPa)	58	60	70	50	70	75	40	70	70
Floc dose (g/t)					250				
Cake formation time (s)	50	60	60	110	110	110	210	210	210
Air flow ($m^3/m^2/h$)	122	115	115	84	92	61	76	76	76
Cycle time (s)	240	110	75	360	180	120	500	360	230
Cake thickness (mm)	10	10	10	15	15	15	20	20	20
Filtration rate ($kg/m^2/h$)	236	481	747	231	461	700	226	314	489
Cake moisture (%)	21.5	27.5	30.5	25.2	28.5	30.9	25.7	29.3	32.5

To ensure amenability and suitability of Martabe's tailings for pressure filtration, laboratory testwork using the laboratory-scale plate and frame unit from Diemme-Aqseptence Group (Diemme) was conducted. The laboratory plate and frame unit was assembled at a metallurgical lab in Jakarta. Different blends of tailings samples with a range of pulp densities (% solids) were tested. The testing was aimed at providing a wide range of possible cake dryness values that could be reached starting from the basic cake formation requirement (semi-solid/compact cake) up to obtaining cakes with very high dryness values (low moisture content) with the use the blowing and squeezing function within the plate and frame pressure unit. The collected filtered cake was then submitted for further geotechnical analysis once it has attained the required moisture content.

Results from the laboratory scale plate and frame pressure filter testwork showed that the filterability on the range of tailings samples submitted were very good with relatively short filtration times to attain the desired moisture content. Figure 3 shows the results (moisture content) achieved for the tailings filtered cake under various operating conditions, i.e. chamber thickness, filter cloth type, feed pressure blowing and squeezing pressure and airflow rate.

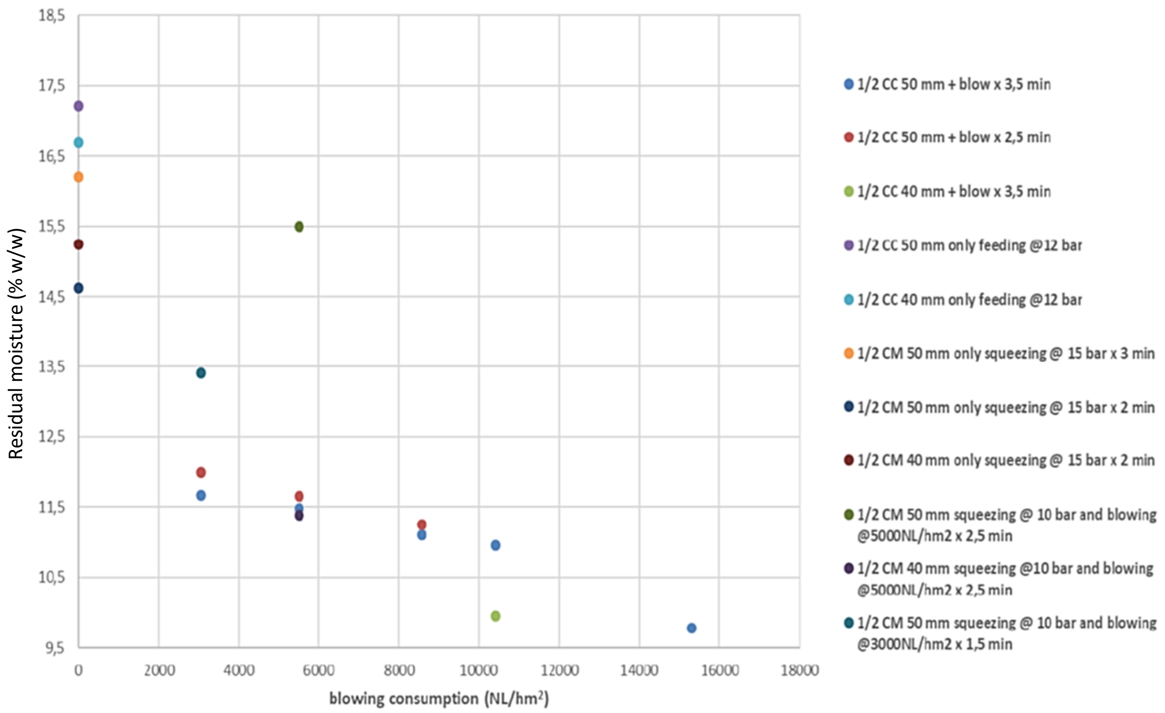


Figure 3 Residual moisture (% w/w) obtained from various pressure filter operating conditions

Figure 4 shows the laboratory scale pressure plant and frame unit from Diemme. All of the samples tested reported a moisture content of under 18% w/w.

Figure 4 Lab-scale pressure filter plate and frame

Figure 5 shows a photo of the filtered cake obtained during the various filtration operating conditions. The filtered cakes are mostly dry, compacted and firm.

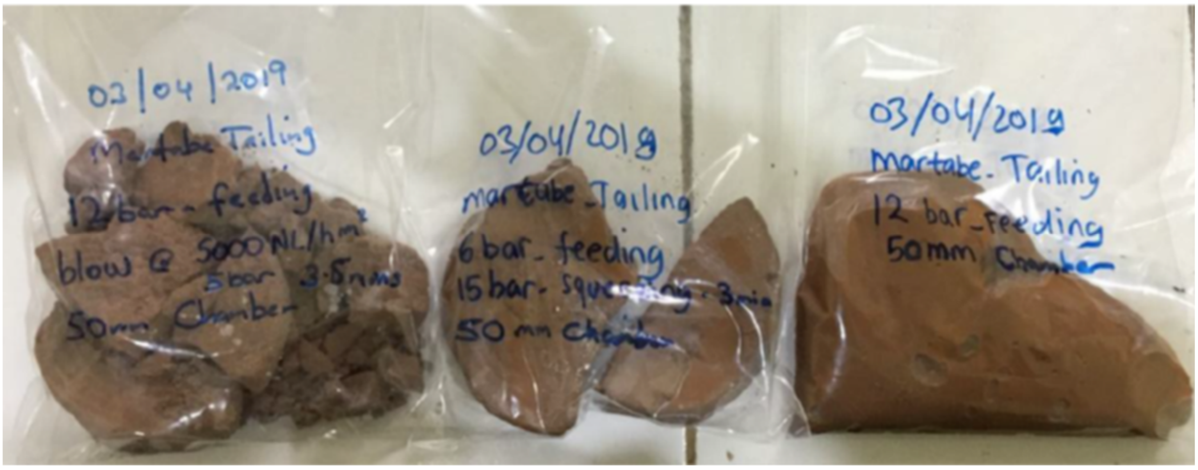


Figure 5 Tailings filtered cake

Following from the success of the laboratory unit, a pilot plant campaign was organised at the Martabe plant site. The pilot unit was assembled and stationed at the back end of the carbon in leach (CIL) plant where it could readily and continuously receive a portion of the plant tailings from a bleed stream into the pilot plant feed hopper.

