Paste 2026 – AB Fourie, M Horta, M Oliveira & S Wilson (eds)

doi:10.36487/ACG_repo/2655_27

Rio Tinto Kennecott manufactured paste backfill: initial concept to pilot testing

Jean-Louis Roberge [a,*], Elio Tomini [a], Bob Chaudoin [a], Kane Moran [b], Courtney McGinn [b], Nikola Jovcic [b], Simon Timballah [b]

[a] *Responsible Mining Solutions, Canada*

[b] *Rio Tinto, USA*

Abstract

This paper explores the development of a novel process which creates a paste backfill product from crushed waste rock in an open pit mining operation transitioning to underground.

Rio Tinto conducted an initial feasibility study for a paste backfill plant that would take tailings from the Copperton Concentrator to produce a paste backfill product for the Kennecott Underground Orebodies located in the northern wall of the Bingham Canyon Pit, Salt Lake City, Utah. After a design review process which focused on capital savings, the concept of a paste backfill produced by crushing the open pit waste rock emerged. This design allows for the elimination of a desliming and thickening plant near Copperton Concentrator, as well as a roughly 8 km pipeline. This results in capital savings, as well as eliminating the environmental risk around a surface tailings pipeline. Although similar concepts have been studied or implemented previously, they typically relied on a partial tailings stream or grinding to produce the fines sufficient for a paste. This paper will focus on a case study for a paste backfill design utilising a simple crushing circuit able to generate a product with a suitable particle size distribution to form a stable paste, sourced from open pit waste rock.

This case study will provide information on the initial index testing on samples from an existing crusher and an extensive testing program supporting conceptual ideas around waste rock mineralogy, particle size distribution, rheology and strength gain potential. Ultimately, the testing program culminated in the establishment of a pilot level testing campaign utilising production-scale crushing equipment which provided critical insight into the design.

The engineering design addressed several key factors including technical scalability, material handling, equipment design/selection, operability and cost considerations. This phase of the engineering study can be directly compared to the more conventional paste backfill.

Keywords: *paste backfill, open pit waste rock, crushing*

1 Introduction

This paper explores the development for a novel process of creating a paste backfill product from crushed waste rock in an open pit mining operation transitioning to underground. An initial feasibility study had been conducted for a paste backfill plant that would take tailings from Copperton Concentrator to produce a paste backfill product for the Rio Tinto Kennecott (RTK) underground orebodies located in the northern wall of the Bingham Canyon Pit. During the capital intensity process, a design review process with a focus on capital savings, the concept of a paste backfill produced by crushing the open pit waste rock was brought up. This design was interesting as it would allow for the elimination of a desliming and thickening plant near Copperton Concentrator as well as an ~8 km pipeline leading to capital savings and eliminate the environmental

* Corresponding author.

risk around a surface tailings pipeline. Although similar concepts were previously studied or implemented, they typically relied on a partial tailings stream or grinding to produce the fines sufficient for a paste.

The material will be designed to be crushed down to a top size of 6.35 mm utilising a 3-stage crusher and then stored in aggregate silos. The aggregate would then be metered into a batch mixer where it will be mixed with water and binder to form a paste. The paste would then be pumped via boreholes and an underground distribution piping network to the underground stopes.

The paste system would produce fill for the RTK underground orebodies located in Salt Lake City, Utah. This paper will focus on a case study for a paste backfill design that resulted in a design utilising a simple crushing circuit to produce a stable paste from open pit waste rock from the Bingham Canyon Pit.

2 Concept development and design overview

The concept of producing a paste utilising open pit waste rock was brought up as an alternative solution as a capital cost saving initiative compared to an initially considered more traditional tailings paste design. This concept had been briefly explored but often with more complex technologies such as high-pressure grinding rolls (HPGR) or milling to produce a targeted fines content of 20% passing 20-micron based on commonly cited rules of thumb for minimum fines content to produce a paste (Landriault & Goard 1987; Tenbergen 2000; Stone 2014). However, the 20% passing 20-micron target is a general guideline that can vary greatly between materials due to factors like mineralogy and particle shape, making it possible to reduce this target while still maintaining material stability. Pumping risks can be reduced through design measures such as limiting the material's top size, using batch mixing for better control of solids content, and implementing careful rock selection and plant operation practices to have operational controls on material feed to the plant. A trade-off study was conducted investigating the concept of paste produced utilising open pit waste rock considering that previously considered fines target may have been overly aggressive considering the mineralogy of the open pit material having soft materials and clays adding to the stability of the paste. Concurrently, onsite testing was initiated to determine the process requirements/targets for the crushing and griding system. Three options were considered including: crushing only, crushing and grinding, and crushing and a tailings stream.

