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Dewatering Polymer Application in an Iron Ore Tailings Dam

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ABSTRACT

Given the current scenario experienced by Brazilian mining industry, the study and development of technologies that enable a more secure and controlled disposal of tailings has gained significant relevance. Among the various alternatives and disposal methodologies, Anglo American has been developing tests on different study fronts. Using dewatering polymers to improve tailings store potentials at tailings dam is one of the methods that has been studied extensively. The tested polymers can enhance de-watering performance and immobilization of mineral slurries during hydraulic deposition, therefore achieving optimization of tailings storage at the existing facility. The studies were divided into laboratory and industrial field-testing phases aiming to evaluate the applicability of this technology for eventual implementation at industrial scale.

During the laboratory testing phase, more than two hundred tests were performed to determine the best polymer type, dilution and dosage. The parameters evaluated were based on yield stress measurements by a rheometer, slump tests performance and water released volume after 10 minutes and 24 hours after polymer addition. The results from laboratory testing phase have provided sufficient information for industrial scale trial. The second phase of the study consisted of an industrial field trial with polymer application in the tailings dam for five days. During the trial, topographic measurements were taken in order to evaluate the increase of settled material during the first kilometer after tailings discharge. The results demonstrated a significant increase of settled material and beach slope angle in the measured area. This showed a good potential for improved utilization of the storage in the tailings storage facility in the coming years.

INTRODUCTION

Increasing awareness of the risk and liability associated with tailings placement and storage at mines has led mine owners, mine operators and their tailings consulting teams to investigate how water may be more effectively and expeditiously removed from tailings prior to or after deposition in tailings storage facilities (TSF). This risk is particularly heightened in tailings facilities where saturated slimes are stored upstream of earthen embankments. One method that has been used to accelerate the rate of water separation from tailings solids involves the injection of polymer into a tailings slurry discharge line prior to the deposition of those tailings into a TSF. In this method the hydrodynamic energy associated with the slurry flowing through the tailings delivery line is used to mix polymer into the slurry prior to discharge. This will result a rapid separation of water from the tailings solids immediately downstream of the plunge pool that typically exists at the tailings discharge location. The method of applying polymers to treat tailings is known as in-line flocculation or in-line polymer addition (Wells and Riley, 2007., Bembrick, 2008., Wells et al. 2011., Mizani, 2013., Guang et. al, 2014., Riley and Utting, 2014., Guang and Longo, 2017., Costine et al, 2018).

Anionic copolymers have been used to increase the rate of dewatering and strength gain in a wide range of tailings slurries for over two decades. When the most suitable polymer has been identified to treat a tailings substrate, it produces a kinetic effect that is evidenced by an increased rate at which water is separated from solids in the slurry. The fundamental mechanisms by which these polymers work is to increase the capture of fine particles using long chain molecules which create bridges between particles to create macro-structures commonly referred to as "flocs." In this case study, the effect of applying polymers that were identified as producing a kinetic effect in a blended tailings stream comprising 85% coarse sands and 15% slimes is described.

METHODOLOGY

The iron ore beneficiation process at the Minas-Rio mine in Conceição do Mato Dentro, Brazil generates three tailings streams with distinct characteristics. The first step of the work involved sampling and characterizing each material. The tailings streams are:

- Coarse Sands flotation tailings constituting approximately 85% of the total tailings stream;
- Slimes from the desliming stages (Figure 3) constituting approximately 15% of the total tailings stream;
- Blended tailings created by combining coarse sand flotation tailings and slimes.

The tailings streams where characterized as follows: material density using pycnometer; solids content determination using pre- and post- drying mass measurements; pulp density determination, pH measurement, and particle size distribution using sieves for the coarse fraction and a Cyclosizer laboratory precision instrument for the ultrafine fraction. Figure 1 illustrates the equipment used.

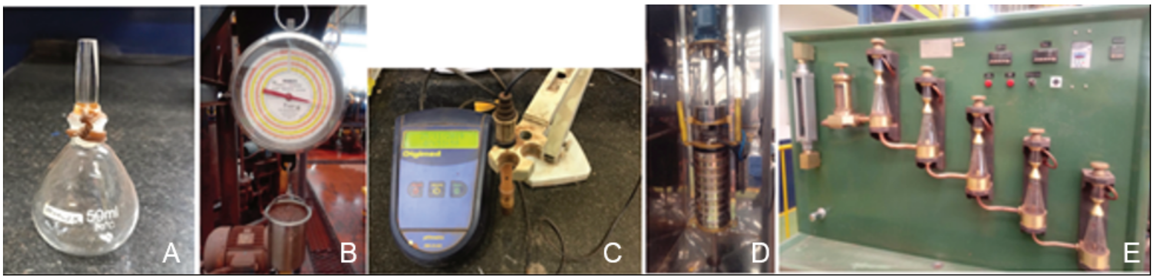

Figure 1 - Equipment used for sample characterization: (A) Pycnometer, (B) Solids Content & Density determination, (C) pH, (D) Mechanical sieves, (E) Cyclosizer

Characteristics of the coarse sand flotation tailings, slimes, and blended tailings are presented in Table 1.

