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Improving filtration efficiency with ATA® rapid dewatering technology

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Abstract

Filtration of tailings slurries is a growing area of interest as operations are increasingly moving to stacked disposal. Fine particles can migrate to the filter cloth and cause blinding, resulting in extended filtration times leading to larger filtration plant sizes. This capital constraint can make tailings filtration uneconomic.

ATA® rapid dewatering technology builds a granular structure in tailings slurries that enhances hydraulic conductivity. ATA is a three-component system in which fine and coarse tailings fractions (either produced using a hydrocyclone or resulting from different plant processes) are each treated with complementary polymeric reagents and recombined to create anchored particles that capture fine particles while increasing the dewatering rate.

This paper compares the filtration efficiency of two different tailings slurries conditioned with ATA. Iron ore tailings from Brazil and copper tailings from Australia were conditioned with ATA prior to conducting gravity drainage tests, followed by filtration with both vacuum and pressure filtration. The impact of ATA as a pre-filtration dewatering process was benchmarked to conventional thickening for the copper tailings. ATA conditioning showed improved filtration rates resulting from enhanced fines capture for both types of tailings. It was also shown that ATA unlocks a lower-cost flow sheet towards dry stackable material, enabling the use of vacuum filtration as the primary dewatering method where pressure filtration would normally be considered due to the ultra-fine particle size distribution. The paper presents an overview of the flow sheets developed and tested to achieve dry stackable tailings using these two different tailings streams and provides an overview of the techno-economic impact of the ATA® technology on these two case studies.

Keywords: *tailings filtration, dry stacking, polymer conditioning, new technologies, case studies*

1 Introduction and objective

The mining industry produces an abundance of waste products annually and the volume produced continues to grow as the industry is increasingly required to process higher tonnages at lower grades. These waste products, called tailings, can cause an enormous risk to the environment and the communities in the vicinity of mines. Historically, tailings were discharged directly into tailings dams, either with or without thickening (‘conventional’ tailings). Tailings dams incur long-term challenges – for example, in the reclamation and closure phases – as well as geotechnical risks (Burden & Wilson 2023).

Due to these challenges, as well as the sheer space needed for tailings dams, and changing regulations, mines have started to approach tailings disposal in a new manner which requires further dewatering to produce a

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self-supporting pile. This is commonly referred to as 'dry stacking'. Stackable tailings have the potential to reduce tailings dams or, even better, to eliminate them altogether (Burden & Wilson 2023).

The following four characteristics are necessary for stacking to be suitable (Amoah et al. 2018):

1. Moisture contents should be close to the standard optimum moisture contents, which allows the material to compact at higher densities compared to conventional tailings.
2. The degree of saturation and compressibility should be lower at deposition compared to conventional tailings.
3. The material should have the ability to be stored without external containment embankments.
4. The material should have the ability to be transported by mechanical conveyors or trucks.

To engineer tailings to have these characteristics, several types of filters can be considered, including pressure filters, belt filters and rotary vacuum disc filters. A challenge to implementation of filtration is the large flow rates and limited filtration throughput, necessitating large, capital-intensive filtration plants.

Dewatering of fine tailings is a complex challenge. ATA® offers a novel approach by separately treating coarse and fine fractions (produced using conventional technology such as hydrocyclones, or already existing in an operation) with pairs of complementary polymeric reagents (see, for example, Berg et al. 2013). The fine stream is treated with an activator while the coarse stream is treated with a tether, creating anchor particles, hence A-T-A (Figure 1).

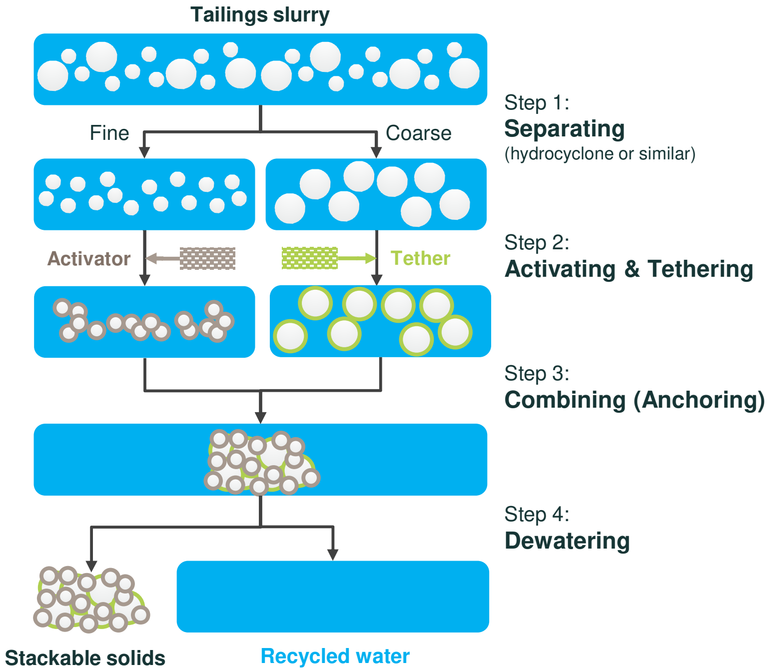


Figure 1 Schematic of the ATA process

When the activated fines are combined with the tethered coarse material (anchors), the fine particles are attracted to the anchors, form large agglomerates and rapidly settle. The agglomerate network has a rigid, open structure that rapidly dewaters through a porous medium such as a screen, geotextile or filter. Due to the attractive forces between the fine and coarse particles, exceptionally low turbidity water is released and fines capture (and recapture) can be dramatically improved compared to conventional flocculation with a single reagent. The reagents are strongly attracted to the solids and have similar environmental profiles to flocculants used in mining and water-treating applications. Once desaturated, the strength of the dewatered solid network is dominated by particle-particle forces rather than the polymers, and therefore long-term stability is not expected to be affected by polymer degradation.