Promising index testing results indicated that a stable paste could be produced at a much lower fines content than the general rule of thumb, as well as significant cost savings. Both capital and operating costs, where possible, led to the crushing only option being further developed. These findings led to further development of the crushing-only option, including a feasibility design, a more comprehensive testing campaign, and ultimately a pilot-scale crushing and pumping test.

A simplified flowsheet comparing the conceived feasibility designs between the tailings paste plant and the manufactured paste flowsheets is included in Figure 1.

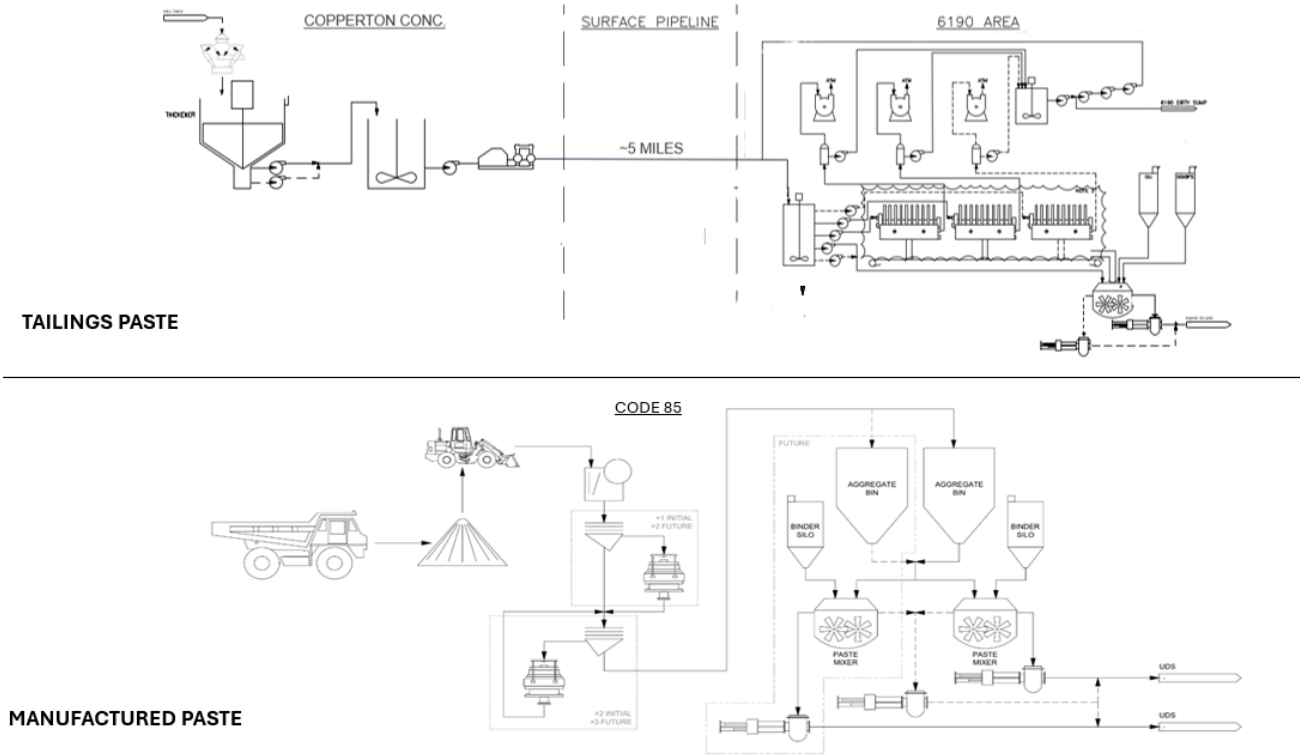

Figure 1 Simplified process flow diagram: tailings paste versus manufactured paste

The tailings paste included 3 main areas; a thickening plant located in the tailings area of the existing Copperton Concentrator. This plant would receive a partial stream of the tailings stream from Copperton Concentrator. The tailings would be deslimed with the use of hydrocyclones to optimise the particle size distribution for backfill and then be further dewatered with a high compression/density thickener prior to being pumped using piston diaphragm pumps via an ~8 km pipeline to the paste backfill plant. At the backfill plant, the tailings would then be further dewatered with the use of vacuum disc filters and blended with cement and a bypass stream of thickened tailings in a continuous mixer to produce a paste which would subsequently be pumped to underground stopes.