Table 1 - Tailings characteristics for each stream

Sample	Mineral SG (g/cm³)	Solids Content (%w/w)	Slurry Density (g/cm³)	pH
Flotation Tailings	2965	50.00%	1.496	9.58
Slimes	3630	5.71%	1.043	9.12
Blended Tailings	3080	52.16%	1.543	9.50

Figure 2 illustrates the particle size distribution of each material.

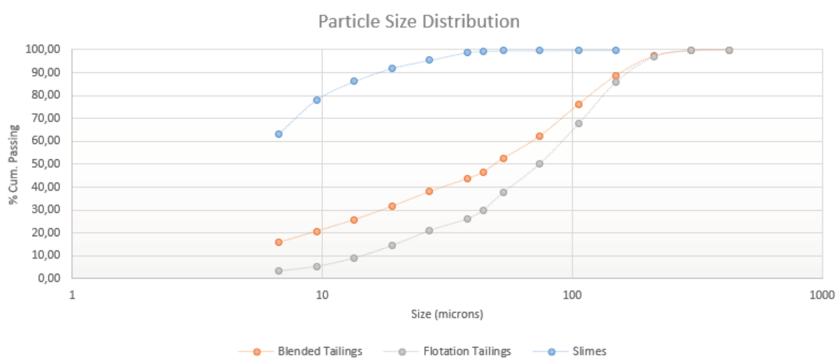

Figure 2 - Samples Particle Size Distribution

The beneficiation plant process flowsheet was used to confirm the sources of the materials to be tested in the laboratory so that the findings could be assessed for an industrial applicability in the actual operation. Figure 3 illustrates the process flowsheet and identifies the locations of each tailings stream.

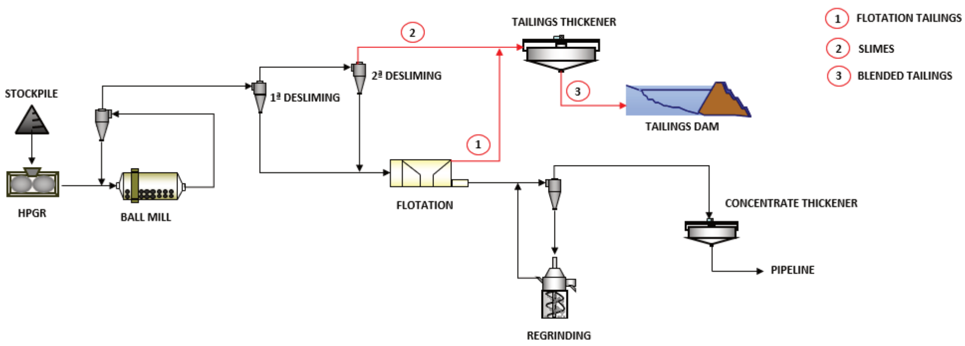

Figure 3 – Process Flowsheet

Initially, visual assessment of the release water rate, quality and quantity resulting when each tailings stream was treated with polymer was completed to verify the efficiency of the polymer-response in each material. The conclusions obtained were as follows:

- Flotation Tailings: It was observed that the application of the polymer was not efficient, since the behavior of the untreated flotation tailings was similar to or better than the response observed when polymer treatment was applied. Consequently, it was decided not to proceed with further polymer testing on this tailings stream.

- Slimes: The use of polymers in the slimes produced satisfactory results when high dosages of polymer were applied. The stream was a highly dilute waste stream (less than 10% solids) containing fine particles. Therefore, high dosage was used in the polymer treatment. Consequently, from both technical and financial points of view, it was decided not to proceed with further polymer testing on this tailings stream.

- Blended Tailings: This material was composed of 85% flotation tailings and 15% slimes and proved to be the most responsive to the application of polymers. Satisfactory results were obtained during the exploratory testing phase and the dosage-efficiency ratio was determined to be adequate. Moreover, from an operational applicability perspective, this tailings stream was the easiest to access to execute an industrial trial or subsequent implementation. It was decided to proceed with additional tests for this material.