ATA has been demonstrated at the laboratory-scale on tailings from a wide variety of commodities, including gold, copper, diamond, phosphate, iron ore and mineral sands, and piloted on diamond, gold and phosphate tailings.

The objective of this paper is to compare the filtration efficiency of two different tailings slurries conditioned with ATA. Iron ore tailings from Brazil and copper tailings from Australia were conditioned with ATA prior to conducting gravity drainage tests, followed by filtration with both vacuum and pressure filtration. The impact of ATA as a pre-filtration dewatering process was benchmarked to conventional thickening for the copper tailings. Indicative equipment sizing was conducted from the fundamental data produced in the experimental process and provides the basis for a techno-economic assessment of the impact of ATA on the dewatering efficiency of fine tailings. Note that all solid concentrations are expressed as dry solids/(dry solids + water) and were measured by the oven drying of slurry samples.

2 Materials and methods

2.1 Polymeric ATA reagents

The ATA activator and tether reagents are proprietary polymers. Solid polymers were dissolved at 0.2% w/w in deionised water while solution polymers were diluted to 0.2% w/w with deionised water. Dosages were optimised based on visual observation of agglomerate formation and settling behaviour.

2.2 Tailings samples

The Brazilian iron ore tailings were sourced from an iron ore mine with a flow sheet including crushing, screening, milling, desliming, grinding and flotation, and which produces multiple tailings streams. Testing was conducted onsite using slurries sampled from the process. For this application the aim was to enable dewatering to dry stackable tailings of the fine desliming tailings by incorporating a portion of the coarser flotation tailings. The desliming tailings are currently managed via conventional wet tailings storage. Due to the ultra-fine nature of the tailings, filtration is unable to reduce the moisture content to the level required for stacking. The coarse-to-fines (CFR) ratio was variable and optimised to the minimum mass flow of coarse required to enable efficient dewatering of the fines. The fines fraction used for ATA conditioning was desliming tailings, while the coarse stream was final flotation tailings.

The properties of the Brazilian iron ore tailings are summarised in Table 1. The particle size distribution (PSD) of the respective streams is shown in Figure 2a. The PSD of the fines stream shows that 80% passes 25 µm, while the coarse has a PSD where 80% passes 150 µm. The flotation tailings were wet screened at 106 µm to produce a simulated cyclone underflow to test the impact of further classification of the coarse stream. Note the extremely low solid content of the desliming tails (3.3% w/w). This results in a high hydraulic loading for any subsequent dewatering process.

The Australian copper tailings were sourced from a copper concentrator which has a conventional crushing, grinding and copper flotation circuit. Current site practice is to thicken tailings prior to deposition in a surface tailings storage facility (TSF). Coarse and fine fractions were generated from the Australian copper tailings sample (bucket of slurry) by decanting and washing. A simulated thickener underflow (TKUF) sample was generated from whole tailings with flocculant (SNF AN905SH) added at 17 g/t. Flocculant was added as 0.025% w/w solution in two stages, with mixing via beaker pours, to achieve a solids concentration of 65% w/w. After flocculant addition, the slurry was agitated with an anchor impeller at around 300 rpm for 10 minutes to simulate flocculent breakage due to underflow pumping. The Australian copper tailings slurry properties and process flows are summarised in Table 1 and the PSD is shown in Figure 2b, respectively. The solid content of the copper tailings slurry is an order of magnitude higher than the iron ore tailings, resulting in a much lower hydraulic loading for any subsequent dewatering process.

Table 1 Properties of Brazilian iron ore (BIO) and Australian copper (AC) tailings

Process stream	Solids (% w/w)	Solid Specific Gravity	Slurry Specific Gravity	Solid flow (dry t/h)	Volumetric flow (m^3/h)
BIO desliming tails	3.3%	3.805	1.025	300	8,953
BIO flotation tails	51.6%	2.922	1.514	150	192
BIO classified flotation tails	49.4%	2.922	1.481	150	205
AC tailings	30.7%	3.351	1.265	903	2,287
AC fine fraction	20.0%	3.192	1.169	430	1,839
AC coarse fraction	60.0%	3.510	1.763	473	447
AC simulated thickener underflow	65.0%	3.351	ND		

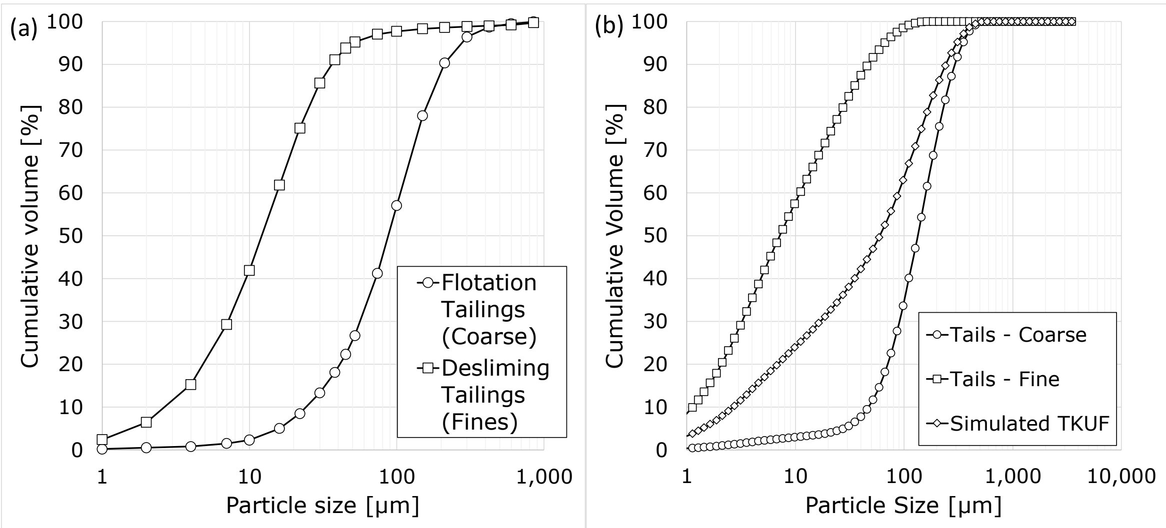


Figure 2 Particle size distribution of (a) Brazilian iron ore tailings; (b) Australian copper tailings