The manufactured paste option would receive a portion of the Bingham Canyon Pit waste rock hauled using the existing fleet of open pit haulage trucks which would be diverted to the manufactured paste plant based on preferred mineralogy. The waste rock would be crushed down to a top size of 6.35 mm utilising 3-stage crushing and then stored in aggregate silos. The first stage of crushing consists of a primary jaw crusher which would feed the second crushing stage. The second stage of crushing consists of an open circuit with a double-deck banana/multi-angle screen and cone crushing. Both the undersize of the secondary screen and crusher products are discharged onto conveyors which feed the tertiary screening and crushing circuit. The tertiary screening and crushing circuit would be a closed-circuit consisting of double-deck banana/multi-angle screens and cone crushing. The undersize product from the tertiary screening circuit would be conveyed to a storage bin for subsequent use for backfill. The screen oversize material would be fed to the crushers and recirculated back to tertiary screening along with the secondary screening and crushing product.

From the aggregate bin, the aggregate would be metered into the mixing plant where it will be metered into a batch mixer along with water and binder. Batch mixing was selected based on the higher water sensitivity of the material and variability in the waste rock types. Batch mixing would allow for torque monitoring on the mixer prior to discharge and tighter paste control. The batch mixer would then discharge into a paste hopper to provide a continuous feed to the paste pumps which would distribute paste to the underground stopes.

3 Testing

Based on the promising results of onsite index testing of samples sourced from an existing road base crusher, a comprehensive testing program that explored key parameters including waste rock mineralogy, particle size distribution, rheology, and strength development potential which are presented in this paper. Insights gained at each stage informed subsequent, more targeted testing aimed at risk mitigation and equipment sizing. The program culminated in a pilot-scale testing campaign, employing production-scale crushing equipment and a full-scale flow loop. This final phase yielded valuable data on operational performance and highlighted logistical considerations related to material storage and transport.

3.1.1 Samples

A comprehensive laboratory testing campaign was completed, covering a matrix of 9 different waste types to provide input into the system design, identify acceptable feed materials, and provide input for operating cost. These were based on the 3 main types of waste rock present in the open pit. These were identified as quartzite (QZ), limestone (LS), and monzonite (MZ). These were then split into 3 different levels of alteration minerals present in the samples defined as weak, moderate or strongly altered. The alteration minerals were primarily argillite and sericite. Initially, 552 kg of the samples were crushed and prepared down to a top size of 37.5 mm to prepare samples for lab scale cone crushing, as well as obtain crushing parameters such as crushing work indices and abrasion indices for input into the crushing design. Samples were then further crushed using a lab scale cone crusher down to 6.35 mm top size to produce a representative sample of what could be expected from 3-stage crushing. A charge, ~500 g, of each sample was split for particle size analysis to 400 mesh (38 µm) with a Malvern particle sizer on the screen undersize. The bulk of each sample was split into 10 kg charges for paste test work including rheology and strength testing. These results are compared to the general mill tailings (GMT 30%) and the deslimed general mill tailings (GMT 20%).

3.1.2 Particle size distribution

Particle size distribution (PSD) was conducted using a mix of sieve and laser analysis on the final product from the lab scale crushing. The results are summarised in Figure 2.