Laboratory Tests

This phase of work included a series of tests aimed at further evaluate the best polymer and optimum dosage range. The trials were performed at Anglo American's Mineral Technology Center with the support from Golder Associates. For performance comparison, several slump tests were performed. The process variables evaluated to determine product efficiency were:

- Yield Stress (Pa) – measured using a Brookfield RST rheometer;
- % of water released after the first ten minutes of polymer application;
- % of water released = $\frac{water\ recovered - water\ added\ in\ polymer\ solution}{water\ in\ tailings\ slurry} \times 100\%$

The process variables used to perform the tests were:

- Polymers: Rheomax® ETD 9040-A / Rheomax® ETD 9060
- Polymer dilution: 0,25%
- Dosage (g/t): 15 / 20 / 30 / 40 / 50

Laboratory Results

All tests were performed using the sample from the tailings thickener underflow, consisting of 85% flotation tailings and 15% slimes. The samples were well mixed in a mixing vessel and collected moments before execution of each test to avoid adverse impacts treatment efficiency. Figure 4 illustrates the relationship between the Yield Stress (Pa) and dosage, Figure 5 shows how release water varied at each dosage for the two polymers tested and Figure 6 shows the Slump Test results.

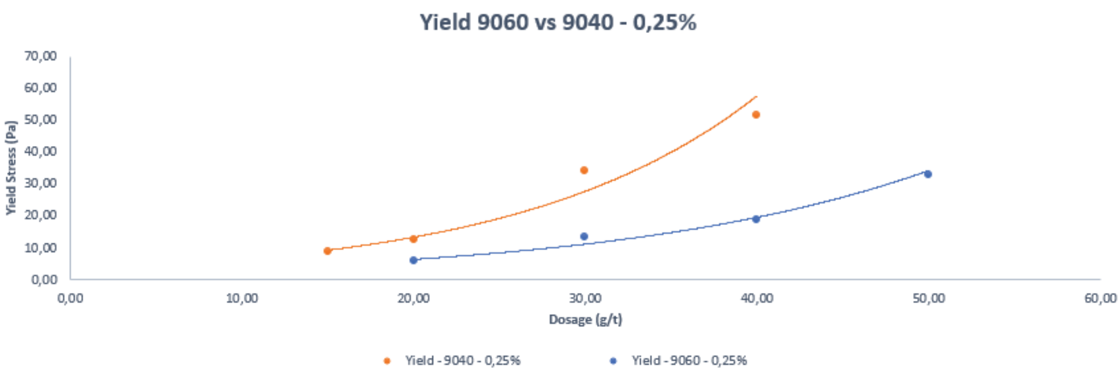

Figure 4 - Yield Stress (Pa) Results

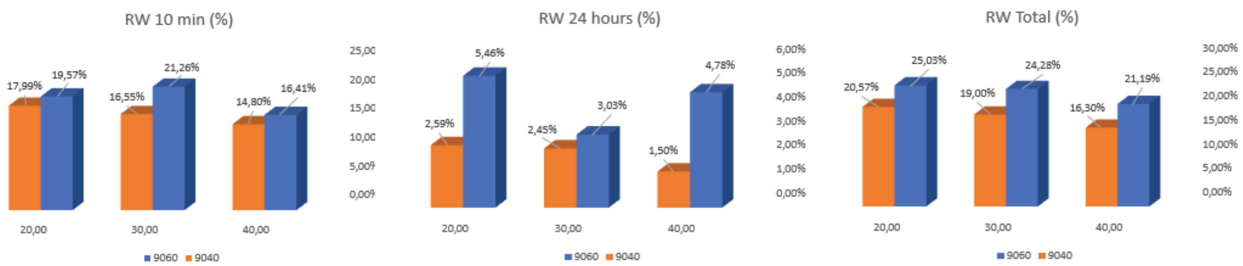

Figure 5 - Released Water (%) Results

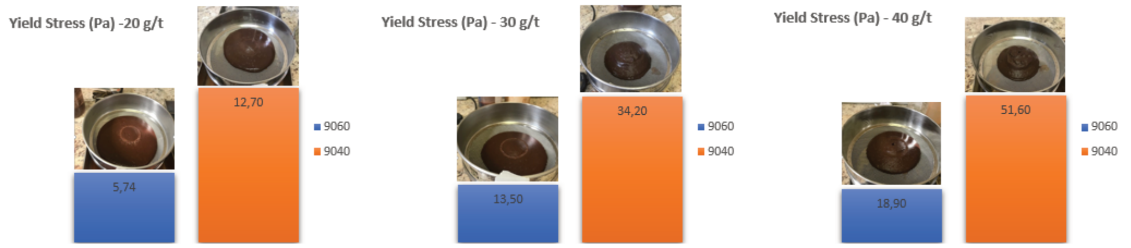

Figure 6 - Slump Test Results

The results show that despite a lower total water release, Rheomax® ETD 9040-A, at 0.25% dilution, provided higher Yield Stress (Pa) values for the same dosage when compared to Rheomax® ETD 9060. Therefore, given the operational need to retain as much sediment as possible near the tailing's disposal point, an industrial testing campaign using Rheomax® ETD 9040-A at a dosage of around 30 grams per ton was selected.