Two pressure plate and frame pilot units from different vendors were tested onsite. The Diemme KE 500 unit was tested first followed by Metso Outotec (OT) VPX 04. Figure 6 shows the Metso (OT) VPX 04 pilot filter unit.

The Metso OT unit ran for 40 days and during that period it generated over 6.5 tonnes of filtered cake with an average metallurgical moisture of 14% when operating under the standard operating parameters in terms of feed, blowing and squeezing pressures. The unit operated well without any major downtime during its duration for over 800 cycles with each cycle at 11.5 minutes and without any samples exceeding 18% in moisture content.

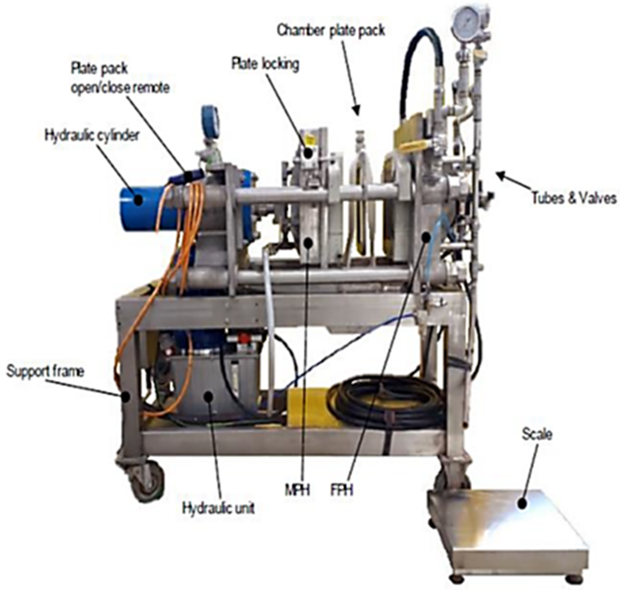


Figure 6 Metso Outotec VPX 04 pilot filter unit

The Diemme pilot filter unit ran for a significantly longer duration than the Metso OT unit at over 90 days. Figure 7 shows the Diemme pilot filter unit. The total cake production was over 90 tonnes. The higher production rate was due to a larger unit being employed by Diemme where it consisted of seven membranes at 1.9 m^2 as opposed to two membranes at 1 m^2 for the Metso OT unit.

The average moisture content was around 14.7%, however, there were several occasions where the moisture content for the filtered cake exceeded the target of 18%. This was attributed to trialling and fine tuning of the operating parameters. The trial also indicated the importance of incorporating both blowing and squeezing functions in order to lower and control the moisture content and achieve its target limits.

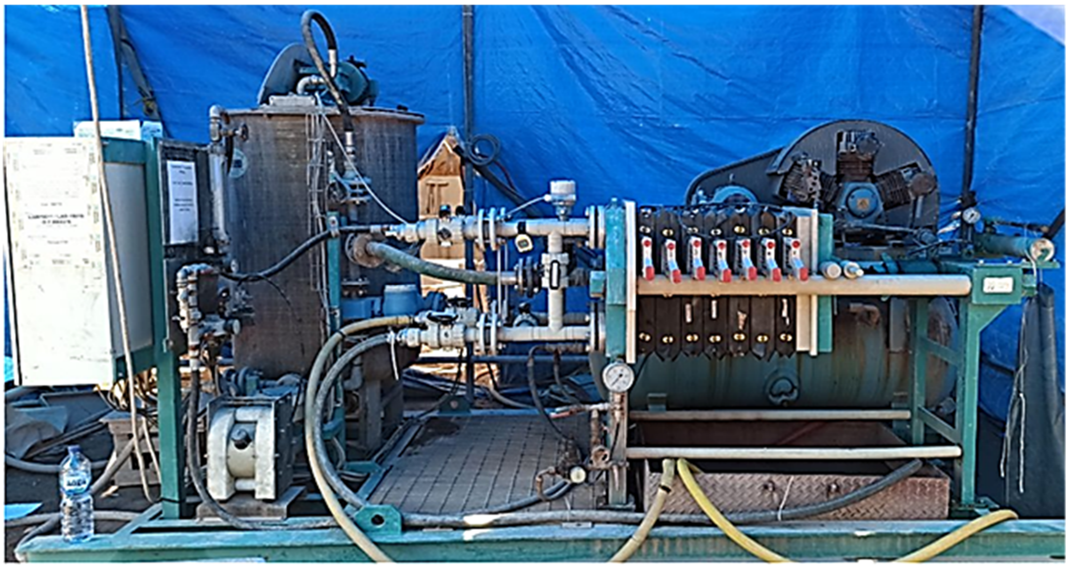


Figure 7 Diemme KE 500 pilot filter unit

The percentage moisture contents achieved during the pilot operation are shown in Figure 8, noting the progressive reduction moisture reduction during its operation and the process was refined. Moisture consistently remained under 17% after operating at steady and optimum conditions.