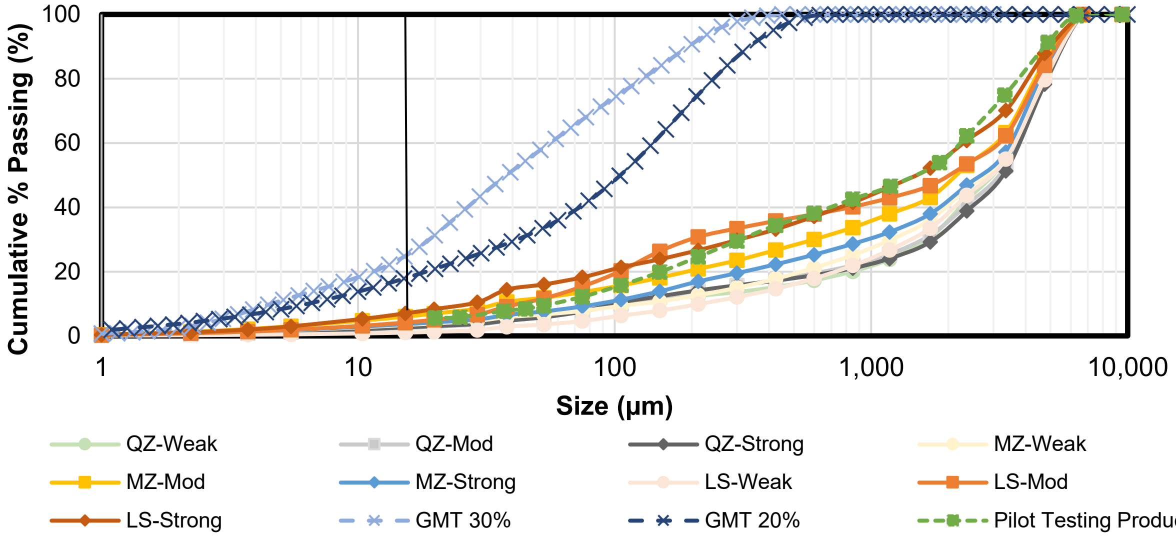

Figure 2 Particle size distribution of waste rock samples (QZ = quartzite, LS = limestone, MZ = monzonite, GMT = general mill tailings, Mod = moderate)

Generally, the samples included relatively low fines contents, in the range of 4–8% passing 20 µm when compared to the tailings and the general rule of thumb for paste (15–20% passing 20 µm); however, as later tested, the majority still formed stable pastes which is an overarching quality while the PSD is simple indicative. Additionally, it should be noted that although not presented here, desliming test work had been conducted on the paste and showed a similar tendency to be able to form a stable paste at lower fines content which is believed to be based on the mineralogy of the products.

3.1.3 X-ray diffraction testing

Qualitative X-ray diffraction (XRD) testing determines the crystalline mineral grouping of a sample. Results for the different waste rock samples tested are outlined in Table 1.

Table 1 X-ray diffraction mineralogical composition

Mineral name	Mineral concentration (wt.%)											
	QZ-Wk	QZ-Mod	QZ-Str	LS-Wk	LS-Mod	LS-Str	MZ-Wk	MZ-Mod	MZ-Str	Pilot test	GMT 30%	GMT 20%
Quartz	87.9	76.8	90.6	85.3	87.5	7.5	10.8	9.2	59.4	70.8	56	55
K-feldspar	6.2	11.6	2.9	11.8	7.1	0	30.7	31.3	18	10.5	15.2	9.3
Plagioclase	0	3.1	0	0	0	0	34.8	26.2	4.5	4.6	8.3	5
Muscovite	2	2.2	0	0	0	0	3.7	0	0	2	0	0
Biotite	0	0	0	0	0	0	2.2	3	1.6	1.2	11.3	0
Chlorite	0.9	0	1.4	0	0	0	3.8	3.9	0	1.2	1.3	5.3
Kaolinite	0	0	0	0	1.9	0	0	0	2.1	0	0.7	0.8
Swelling clay	2.3	2.5	5.1	2.9	2.8	10.7	5.1	15.5	11.9	4.9	0	0
Talc	0	2.8	0	0	0	0	0	0	0	0	0	0.3
Amphibole	0	0	0	0	0	0	2.5	1.5	0	1.2	0	0
Calcite	0.5	0.6	0	0	0.7	78.7	0	3.9	0	2.4	1.4	3.7
Dolomite	0	0	0	0	0	2.7	1.8	0	0	0	0.5	0
Siderite	0	0	0	0	0	0.4	0	0.6	0	0	0	0
Magnetite	0	0	0	0	0	0	4.3	2	1.4	1.2	0.3	0
Pyrite	0.3	0.4	0	0	0	0	0.3	2.9	1.1	0	0.8	1.9
Hornblende	0	0	0	0	0	0	0	0	0	0	2.6	3
Augite	0	0	0	0	0	0	0	0	0	0	1	1.6
Anatase	0	0	0	0	0	0	0	0	0	0	0.4	0
Gypsum	0	0	0	0	0	0	0	0	0	0	0.3	0