Field Trial

BASF provided polymer preparation equipment (Figure 7) to Anglo American to complete an exploratory field trial. Due to equipment capacity limitations, the actual applied dosage was lower than the amount indicated in the laboratory tests.

Figure 7 – Equipment for polymer preparation.

Table 2 summarizes capacity data for the polymer preparation equipment, tailings generation data during the industrial test period, and an estimate of the polymer dosage used.

Table 2 – Polymer Dosing Unit Data

Capacity	Residence Time	Powder mass	Dilution	Tailings mass	Dosage
5 m^3	1 hour	15 kg/h	0,30%	2991 tph	5.0 gpt

To validate the results obtained during the field trial, a topographic survey was carried out to evaluate tailings deposition characteristics including settled volume within 1100 meters downstream of the deposition site before and after polymer treatment was applied. The settled volume and deposition characteristics of deposited material created from untreated blended tailings that were discharged during a 120-hour period was determined. Then, a similar survey and settled volume determination was made following a 120-hr period of injecting polymer directly into the blended tailings discharge pipe upstream of the pipe discharge location.

RESULTS AND DISCUSSION

At the end of the field trial, the data collected were processed to measure the settled volume differences between with and without polymer treatment and to evaluate the efficiency of the polymer dosage applied. The main objective was to verify the increase of the volume of settled material near the tailing's disposal point. Finally, a series of photos of the area were taken to enable comparative visual evaluations. The comparison between untreated and treated settled tailings volumes (Figure 8) and deposition characteristics (Figures 9 and 10) are shown below.

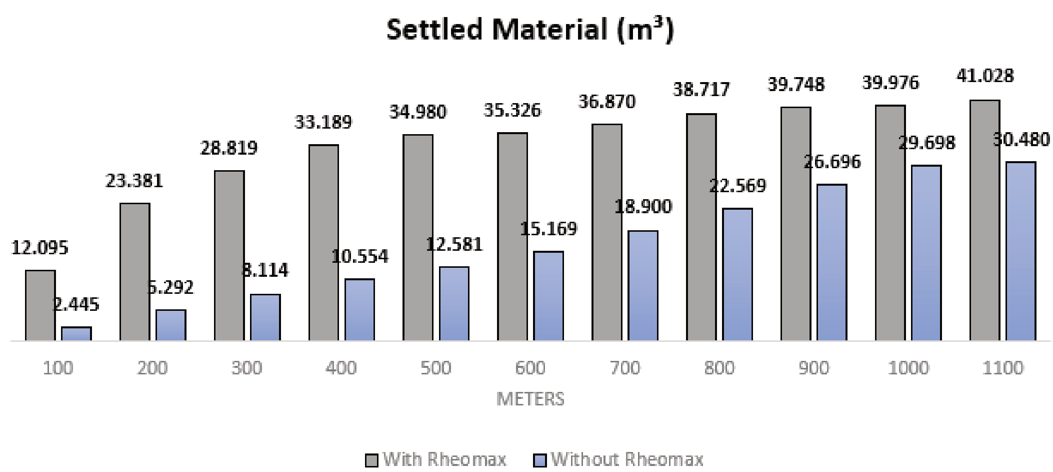

Figure 8 – Settled volume with and without Rheomax® along 1100m profile of discharged tailings

Figure 9 - Settled material before and after polymer treatment

Figure 10 - Settled material before and after polymer was applied

CONCLUSION

In the first stage of industrial tests, a 6% increase in the settled material volume near the tailing's disposal point was observed. Additionally, a high potential for sedimentation and rapid settling of the treated tailings was observed. It is concluded that the sedimentation achieved is satisfactory but new industrial test campaign should be completed using the optimal dosage indicated in the laboratory tests to prevent the arrival of material into the water recovery pond. The new test campaign should be conducted at a longer duration and geotechnical engineering properties of untreated and treated blended tailings should be evaluated. Sample collection for the inline treated tailings in the tailings dam will be one of the challenging aspects for the future campaign.

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