2.3 Iron ore tailings procedures

ATA conditioning scoping tests were conducted in jars using the desliming tailings as the fines fraction and the classified and unclassified flotation tailings as coarse fractions. The jar tests were carried out by treating the fines with an activator reagent and the coarse fraction with a tether reagent, then combining the activated fines with the tethered coarse fines. Mixing in each case was done by gently inverting the jars several times, as over-mixing can be detrimental to the structure of the ATA-conditioned material. Two different CFR were tested with the classified flotation tailings as the coarse fraction. The ATA-conditioned material was deposited on a 300 µm screen, and the solids% of the material retained on the screen was measured by oven drying. The optimal dosages of activator and tether were selected based on visual assessment of the granularity of the material structure as well as the consistency of the deposited material and the final drained solids%, as settling was rapid. In the case of the iron ore tailings, the clarity of the water that passed through the screen was not critical, with emphasis placed more on the structure and stability of the ATA-conditioned material.

Once optimal activator and tether dosages were established, the settling rate of the conditioned material was tested using an undrained cylinder settling test, to provide data for sizing of pre-thickening processes. Vacuum filtration tests were performed by first decanting the supernatant and thereafter dewatering the

ATA-conditioned material using a benchtop vacuum filtration set-up operated at a vacuum pressure of –65 kPa, with filter media with cloth permeability of 102 m^3/m^2.min at 200 Pa and a filtration area of 0.01 m^2. Cake form time, cake thickness, cake moisture content, filtrate volume over time and filtrate turbidity were measured. The yield stress of the formed filter cake was measured upon completion of each test.

2.4 Copper tailings procedures

The tailings were split into coarse and fine fractions by manual decanting and washing to simulate hydrocyclone overflow and underflow. This resulted in a CFR of 1.1. A selection of ATA reagent types and dosages were tested in small-scale jar tests. The jar tests were conducted in the same manner as described in section 2.3. The combined ATA-conditioned material was then deposited on a 212 µm screen, and the solids% of the material retained on the screen was measured by oven drying. The optimal combination of activator and tether was selected based on the structure of the combined material (which should be granular), the clarity of the water that passed through the screen (which should have low turbidity) and the consistency of the material on the screen (which should release water easily and not spread out).

Further dewatering tests at the optimised dosages consisted of drained and undrained water release using a two-segment cylinder, and compression-permeability (C-P) tests using a laboratory-scale automated pressure filtration apparatus at the University of Melbourne (de Kretser et al. 2001). Yield stress was measured with a Haake VT550 controlled rate viscometer. The details of these procedures are provided in Spagnuolo et al. (2024). The pressure was progressively increased using a solid piston to obtain the relationship between solid concentration and compressive stress under saturated conditions. Separate tests were conducted at 65 and 600 kPa using an air-driven cell to obtain the equivalent data under desaturated conditions (due to the displacement of porewater with air).

3 Results and discussion

3.1 Copper tailings

The appearance of the samples after treatment at the optimised ATA conditions is shown in Table 2. The activated fines show an agglomerated structure with residual turbidity in the supernatant. The tethered coarse fraction shows less change but the turbidity of the supernatant is lower. After combining the activated fines with the tethered coarse fraction, the tailings developed a granular structure and the supernatant had dramatically improved clarity. Deposition of the ATA-treated tailings on a 212 µm screen resulted in dewatering to 68% w/w solids (from 31% w/w in the combined feed) within minutes. The deposited tailings formed a coherent mass and did not spread out: i.e. they did not show slurry-like behaviour.

Drained and undrained dewatering tests were carried out in duplicate, and an additional screen drainage test was done using a 425 µm sieve (Table 3). The screen drainage test consisted of depositing the conditioned material into a cylinder placed on the sieve to assess 1D drainage for 10 seconds (no lateral liquid flow possible), followed by removal of the confining cylinder and allowing an additional 10 seconds of drainage with lateral flow possible. This was intended to be representative of a gravity drainage belt, where ploughs create open areas in the cake for water to drain into. Rapid dewatering due to sedimentation to around 60% w/w was almost instantaneous, with further increase in solids% as drainage continued. The static screen drainage test indicated that dewatering to over 60% w/w solids occurs within 20 seconds of deposition.

The C-P and cake desaturation data were used to perform vacuum and pressure filtration modelling. Using the data in this way provides the flexibility to assess equipment sizing and explore impacts of variable feed solids concentration, or other operational and design parameters, without the need to conduct further testing (de Kretser et al. 2010). In addition, the C-P data are equally applicable to the assessment of material consolidation behaviour under TSF deposition conditions. The analysed C-P data are presented in Figures 3 and 4.

Table 2 Appearance of the copper tailings samples at the optimal ATA conditions

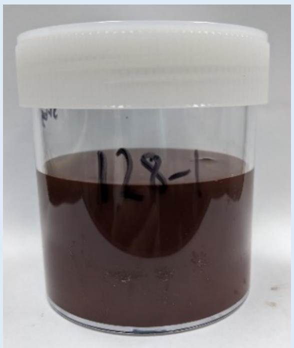
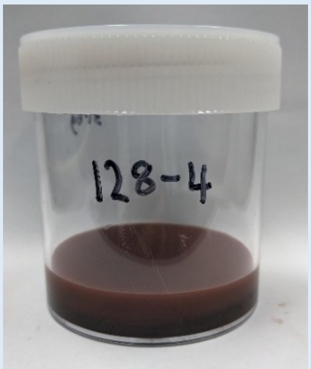
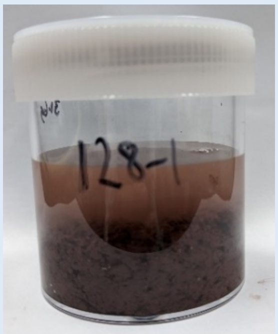
Fines at 20% solids Above: untreated Below: activated at 250 g/t 110A	Coarse at 60% solids Above: untreated Below: tethered at 50 g/t 210T	Combined treated fractions Above: ATA-treated (31% w/w) Below: screen dewatered (68% w/w)
		