QZ = quartzite, LS = limestone, MZ = monzonite, GMT = general mill tailings, Mod = moderate, Str = strong, Wk = weak

XRD analysis has some limitations for direct comparison. Signature peaks and troughs can be difficult to differentiate, especially between similar mineralogical families such as mica groups (illite/mica, biotite, etc.) or felsic groups (orthoclase, albite, potassium feldspar, etc.). Generally, QZ and LS samples were dominated by quartz with varying level of felsic mineral groups and clays and micas which was relatively similar to the tailings in varying proportions. The MZ was more strongly dominated with felsic group.

3.2 Rheology

Initial assessment was conducted on all uncemented samples to test if they made a stable paste material. MZ and LS weak samples were determined to not make a stable paste and as such were not used in the following tests.

3.2.1 Slump versus solids

Slump testing was carried out by beginning with a low slump paste and measuring the slump with a standard ASTM 300 mm slump cone and collecting subsamples to determine the solids content. The paste was then gradually watered down, checking slump and solids content after each water addition, until the sample is outside the slumpable range (>250 mm slump).

Figure 3 summarises the slump versus solids test work. Generally, as expected the manufactured paste samples resulted in a higher density paste range compared to the tailings paste believed to primarily being a result of the particle size distribution.

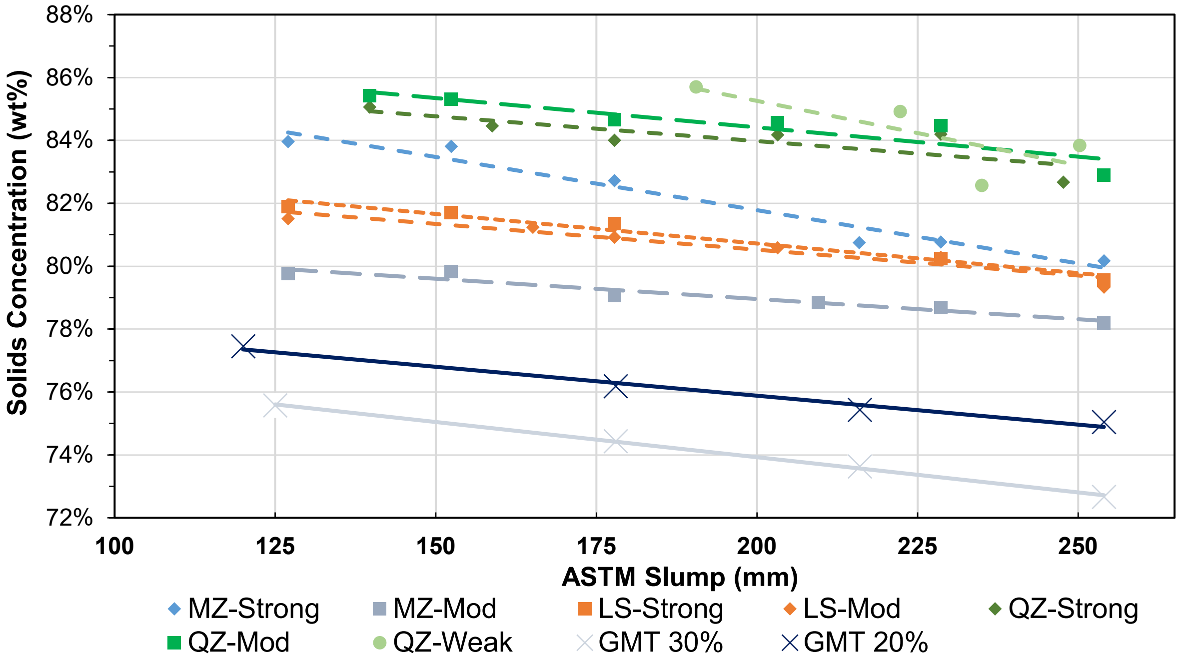

Figure 3 Solids concentration versus ASTM slump (mm) (QZ = quartzite, LS = limestone, MZ = monzonite, GMT = general mill tailings, Mod = moderate)

3.2.2 Water bleed testing

Samples at 175 mm and 250 mm slump were allowed to sit idle in test beakers for set amounts of time at which point the water separated were measured (Figure 4). Yield stress was not possible due to the top size of the aggregate interfering with spindle measurement. Generally, all samples tested produced a relatively stable paste with reasonable amount of water bleed, generally under 1 wt%, throughout the test period (24 h).