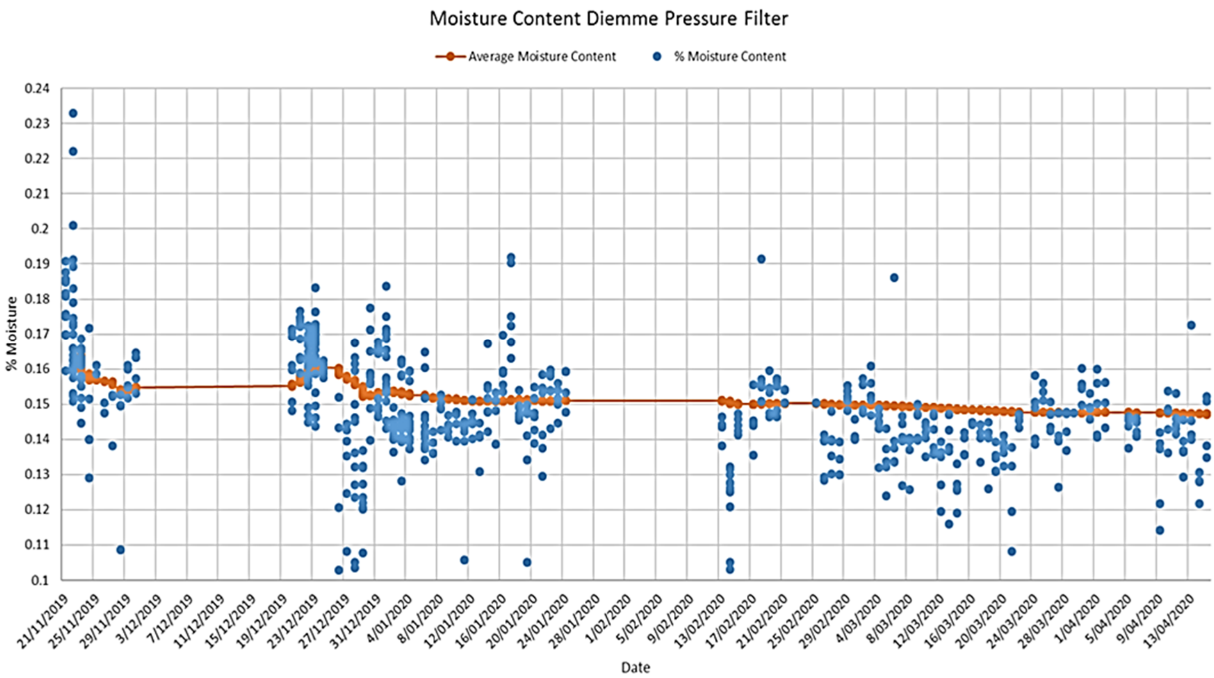


Figure 8 Diemme residual moisture (% w/w) obtained from various operating conditions

3 Filtered tailings properties and placement

Ore from the pits is sent to a conventional primary and secondary crusher, followed by a milling and CIL circuit. Following conventional CIL gold and silver extraction, the tailings waste product is currently deposited to a wet tailings facility as slurry. Filtering of tailings is an intermediate process to remove sufficient water, typically to less than 20% moisture to change the tailings properties to a filtered 'cake' for stacking similar to mine waste. The reduced moisture results in different material characteristics, although some physical properties would be similar. In terms of viscosity, the filtered cake can no longer be pumped and must be transported from the filter unit to the placement area by trucking or a conveyor system.

Filtered tailings 'cake' is deposited as a solid material with a moisture content range of 14–16%. The cake has a majority of fines content passing 0.075 mm in range 55–65% with silt domination, followed by a clay portion and some sandy particle content. The specific gravity (SG) of the material is similar between the slurry and cake tailings, indicating that the filtration process does significantly change the physical solid particle of the tailings. The average SG for tailings is 2.75 t/m$^{3.}$ The particle varies after filtration and the size distribution comparison of slurry tailings and filtered tailing cake is shown in Figure 9.

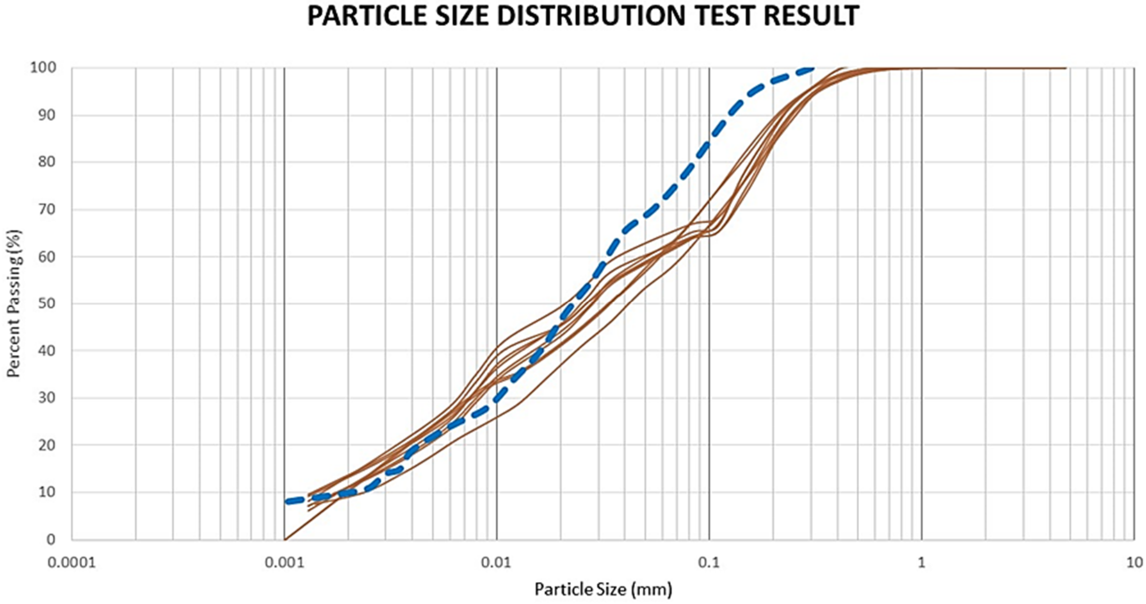
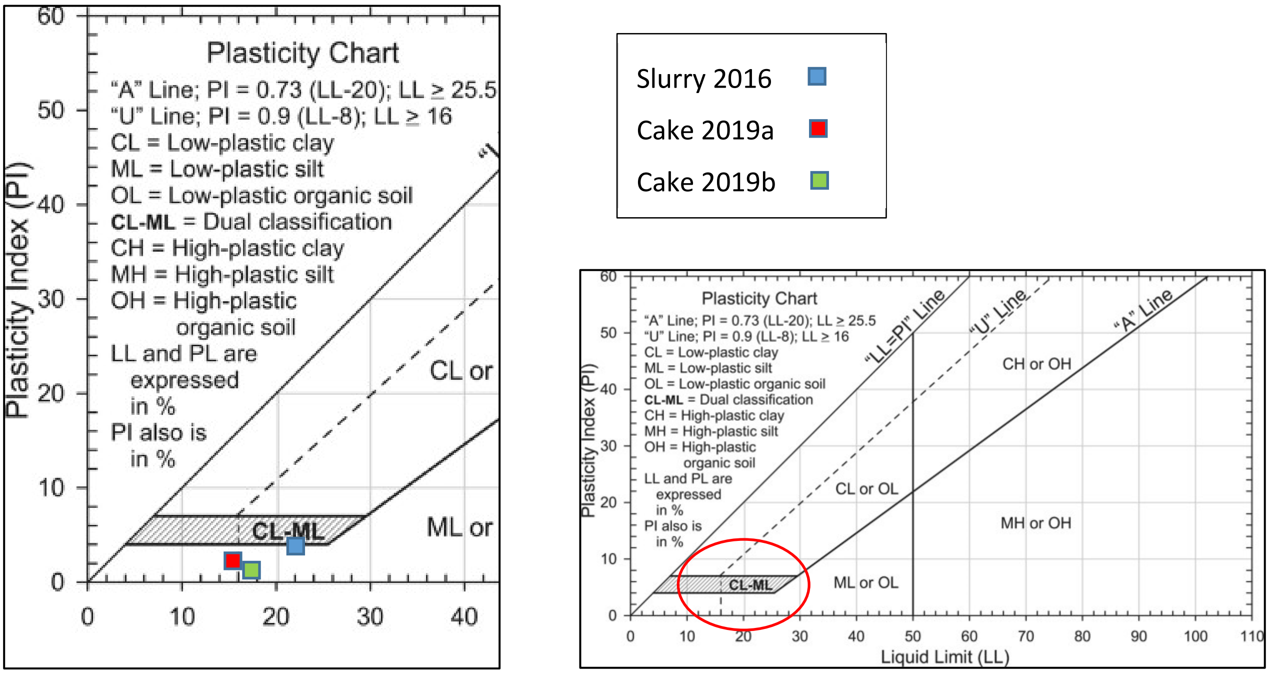