		

Table 3 ATA-treated tailings dewatering and yield stress data (initial combined solids 31% w/w)

Test	Released water	Drained sediment		
Parameter	Turbidity (NTU)	Drained solids (% w/w)	Dry density (t/m^3)	Yield stress (Pa)
Cylinder drainage	25.5	65.3	1.21	975.6
	38.4	66.7	1.26	942.2
425 µm screen drainage	–	62.0	1.10	–

Marginally higher cake solids (1–2% w/w) were achievable for a given applied mechanical pressure with the simulated TKUF compared to the ATA-treated tailings (Figure 3a). This is to be expected, as the ATA treatment results in a material with increased interparticle forces (hence the high shear yield stress) and this is a common behaviour in any strongly flocculated system. The stiffer, more open network structure generated via ATA treatment resulted in permeabilities around an order of magnitude higher than for the simulated TKUF (Figure 3b). This illustrates that while ATA treatment slightly reduces the final cake solids achievable for a given applied mechanical pressure, the rate at which a final dewatered cake can be achieved is significantly increased.

The coefficient of consolidation data in Figure 4 provide another indicator of the kinetic benefits of ATA conditioning on dewatering and consolidation rates. These data highlight again the order of magnitude improvement in consolidation kinetics, which has implications in conventional wet tailings deposition from the perspective of reducing the operational TSF area required to maintain a target operational dry density.

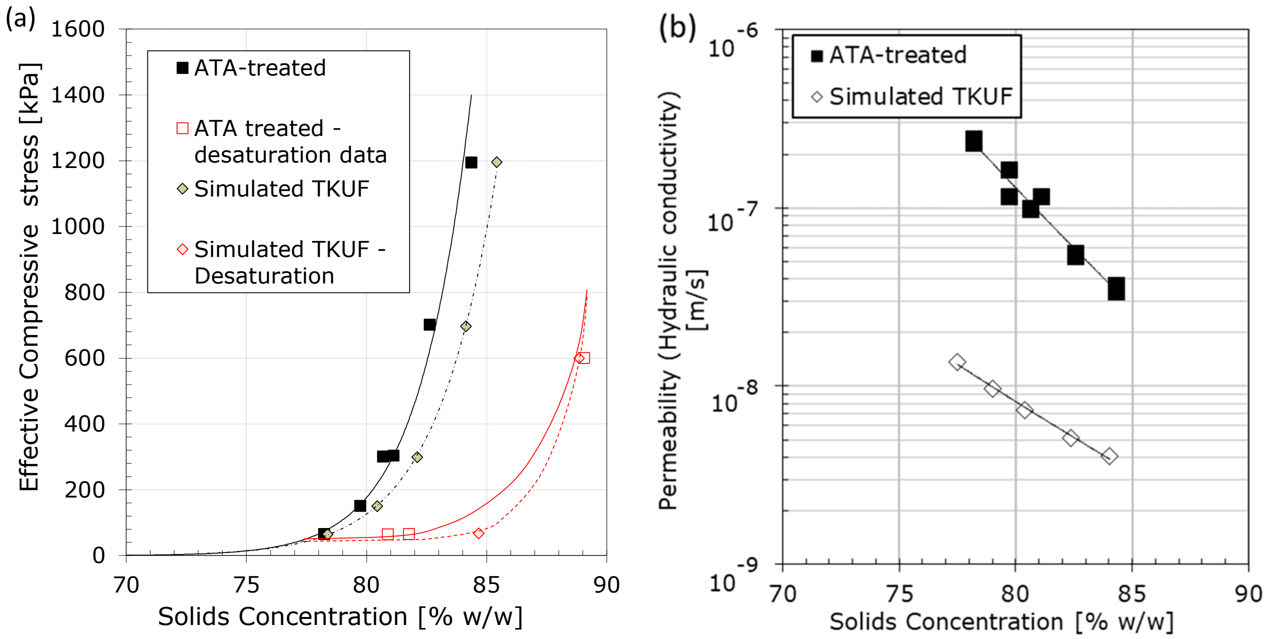


Figure 3 Relation of dewatered solids concentration for ATA-treated copper tailings and simulated thickener underflow with: (a) effective dewatering stress; (b) hydraulic conductivity

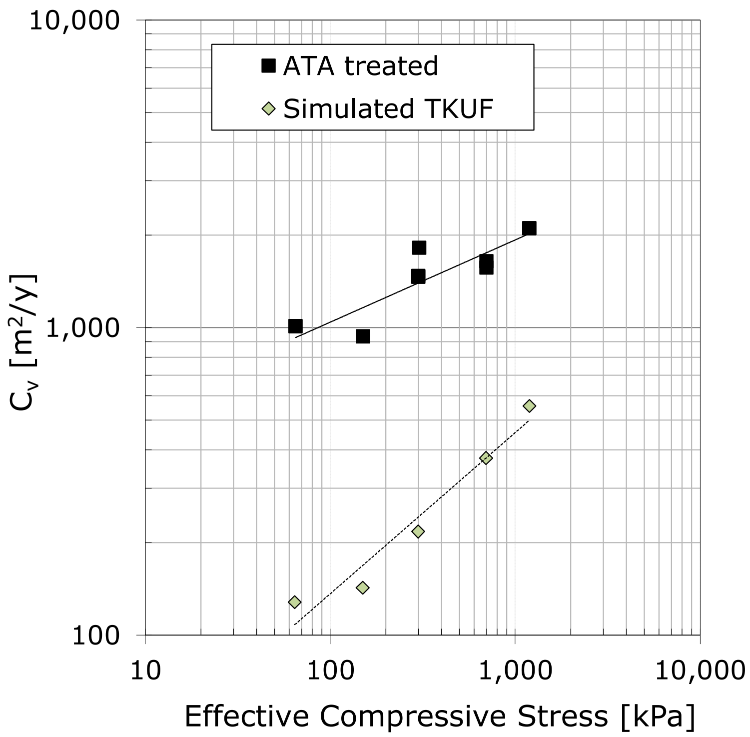


Figure 4 Coefficient of consolidation (c_v) versus compressive stress for ATA-treated copper tailings and simulated thickener underflow

The cake solids versus pressure data in Figure 3a also illustrate achievable cake solids via desaturation as opposed to mechanical compaction of a saturated cake. These data illustrate that significantly higher cake solids approaching 89% w/w are achievable at moderate desaturation pressures of 600 kPa. No material difference is evident in the achievable cake solids between the ATA-treated and simulated TKUF.