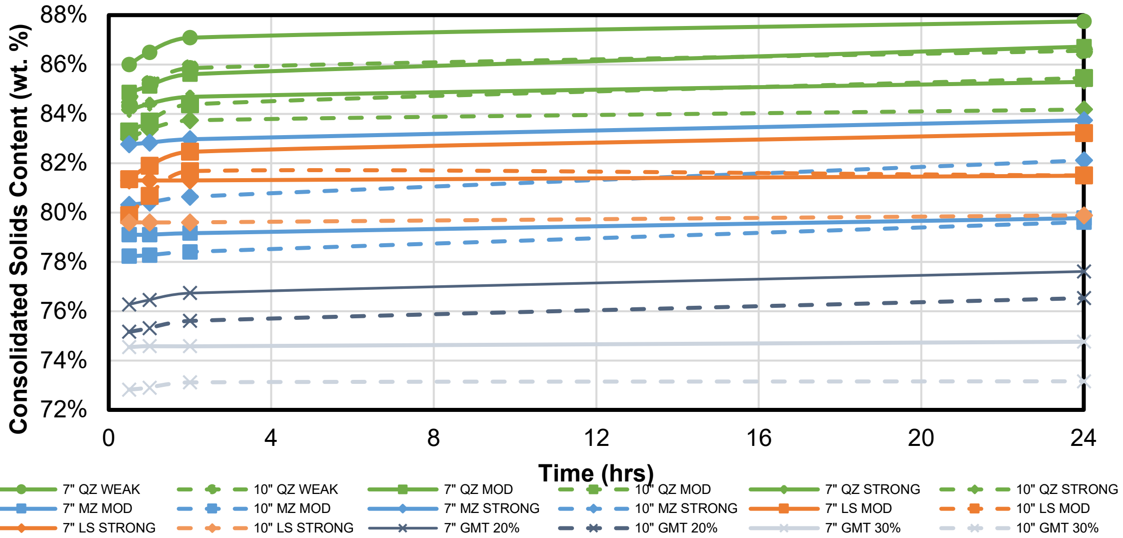

Figure 4 **Water bleed results (QZ = quartzite, LS = limestone, MZ = monzonite, GMT = general mill tailings, Mod = moderate)**

Unconfined compressive strengths

The unconfined compressive strength results demonstrated that the manufactured paste samples achieved higher strengths than the GMT at the same percent binder composition (Figure 5). There is relatively large variability between the waste rock types, with almost 5 wt% difference for the same slump between some of the waste rocks, which will need to be managed to the extent possible with selection of the aggregate feed to the paste plant, similar to the existing practices with the existing cemented aggregate fill system, while also selecting recipes that will achieve strengths even for some of the lower strength materials. Additionally, the majority of the waste rock from the open pit is expected to be QZ which achieved the highest results of the materials tested and should lower the expected variability.

All samples presented were cast with ground granulated iron blast furnace slag (GGIBFS) and general use cement (GU) in a ratio of 80:20 GGIBFS:GU as the binder.