Figure 9 Particle size distribution of slurry (in dotted blue) and cake (in continuous line brown)

3.1 Atterberg limit and Unified Soil Classification System

Martabe tailings having low liquid limit (LL) is classified as a low plasticity material. A slurry sample in 2016 demonstrated a LL of 23% with a plasticity index (PI) of 4%, while a cake that produced in 2019 having 18% of LL and PI 1%. Figure 10a shows the plasticity classification and both slurry with the filtered cake considered as low plastic silt (ML) with reference to the Unified Soil Classification System (USCS) (Casagrande 1948) symbols as described in Figure 10b.



(a) (b)

Figure 10 (a) Plasticity classification slurry and filtered cake; (b) USCS plasticity chart and symbols

3.2 Density, compaction and consolidation

Density plays an important role for the implementation of tailings facilities that utilise filtered tailings. Higher density of cake compared to a slurry results in an increased storage capacity and minimised footprint of a tailings facility. Furthermore, placement of cake with high solids content and low moisture would produce sufficient bearing capacity to retain heavy equipment load. Placement trials demonstrate that the cake could be compacted using heavy equipment with compaction reaching the maximum dry density (MDD) resulting in adequate strength to promote stability of the filtered tailings embankment.

Filtered tailings is less compressible compared to a slurry tailings which takes a considerable period to settle, impacting the tailings profile for closure rehabilitation. In comparison, filtered tailings can be progressively rehabilitated due to the minimal settlement.

Field trials indicate an initial bulk density of 1.85 t/m^3 for cake, with a potential increase to 1.94 t/m^3 if compacted to the MDD. Standard proctor compaction testing resulted a MDD in range 1.85–1.89 t/m^3 with an OMC in range of 13–15%. Result of standard proctor used as reference for the field compaction of filtered tailings placement. Cake density is much higher compared to a slurry which ranges from 1.1 t/m^3 when initially placed to 1.4 t/m^3 over several years, typically as a result of compressive settlement from additional tails deposition loading. The relationship between moisture content and achieved standard compaction density is shown in Figure 11.

Oedometer testing completed on two cake samples indicated increasing dry density from 1.83 t/m^3 to maximum 1.89 t/m^3 in the final consolidation phase. The cake void ratio was initially 0.48 and decreased to 0.45 at the final stage.

Comparison of cake dry density and void ratio in a compacted and post consolidation is similar, indicating that only a small amount of consolidation settlement will occur. The compression index Cc resulted from the test is 0.05 in average that much lower than slurry which is 0.263. While the coefficient of consolidation Cv of a cake is much higher compared to the slurry, with values in range 404–1,520 m^2/year for a cake and 80 m^2/year for a slurry.

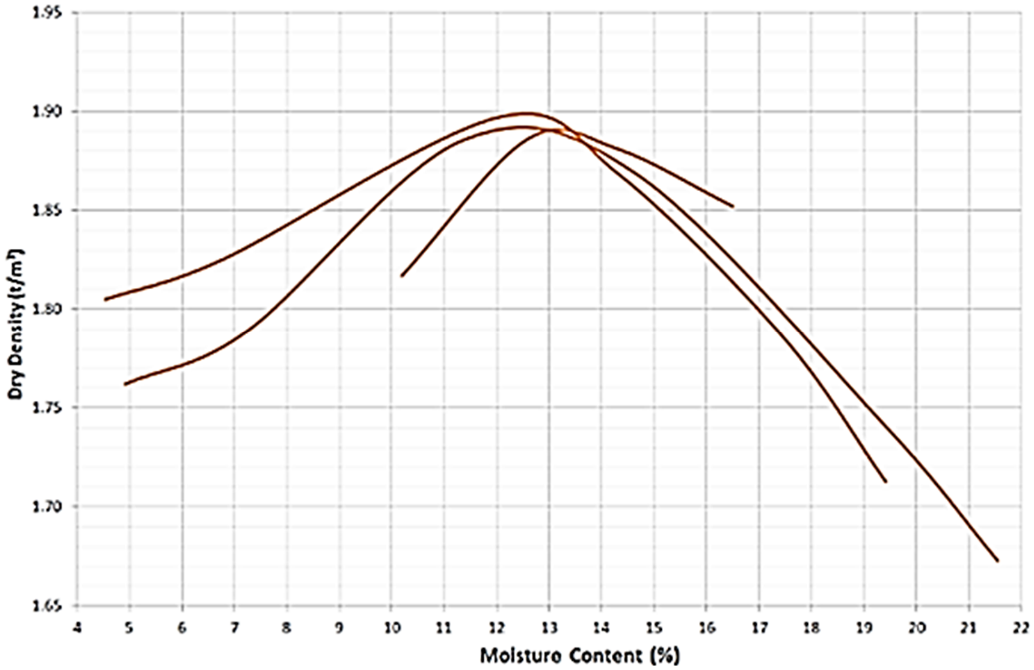


Figure 11 Standard compaction density versus moisture for various samples of filtered tailings