The shear yield stress as a function of dewatered solids concentration for the ATA-treated tailings and simulated TKUF are presented in Figure 5. These data illustrate the significantly higher shear yield stresses for the ATA-treated tailings at any given solids concentration. The difference approaches two orders of magnitude at lower solids concentrations, and notably this is only moderately impacted by low levels of shearing. This difference narrows with increasing solids concentrations, however, at solids concentrations in the range of filter cakes (80–90% w/w), the ATA-treated material still exhibits enhanced strength.

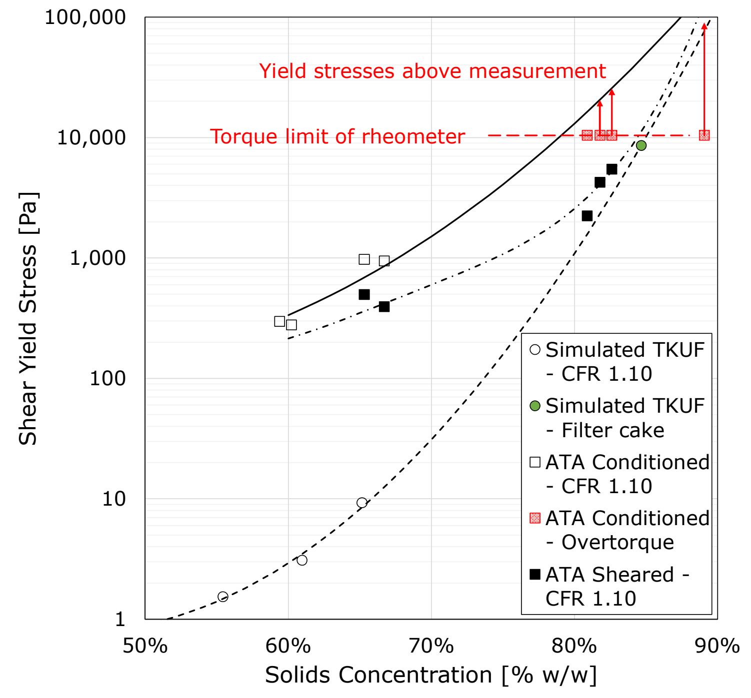
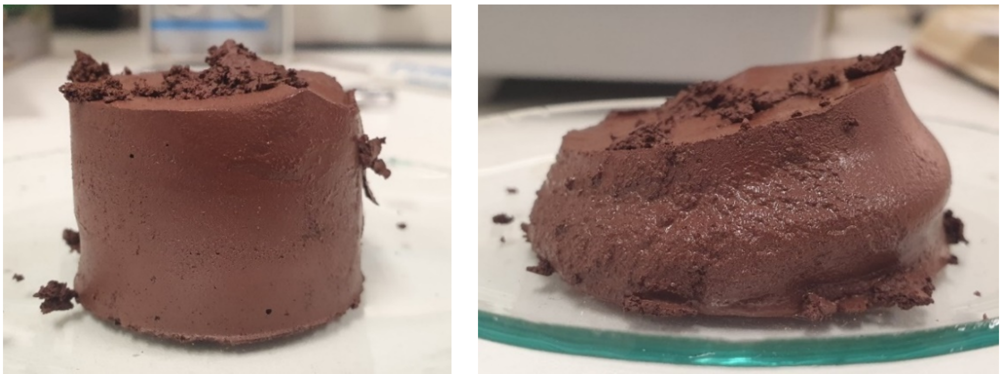


Figure 5 Vane shear stress versus dewatered solids concentration for ATA-conditioned copper tailings and simulated thickener underflow

For both the ATA-treated tailings and simulated TKUF, at solids concentration in excess of 85% w/w where cakes had been desaturated via air blowing, cakes were dry, friable and exhibited no tendency to fluidise. With desaturation at lower pressure (i.e. 65 kPa typical of vacuum filtration) both the ATA-treated tailings and simulated TKUF exhibited fluidisation under vibration. However, consistent with its higher yield stress in general, the fluidisation of the ATA sample was markedly less than the simulated TKUF. The large degree of fluidisation of the simulated TKUF sample is illustrated in Figure 6, despite the high cake solids of 84.7% w/w.

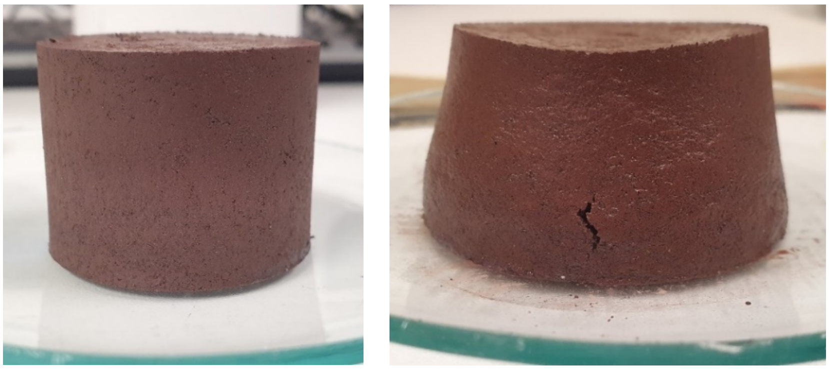
In all cases, for both the ATA-treated tailings and simulated TKUF, after mechanical compression only the saturated filter cakes exhibited a tendency for vibration-induced fluidisation. This tendency clearly was proportional to the cake solids achieved, however, in all cases the ATA-treated filter cakes exhibited a reduced tendency to fluidise. As an example, Figure 7 illustrates the relatively low degree of fluidisation evident in an ATA-treated filter cake at 82.6% w/w solids. Contrasting this with the behaviour for simulated TKUF at a higher cake solids content of 84.7% in Figure 6 illustrates the tendency for ATA to develop increased strength at lower cake solids concentrations.