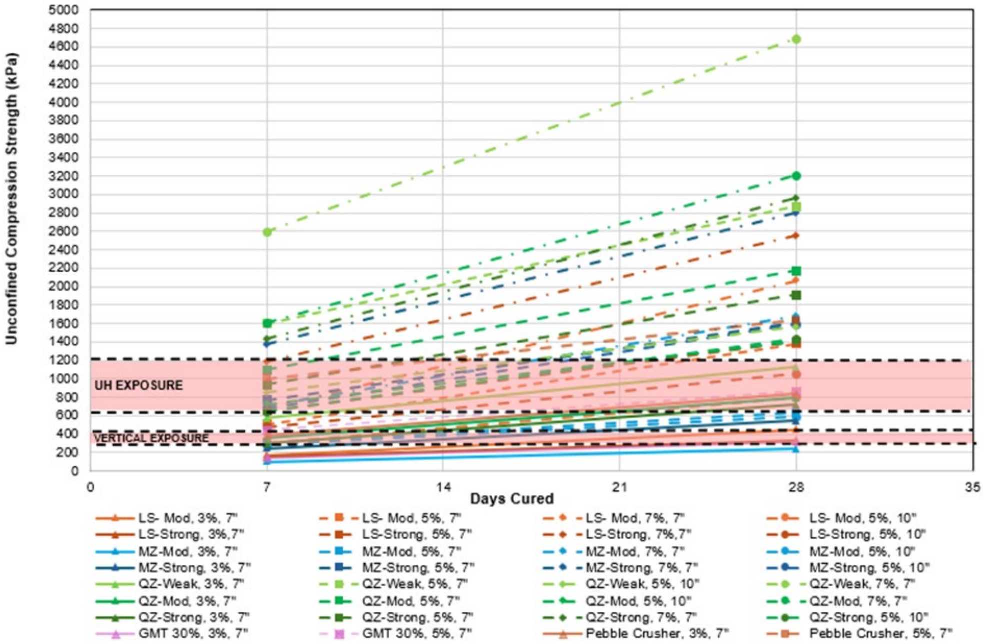

Figure 5 **Unconfined compressive strengths results (QZ = quartzite, LS = limestone, MZ = monzonite, GMT = general mill tailings, Mod = moderate)**

4 Pilot testing

Following the laboratory test work, pilot testing was conducted to validate the process design and provide input to the paste distribution design. Pilot crushing tests were conducted utilising the existing 2-stage crusher to provide feedstock to a temporary circuit tertiary crushing and screening plant to confirm the generation of suitable paste aggregate plant feed material (P90 6 mm) using full-scale crushing equipment. The tertiary crushing and screening circuit was of closed-circuit configuration and consisted of a Masaba 3 × 4.9 m portable belt feeder w/grizzly deck and hopper; 1.8 × 6.1 m triple deck mobile screen plant; HP3 cone crusher on a mobile chassis; ancillary 0.9m portable conveyors; Masaba 0.9 × 30.5 m; portable stacker and a portable diesel generator. Crushing was conducted over a few days adjusting some of the crusher setting. The material generated from this testing was subsequently used for a flow loop test to evaluate the materials pumpability, stability and friction losses.

5 Flow loop testing

Flow loop testing was conducted using a concrete pumping truck consisting of a 150 and 200mm (pipelines. The results were used to determine friction losses for input into the design and confirm the materials stability. A picture of the flow loop set up can be seen in Figure 6.

Figure 6 Flow loop testing installation

The friction factors were determined from the pressure transducer readings over the distance between the pressure transducers on a given pipe diameter. The relative height differences between the transducers were surveyed and corrected for this calculation. The friction loss results are included in Table 2.

Table 2 Flow loop data summary (150 and 200 mm pipe)

Approximate slump	Friction loss (kPa/m)			
	150mm pipe		200mm pipe	
	1 m/s	1.5 m/s	1 m/s	1.5 m/s
7	7.0	9.8	4.5	5.9
8	7.2	9.6	4.6	6.0
10	6.1	8.3	3.9	5.1

In addition, Table 3 compares the results against the results of the previous flow loop tests conducted on the RTK tailings (GMT30). This previous testing was performed with a 101.6 mm and 152.4 mm diameter pipe loop. A comparison has been compiled to compare results from the tailings paste tested previously with the aggregate paste tested as part of this current scope of work. For this comparison, data on corresponding slumps are averaged with the exception of reference point 3 as the data seems to be an outlier. The data comparison summary can be seen in the following table.

Table 3 Flow loop data comparison (paste to aggregate friction losses)

Approximate slump	Friction factor (kPa/m) in a 150 mm Sch 40 pipe			
	Aggregate paste		Tailings paste	
	1 m/s	1.5 m/s	1 m/s	1.5 m/s
7	7.0	9.8	16.0	16.0
8	7.2	9.6	10.0	10.0
10 (reference 3 included)	6.1	8.2	7.0	7.0
10 (reference 3 eliminated)	5.0	6.8	7.0	7.0

The results demonstrated the manufactured paste product has lower friction losses based for the samples tested. This would lead to lower pumping pressures and allowing for lower slumps to be pumped over a broader distribution. This results in a lower binder consumption as it does not require as much water addition to lower friction losses to accommodate distribution and pumping limitations.