3.3 Strength parameters

3.3.1 Static shear strength

The dynamic simple shear (DSS) tests of the cake indicated a maximum shear stress of 363 kPa with a ratio of shear stress and effective vertical stress S_u/σ'_v of 0.45. The triaxial tests simulate several vertical and horizontal stresses applied into the cake sample which resulted S_u/σ'_v, as described in Table 2. Samples for the DSS and triaxial prepared at the optimum moisture content. A plot of Mohr–Coulomb circle into the triaxial σ1'and σ3' resulted an interpretation of effective strength parameters of σ'_v 310 with zero effective cohesion for conservative drained condition. While plot of correlation between σ'v and S_u/ σ'v of the triaxial and DSS resulted an interpretation of undrained strength properties with S_u/ σ'v 0.30 and S_{umin} 10 kPa. S

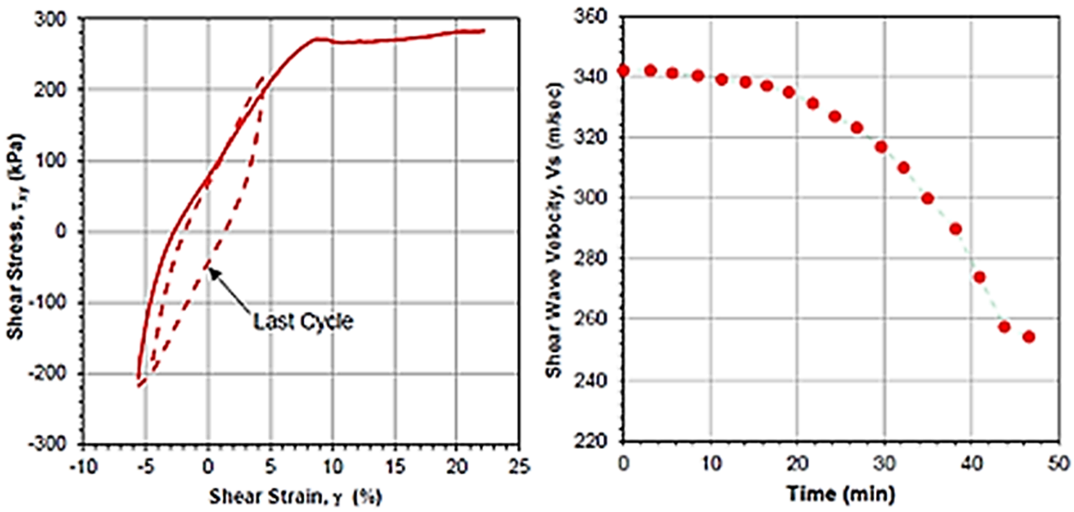
Table 2 Static triaxial (consolidated isotropic undrained/consolidated anisotropic undrained) tests

Test type	σ'_v (kPa)	σ'_h (kPa)	q_{max} (kPa)	S_u/σ'_v
Triaxial	250	250	515	1.03
	500	500	740	0.74
	800	400	640	0.40

3.3.2 Dynamic shear strength

The cyclic direct simple shear (CDSS) test was conducted using a similar setting to the DSS of the initial stress in vertical and horizontal direction, with a maximum shear stress in cyclic shearing 217 kPa in 11 cycles. This simulation produces a post cyclic shear stress of 285 kPa and the ratio of remoulded strength to initial stress S_u/σ'_v is 0.36. A plot of the CDSS results is presented in Figure 12a.

One resonant column was completed as well for the filtered tailings samples. The test resulted a maximum shear modulus G_{max} 243 of MPa. A plot of shear wave velocity (Vs) in sequential time was also produced from the test which presented in Figure 12b.



(a) (b)

Figure 12 (a) CDSS result; (b) Resonant column test results

3.4 Co-disposal of mixed filtered tailings and mine waste

The Martabe site is highly sensitive to earthquake activity, hence development of a tailings facility must consider response to earthquake/seismic events as one of design criteria. As an option to increase strength and minimise liquefaction potential, filtered tailings could be mixed with a mine waste rock sourced directly from the open cut to establish a co-disposal. Tests that were conducted at ratios of 1:1 and 1:2 for co-disposed (tailings/waste) showed improvements in strength, reducing the risk of filtered tailings deposition. Depending on the specific case and location, a facility could apply a filtered tailings ratio of 1:1 co-disposal or 1:2 co-disposal for the tailings placement. The various available sites for co-disposal are shown in Figure 13.