Note that the yield stress data in Figure 5 indicate that after significant shearing there is a tendency for ATA-treated filter cakes to approach yield stress levels comparable to the simulated TKUF. This means that from a longer-term geotechnical stability perspective, enhanced shear strength should not be assumed (and requires further assessment). However, the improved cake-handling behaviour evident across Figures 6 and 7 indicate that, provided cake placement and stacking is appropriately managed to reduce geotechnical risk, ATA may require less aggressive cake moisture targets for operability of tailings transfer systems, i.e. resistant to fluidisation during truck or conveyor transport.



(a) (b)

Figure 6 Simulated thickener underflow. An illustration of vibration-induced fluidisation of cake generated after desaturation at 65 kPa (cake solids 84.7% w/w). (a) As filtered; (b) After vibration



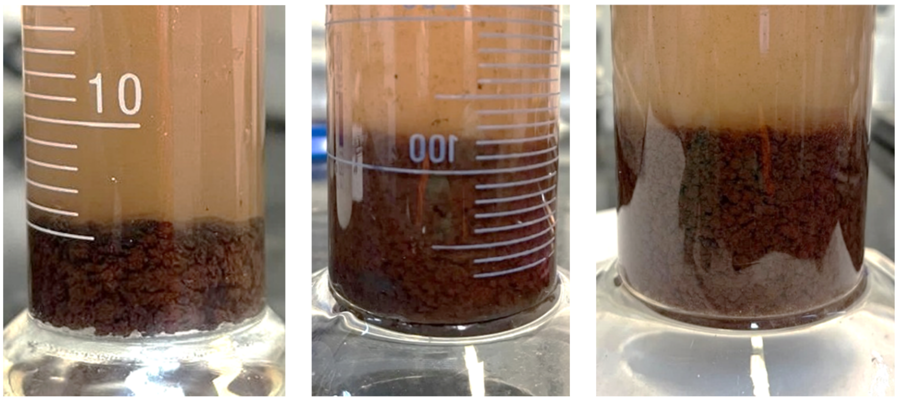
(a) (b)

Figure 7 ATA-treated tailings: cake generated after filtration at 300 kPa with no desaturation (cake solids 82.6% w/w). (a) As filtered; (b) After vibration

ATA-treated slurries exhibited rapid dewatering and solids concentrations of around 60% w/w were evident almost instantaneously via sedimentation, increasing to around 65% w/w after drainage. Screen drainage tests indicated that dewatering levels in excess of 60% w/w could be achieved within 20 seconds of deposition. The yield stress of ATA-treated and dewatered solids was up to an order of magnitude higher than the simulated TKUF at comparable solids concentrations. Marginally lower cake solids were measured at a given applied pressure for the ATA-treated tailings compared to the thickener underflow, due to the more strongly flocculated network present. This network resulted in materially higher permeabilities for the ATA-treated tailings, by around an order of magnitude, and a similar increase in the coefficient of compressibility, due to the more open, uniform pore structure. The higher shear yield stresses and more structured interparticle network in the ATA-treated tailings delivered more cohesive dewatered cakes at lower solids concentrations, with a lower tendency for vibration-induced fluidisation.

3.2 Iron ore tailings

Figure 8 compares the structure of the ATA-conditioned iron ore tailings using the different coarse fractions, showing that the classified flotation tailings (Figures 8b and 8c) produced a more granular and homogeneous structure. Figure 9 shows the same tests after screen drainage. The tests using classified flotation tailings (Figures 9b and 9c) showed improved free drainage and permeability, and higher solid% than the test using unclassified flotation tailings (Figure 9a). Visually, the stability of the screen deposited material at CFR = 1 for both classified and unclassified flotation tailings was more structured and stable than classified coarse at CFR = 0.5, forming a coherent mass. At the lower CFR the deposited material showed some spreading and slurry-like behaviour.



(a) (b) (c)

Figure 8 Appearance of undrained ATA-conditioned Brazilian iron ore tailings (300 g/t activator 120A, 200 g/t tether 210T) using (a) unclassified flotation tailings, CFR 1.0, 6.2% w/w; (b) classified flotation tailings, CFR 0.5, 4.8% w/w; (c) classified flotation tailings, CFR 1.0, 6.1% w/w

(a) (b) (c)

Figure 9 Appearance of screen dewatered ATA-conditioned Brazilian iron ore tailings (300 g/t activator 120A, 200 g/t tether 210T) using (a) unclassified flotation tailings, CFR 1.0, 51% w/w; (b) classified flotation tailings, CFR 0.5, 55% w/w; (c) classified flotation tailings, CFR 1.0, 55% w/w

Table 4 shows a summary of the settling rate and final settled solids concentration of the three different ATA-conditioned samples. The classified flotation tailings at the higher CFR of 1.0 showed the highest settling rate at 205 m/h with a final solids concentration of 39%. Due to the low solids concentration of the combined material, a very high hydraulic load would need to be managed. Consequently, a pre-thickening step would be required to enable primary dewatering with vacuum filtration. The rapid settling rate of the ATA-conditioned material enables unique pre-thickening options such as the use of a spiral dewaterer or the use of pre-thickening filter feed box.