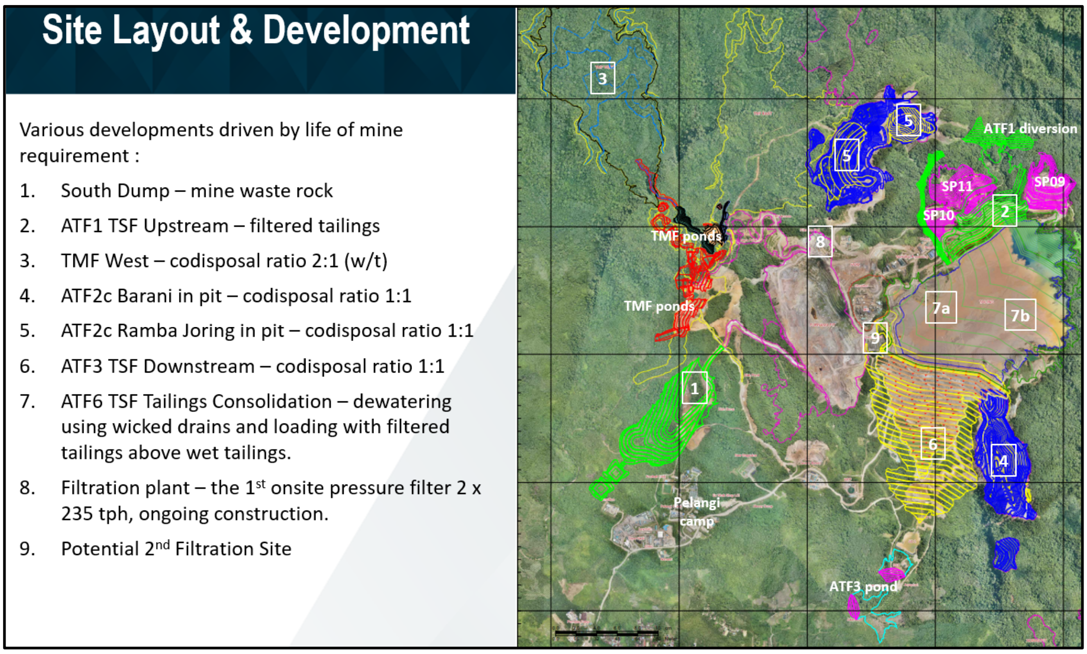


Figure 13 Martabe filtered tailings and co-disposal sites

The co-disposal particle size would be much coarser with material classified as ‘CL’ referring to the USCS including higher LL and PI, compared to filtered tails which is ML. Furthermore, this would produce higher density, higher strength and a reduced risk of liquefaction potential. This mixed material would also provide improved bearing pressure for placement by heavy equipment during construction. Comparison of particle size between a filtered tailings and co-disposal is presented in Figure 14, while a photo of compacted co-disposal ratio 1:2 (tails/waste) is provided in Figure 15. All geotechnical laboratory testwork was conducted by Hydrocore PT (2020) and all material placement trials where conducted by PT Agincourt Resources on site (PT Agincourt Resources 2020a) and results compiled internally (PT Agincourt Resources 2020c) for placement structure design by Knight Piesold (Knight Piesold 2021)

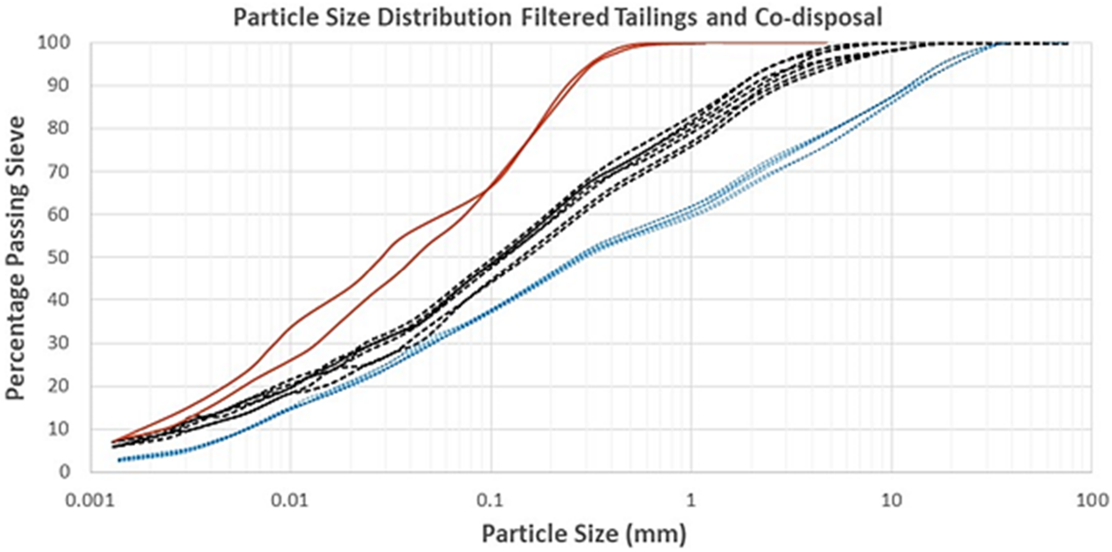


Figure 14 Comparison of particle size distribution. Continuous brown for filtered tails, black dot for co-disposal ratio 1:1, and blue dot for ratio 2:1 (waste/tails)

Figure 15 Compacted co-disposal during field trial

4 Tailings filtration plant: design and engineering

Ausenco was engaged to complete the front end engineering and design after successful completion of both pre-feasibility and feasibility studies. Both studies were completed by 2021 and PTAR decided to proceed with installation of the plate and frame pressure units to accommodate initially 50% of the total tailings flow rate.

The key deliverables included:

- Project and engineering design of the process facilities, plant services/equipment and supporting infrastructure.
- Procurement package on equipment and bulk supply and materials.
- Issue for construction material take-offs, equipment list and all engineering disciplines (earthworks, concrete, mechanical and electrical).
- Provide opex and capex cost estimates on the vertical mill expansion circuit.

Diemme was the preferred vendor chosen to supply the plate and frame pressure filters since it is reputably used in large, filtered tailings application and it was also able to offer in its inherent design the automatic backwash on the filter cloths. The filter cloth replacement on the Diemme unit was also a lot easier, simpler and practicable with compared against the other commercial units.

The design criteria used in the filtration plant were derived from the laboratory test work results which was carried out on a laboratory Diemme unit at Jakarta and data based on the GHT-F filter press from the Aqseptence Group (Diemme). Where information has not been available, assumptions have been made in line with typical operating plant practices derived from the Ausenco database.

The following key parameters were used in the design and engineering for the filtration plant:

- Filtration plant throughput of 3.2 Mt/y (400 t/h).
- Filtration plant operation on a 24 h/d basis with utilisation of 91.6%.
- Nominal filtration plant feed density of 47% solids (w/w).
- Target filter cake moisture of 12% water (w/w).
- Specific filtration rate of 600 kg/m^2/h.

The filter selection was undertaken by Aqseptence Group based on tailings filtration testwork managed by PTAR. A summary of filter technical specifications is provided in Table 3. All filtration trials where conducted by PT Geoservices and managed by PTAR with a compiled internal report (PT Agincourt Resources 2020b)

The tailings filtration circuit will consist of two filter feed tanks and two plate and frame filters. Tailings will be collected in the existing tailings hopper. Tailings to the filter will be directed to the tailings filtration transfer hopper, and pumped to the filter feed tanks at the tailing filtration plant.

The filter feed tanks provide a one hour surge capacity at nominal production rates. Filter feed will be pumped to the plate and frame filters to produce a filter cake of 12–14% w/w moisture. The tailings filter cake will be discharged by gravity to the filter bunker.

Process water will be used for low pressure cloth rinsing and to flush the filter manifolds. Raw water will be used for high-pressure cloth washing.

The filtrate, cloth wash, cloth rinse and manifold flushing water will be collected in a filtrate tank and pumped to the TSF.

The tailings filter bunkers (vault) and storage shed will provide storage capacity for 18 hours at nominal production rates. A front end loader (FEL) will be used to load the filtered tailings into 40 tonne articulated dump truck.

Table 3 Technical specifications of Diemme pressure filter

Technical characteristics	Specifications (per filter)
Supplier	Aqseptence Group
Model	Diemme Filtration model GHT 2500 F30
Filter type	Recessed plate
Total volume of filter press	22,280 L
Total filter press surface	930 m^3
Chamber/cake quantity	100
Operating pressure	10 to 16 bar
Recessed plates quantity	139 + 2 end plates
Plate size	2,640 × 3,050 mm
Chamber thickness	50 mm
Volume per plate	222.8 L
Filtering surface area per plate	9.3 m^2
Plates material	Polypropylene
Filter cloth material	Polypropylene
Quality requirement for cloth rinse water	<1,000 ppm TSS, 100% under 100 um
Quality requirement for high-pressure wash water	<150 ppm TSS, 100% under 100 um

Other major infrastructure associated with the filter press plant included:

- Transfer pump and pipeline
- Tailings pipeline to TSF
- Plant electrical load and supply
- Earthworks.

The tailings transfer pipeline is approximately 1.3 km long and discharges at approximately 53 m higher elevation than the process plant. The transfer pipeline will normally operate at a throughput of 400 t/h and slurry density of 47% (w/w solids). For the selected pipeline selection and predicted solids deposition velocity, the minimum throughout will be approximately 291 t/h. Once per day, the filters will undergo a high-pressure wash cycle for 1.5 hours each. During this period, the filter system demand will decrease to 200 t/h and the filter feed tank level will rise by approximately 140 m^3/h. The total filter feed tank capacity of 600 m^3 is sufficient to contain the excess flow during this period.

If one filter is offline for more than four hours, slurry transfer should be changed to batch operation, or alternatively, the tailings transfer line can be flushed and then shut down. The tailings transfer pumps to location 2 have been selected for 400 t/h with an additional 10% flow margin.

The system requires two pumps in series to achieve the duty. A standby train shall also be installed. The selected pumps are Warman 150 WBH centrifugal slurry pumps with 250 kW motors. One pump in each train will be direct online and one will have a variable speed drive (VSD). At the termination of the pipeline, a ceramic choke shall be installed to avoid slack flow at the pipeline high point (at chainage 1,050 m).

When tailings filtration is implemented, significant system redesign is required in order to accommodate the full range of throughputs, concentration ranges, different spigot selections, and dam reduced levels (RLs). The following proposed changes will take place:

- Replacement of the piping along the TSF wall with DN400 PN16 HDPE to avoid low velocities (and hence solids deposition and blockages) when the filters are operating.
- Replacement of the ceramic chokes with an automatic slurry flow control valve. The control valve will be controlled by a PLC and will maintain a pressure set point at the start of the tailings line, thereby avoiding slack flow. The valve will close more in times of low throughput and/or during use of closer spigots.
- The slurry flow control valve must be located at the start of the flat section of piping along the TSF wall. It is recommended that the control valve be installed on a skid such that the skid can be relocated to the new wall start location each time the TSF level is raised.
- Install a single centrifugal slurry pump (Warman 300L or equivalent) at the tailings hopper. The pump will be required when the dam reaches RL377 m and only for when discharging from the furthest spigot. When the pump is in use, the slurry control valve will be set to fully open.

Only a single duty pump will be required. When the pump is not operational, closer spigots (which can be gravity fed) can be used until the pump is brought back online. The pump will require a VSD to provide control and accommodate the required flow range. The slurry control valve will include bypass piping and valves to allow maintenance while the process plant is operating.

The estimate of plant power draw has been determined for the filtration plant based on calculated processing duties. Typical load factors have been applied to other equipment, motor control centre (MCC) building loads, lighting and small power. Equipment utilisation factors are applied to the load list to calculate the average facility power draw and account for the batch operating nature of the filters and intermittent operation of sump pumps and standby equipment.

It is estimated that the actual half-hour peak demand will be 1,198 kVA for the tailings filtration area and 544 kVA for the new loads connected to the MCC. The proposed tailings filtration facility will be fed from the overhead 11 kV powerline which runs past the maintenance workshop.

The final location selected to construct and house the filtration plant and ancillary equipment is located northeast of the main Purnama pit. This location was selected based on close proximity to the TMF which will reduce the trucking and haulage cost. The option of using collection and transfer conveyors to deliver filtered tailings to the TMF will be investigated in the next phase of the filtration plant upgrade.

A three-dimensional layout and plan view schematic of the filtration plant is shown in Figures 16 and 17, respectively.