Table 4 Settling rate results for Brazilian iron ore tailings

Coarse fraction	Coarse-to-fines ratio	Settling rate (m/h)	Settled solids concentration (% w/w)
Unclassified flotation tails	1.0	153	31
Classified flotation tails	0.5	200	30
Classified flotation tails	1.0	205	39

Vacuum filtration for all the flotation tailings scenarios delivered competent, handleable cakes with moderate to negligible plasticity (qualitative assessment). The cakes were cohesive and had very high shear yield stresses (Table 5). The best performance in terms of achievable solids concentrations was exhibited by the Classified CFR 1.0 flotation tailings scenario, achieving a final solids% of 78% w/w. This scenario also represents the lowest cake resistance relative to cake solids concentration, showing an improved permeability, due to a combination of the lower fines concentration and the more granular and homogeneous structure created by ATA conditioning in this scenario. Equipment sizing was conducted only on the optimal scenario and therefore only CFR 1.0, classified flotation tailings as coarse, is included in section 3.3. These results show that ATA, together with incorporation of the flotation tailings at CFR 1.0, improves the filterability of the fine desliming tailings, enabling dry stacking when combined with the flotation tails.

Table 5 Vacuum filtration results for Brazilian iron ore tailings

Coarse	Coarse-to-fines ratio	Vacuum pressure (kPa)	Cake formation solids (% w/w)	Final cake solids (with drying time) (% w/w)	Specific cake resistance (m/kg)	Yield stress (kPa)
Unclassified flotation tails	1.0	65	72	75	7.0×10^{10}	5–27
Classified flotation tails	0.5	65	70	74	1.3×10^{11}	8.5–24
Classified flotation tails	1.0	65	70	78	3.5×10^{10}	5.5–28

3.3 Dewatering technology assessment and estimated equipment sizing

The unique dewatering properties of ATA-treated tailings requires a holistic assessment of dewatering technologies to identify the most favourable process flow sheet to exploit these properties. Table 6 briefly describes the pre-thickening options considered, and Table 7 summarises the primary dewatering options.

In filtration applications, increased feed solids concentration typically improves filter throughput; therefore the impact of pre-thickening to remove excess hydraulic load after ATA conditioning was assessed. While pre-thickening was considered as an option for copper tailings, for iron ore tailings the low feed solids and consequent high hydraulic load dictated that pre-thickening was necessary before more intensive dewatering. Spiral dewaterers and gravity drainage decks (GDDs) were considered. Spiral dewaterers are typically used for coarse to ultra-fine sand sized material which settles rapidly. However, due to the rapid sedimentation of the ATA-conditioned iron ore tailings (Table 4) and its consolidation to form a dense bed which could be conveyed by the spiral, the technology may be viable to effect rapid separation of the high volume of liquid in this case. Note conventional settlers are not preferred due to the impact of underflow pumping on the ATA structure.

For the copper tailings, the primary dewatering options assessment process resulted in the exclusion of a number of options based on a range of operational, sizing, performance and client-based criteria, including a desire to obtain a dry stackable material, ideally in a partially saturated state. Options excluded on this basis were vibrating screens (highest moisture, poor solids capture), centrifuges (high moisture, unfavourable sizing) and screw presses (high moisture, uncertain solids capture). Belt presses demonstrated favourable sizing and operability for the copper tailings but produce a saturated cake which would require operational management for acceptable stability. Therefore, the horizontal vacuum belt filter (HVBF) and pressure filtration options were considered the most viable and low-risk options to meet site objectives.

For the iron ore tailings, based on guidance from the client, assessment of primary dewatering was confined to the use of HVBF. In this flow sheet, based on the HVBF sizing, pre-thickening and filtration were configured as six parallel trains. A summary of HVBF sizing for both the iron ore and copper is shown in Table 8. For the copper tailings, the higher feed solids and lower hydraulic load combined with the rapid filtration rate of ATA-treated tailings would permit direct filtration. Assessments were made of both pre-thickened and direct feed to HVBF and pressure filters, with some surprising conclusions.

Table 6 Summary of pre-thickening technologies assessed

Technology	Description
Gravity drainage deck	Effectively a continuous belt filter without a vacuum. Dewatering is via gravity with arrays of ploughs gently moving the flocculated feed into heaps, which promotes both lateral drainage as well as creating open areas of cloth for drainage of the high levels of water rapidly released after chemical conditioning
Spiral dewaterer	An open inclined trough with a settling tank at its lower end into which feed slurry is added. Solids will settle to the base of the trough, where they are conveyed upwards by a transport spiral. The solids further dewater by drainage in the upper part of the spiral before discharge

Table 7 Summary of dewatering technologies assessed

Technology	Description
Vibrating screen	Deposition of feed slurry onto a vibrating inclined screen deck composed of modular panels. The vibrating action promotes accelerated drainage, with the incline and discharge weir height promoting solids hold-up and cake build to enhance dewatering
Horizontal vacuum belt filter	Conventional implementation involves deposition of thickener underflow, but the high yield stress of ATA-treated tailings prevents self-distribution on the belt. Integration of Jord's proprietary Viper vibratory compression roller technology (Whatnall et al. 2021) overcomes this issue by effectively distributing feed across the belt
Belt press filter	The filter feed is typically re-flocculated to facilitate gravity drainage of liberated water with the assistance of ploughs prior to compressing the cake between two belts running around a series of rollers. Ideally the pre-thickening by gravity can take place on the gravity drainage section of the belt to remove excess hydraulic load before filtering
Centrifuge	The centrifuge feed is typically re-flocculated, following which solid-liquid separation occurs on entry to the centrifuge. For ATA-treated tailings either direct feeding or reduction of hydraulic load by pre-thickening are possible, although there is an upper limit on the feed solids concentration
Screw press	A continuous dewatering device in which heavily flocculated feed slurry is fed into a cylindrical perforated screen with a helical screw running along the central axis. Liberated water flows through the screen and cake builds up. The cake is conveyed through the press by the screw and back pressure at the outlet provides additional compression to further dewater the cake before discharge. Pre-thickening will enhance the solids capture and reduce the hydraulic load
Pressure filter	Batch process suitable for either pre-thickened or direct pumping of ATA-treated tailings into the filtration chambers. Air blow will produce a desaturated cake

Table 8 shows that direct dewatering of copper tailings by HVBF would require four units, whereas the number of units would be reduced to three after pre-thickening by GDD (requiring 1 GDD per HVBF unit). The cost saving of one less HVBF unit is therefore offset by the requirement for three GDD units. The estimated filtration throughput for TKUF was lower, due to the absence of any flocculated structure, requiring seven HVBF units. Note that all sizing incorporates Jord's proprietary Viper vibratory compression roller technology to effectively distribute the paste-like feed across the belt.