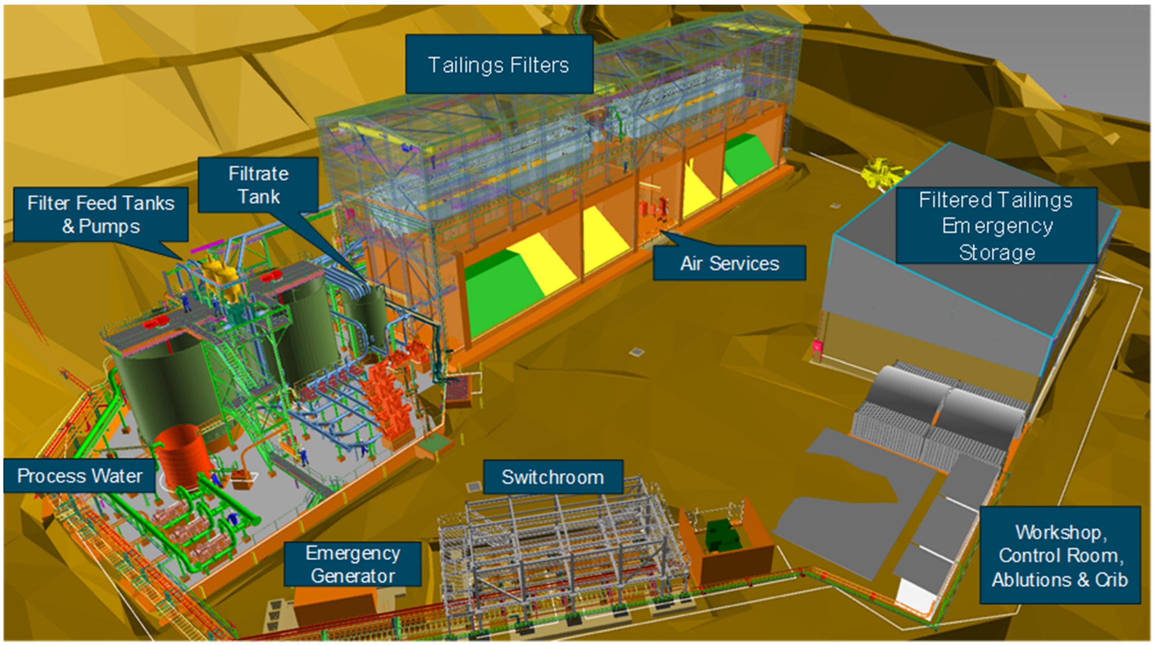


Figure 16 Three-dimensional layout of filtration plant

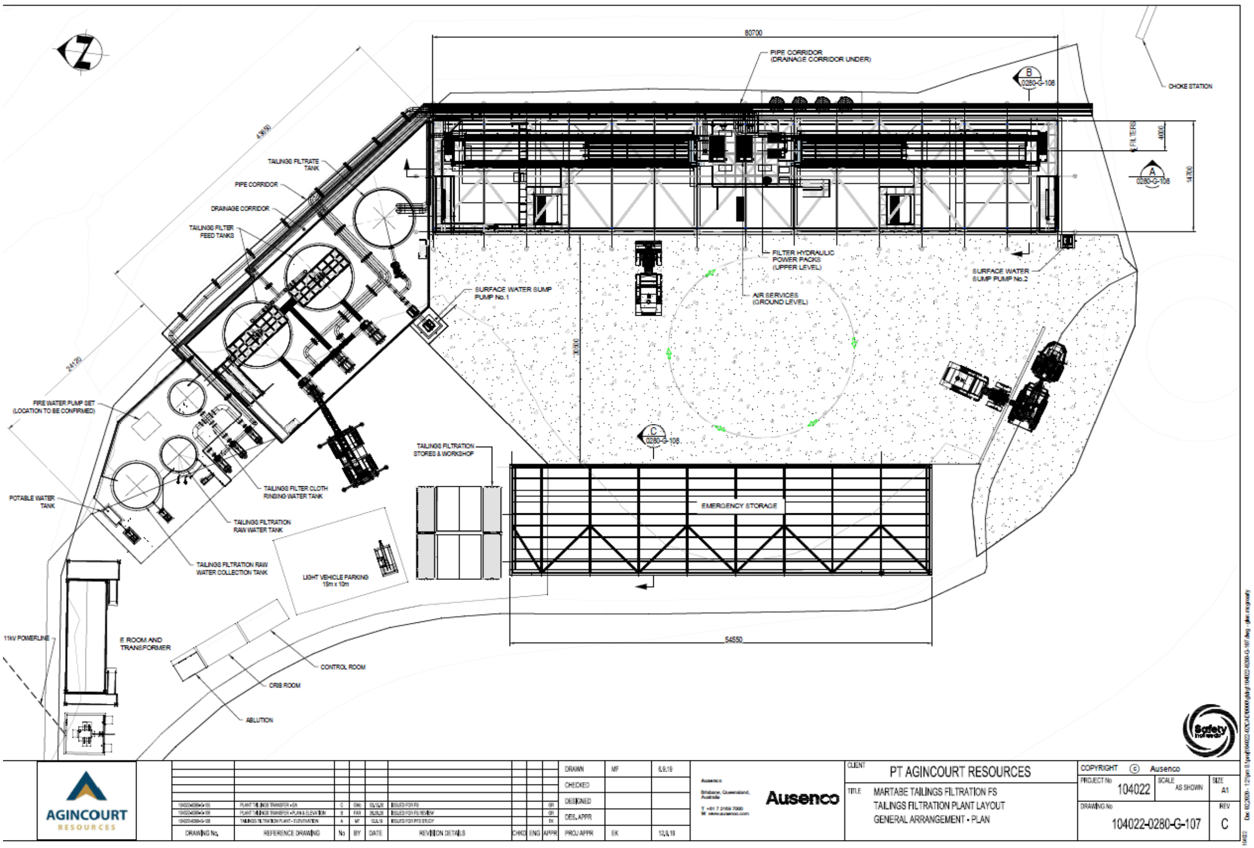


Figure 17 Plan view of filtration plant

5 Capex and opex for filtration plant operation

The capital cost for the Martabe tailings filtration plant – which includes the tailings filtration facility, modifications to the existing process plant, upgrading the tailings line to the TSF, upgrades to plant infrastructure and contingency – is estimated at USD 39 million. Earthworks and owners' costs (management, procurement, construction management) have not been included as the project is managed in-house and is costed internally. The two Diemme filters GHT 2500 F series were quoted at USD 6.5 million. The total direct cost is estimated to be USD 30 million, with the majority being site preparation and the supporting structure.

The operating cost includes all process plant related operating costs associated with the tailings filtration plant, and is estimated at USD 0.68/t of filtered tails. Since the filtration plant is designed for 50% tailings filtration the unit cost per tonne of ore is estimated at USD 0.26/t.

6 Conclusion

The paper concludes that there are significant advantages to changing from slurry tailings deposition and containment in a conventional wet tailings facility to a filtered tailings stack or co-disposal site, especially in relation to site constraints, including:

- Limited suitable locations for an additional wet tailings facility of adequate capacity
- Limitations of further vertical raises of the existing wet tailing facility, now at the design limit
- Consideration of reduced risk for any additional facility with reference to Global Industry Standard on Tailings Management guidelines
- Requirements for disposal of both mine waste and tailings in limited suitable footprints
- Provides more flexibility in site selection, including currently disturbed areas, minimising impacts on biodiversity.

Site selection for the filter plant was driven by proximity to the proposed deposition site at TMF east and west to minimise haulage costs, also close proximity to the process plant for ease of extension of services and delivery of the slurry tailings.

Potential application of filtered tailings and co-disposal with mine waste at various Martabe disposal sites, including a dedicated separate TMF facility, TSF upstream beyond the wet tails deposition limit, TSF downstream providing additional support to the existing embankment and in-pit co-disposal making use of completed pit voids and providing partial slope rehabilitation. The additional options, pending feasibility study, provide sufficient capacity for Martabe 2 sulphide open cut and underground expansions.

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