In general, this work has shown that HVBF can be a viable option for the dewatering of fine tailings for dry stacking purposes, with ATA conditioning also shown to improve dewatering efficiency and in turn resulting in a reduced number of HVBF units required. Table 8 also shows a capital cost estimate of the HVBF dewatering flow sheets for the four different scenarios. Note all capital cost estimates are for equipment only and exclude installation, ancillaries, and engineering, procurement and construction management. Benchmarked against conventional thickening, ATA conditioning has been shown to have a lower capital cost due to the reduced filtration area required as a result of the improved permeability and enhanced desaturation kinetics. For copper tailings, the direct filtration option (no GDD) is the most favourable as it not only has the lowest capital cost but also the least operational complexity.

Table 8 Vacuum belt filter equipment sizing data (65 kPa vacuum) and capital cost estimates (±20%)

Item	Units	Iron ore ATA C Float coarse-to-fines ratio 1.0	Copper tails ATA no pre-thickening	Copper tails ATA pre-thickened	Copper tails TKUF
Sizing					
Solids duty	t/h	600	903	903	903
Feed solids	% w/w	50	30.7	60.0	65
Feed volume	m^3/h	780	2,287	866	751
Cake solids – w. Viper™	% w/w	79	80	80	83
Throughput – w. Viper™	kg/hm^2	750	1,684	2,026	825
Total required area	m^2	800	680	510	1,190
Number of units	–	6	4	3	7
Capital cost estimates					
Hydrocyclones	M USD	0.30	0.32	0.32	–
Inline mixers	M USD	0.08	0.08	0.08	–
ATA polymer make-up	M USD	0.81	0.83	0.83	–
Gravity drainage deck	M USD	2.74	–	1.34	–
Conventional thickener	M USD	–	–	–	2.28
Horizontal vacuum belt filters	M USD	14.27	9.92	8.78	17.35
TOTAL CAPEX	**M USD**	**18.20**	**11.15**	**11.35**	**19.63**

Table 9 shows the pressure filtration sizing for the copper tailings. Pressure filtration generally provides the lowest risk option for dry stacking, enabling high cake solids% and improved desaturation compared to an HVBF. ATA conditioning has been shown to provide an order of magnitude improvement in filtration efficiency compared to conventionally thickened tailings, reducing the number of filtration units required from three to two. Notably, direct filtration of the ATA-conditioned feed had comparable throughput to the pre-thickened ATA-conditioned tailings, rendering this step redundant. The reduction in the number of filtration units required, as well as the elimination of pre-thickening, results in a significant reduction in capital cost, as shown in Table 9.

A complete techno-economic assessment of tailings dewatering with ATA also requires consideration of operating costs. While a detailed assessment of the operating costs is beyond the scope of this study, for ATA these include reagent consumption, power, consumables and maintenance of the hydrocyclones. A reduction in the number of filtration units will decrease operating costs associated with filtration, i.e. power, filter cloths and maintenance.

Table 9 Pressure filter sizing and capital cost estimates for copper tailings (accuracy ±20%)

Item	Units	ATA no pre-thickening	ATA pre-thickened	TKUF
Sizing				
Feed solids	% w/w	30.7	60	65
Feed volume	m^3/h	2,287	866	751
Total cycle time	s	585	586	723
Cake solids	% w/w	86	86	87
Cake thickness	mm	42	44	42
Throughput	$kg/h/m^2$	255	269	214
Number of units	#	2	2	3
Throughput/unit	t/h	451.5	451.5	301
Capital cost estimates				
Hydrocyclones	M USD	0.32	0.32	–
Inline mixers	M USD	0.08	0.08	–
ATA polymer make-up	M USD	0.83	0.83	–
Gravity drainage deck	M USD	–	1.37	–
Conventional thickener	M USD	–	–	2.28
Pressure filters (with air blow)	M USD	2.41	2.41	3.62
TOTAL CAPEX	**M USD**	**3.64**	**5.01**	**5.90**

903 t/h total feed rate, 50 mm chamber thickness, 700 kPa feed and pressing pressure, 600 kPa air blow pressure, 240 s technical time

4 Conclusion

Dewatering of ATA-conditioned tailings by HVBF can be a viable option for stacked tailings disposal, with the ability to produce a desaturated filter cake. As a continuous process, HVBF is well suited to interface with the continuous ATA process. The throughput strongly increases with reduced cake thickness, and the Viper technology is expected to improve the ability to operate at lower cake thickness. Pressure filtration is the preferred dewatering process to achieve the highest dewatered solids content. While there is increased complexity at the interface of batch pressure filtration with continuous ATA conditioning, this can be managed with a buffer tank.

The high hydraulic load of the low solids% iron ore tailings required a pre-thickening step ahead of filtration by HVBF, whereas direct filtration without pre-thickening was the optimal copper tailings flow sheet for both HVBF and pressure filtration. The resulting filter cakes have improved cohesion with lower susceptibility to liquefaction at a given solids concentration. This study demonstrated that ATA conditioning improved the dewatering and filtration efficiency of two different types of tailings by engineering a material with enhanced permeability. ATA conditioning delivers a step-change reduction in the size of the required filtration plant compared to conventional thickener underflow as the filtration feed.

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