5.1 Start stop conditions

Start stop conditions were tested on the aggregate paste flow loop test to understand potential risk regarding periodic stops in the pumping of the material. Over the course of this start stop testing, 4 reference points were tested. A sample plot and associated pre-stop and post-stop friction losses are presented in Figure 7.

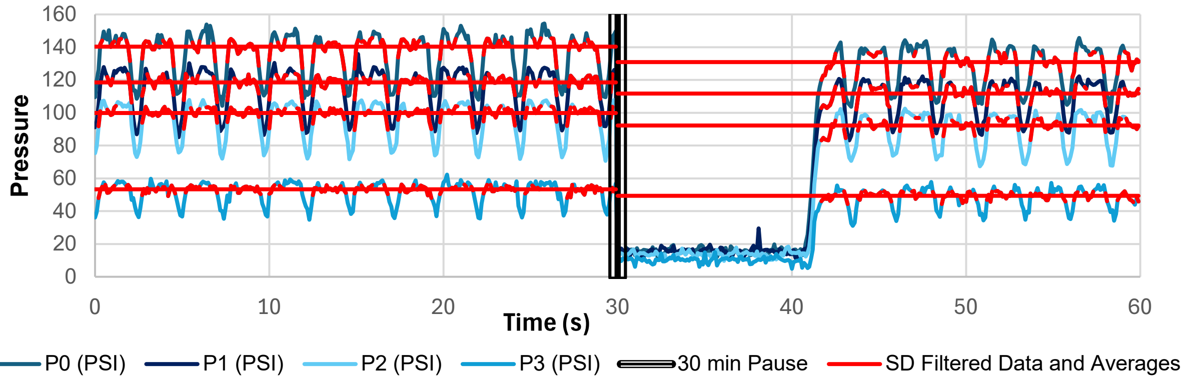

Figure 7 Reference 4: 175mm slump 10% binder – start stop data comparison

The data obtained in the start stop testing shows a low difference, generally 5–10% lower than prior to the pause, in the restarting pressures for the aggregate paste demonstrating that the manufactured paste material is stable even after a 30 min pause. The small variance observed may be the result of the analogue pump speed control. It is believed that more significant departures such as a larger increase in pressure after restart would be able to be observed with these small differences in speed control regardless. It does appear that there is a small momentary increase in pressure loss in the first moments of restarting which could be attributed to momentum changes of the fluid as it is accelerated. These would be expected to be larger the longer the pipeline that is installed.

6 Costing comparison

Based on the feasibility level designs conducted for both solutions, manufactured paste and tailings paste, the manufactured paste solution resulted in significant capital cost savings based on the reduction in fixed infrastructure and consolidation of the infrastructure to one site. In addition, it provides further opportunity to reduce or defer some of the capital costs by modifying the existing road base crusher as opposed to a standalone crushing system as estimated.

Operating costs were also built up. Manufactured paste resulted in a reduction in operating costs primarily due to the reduced labour as the original tailings paste had separate operators for the thickening plant and paste plant while a single operating crew is required for the manufactured paste solution. Additionally, manufactured paste had reduced consumables primarily based on the reduction in binder consumption due to the higher strengths.

7 Conclusion

This paper investigated the technical merits that are related to the viability of a manufactured paste backfill plant. This study was developed using the data obtained through laboratory testing as well as the pilot testing conducted on site. Based on the results, it appears the manufactured paste system offers a technically viable backfill solution with lower capital and operating costs when compared to the previously studied tailings paste system. Although this would be a relatively unique backfill process, waste rock only paste, it was designed considering challenges around similar plants globally that utilise aggregate in paste as well as a robust testing campaign including lab testing as well as pilot testing to prove the viability of the process. This design additionally simplifies the brownfield tie-ins and leverages the strengths of the Kennecott's operations in material handling and crushing from their open pit experience.

Based on the technical and commercial merits, it is recommended to implement the manufactured paste solution for the RTK underground orebodies.

Acknowledgement

The authors would like to thank Rio Tinto for its support in the development of this case study. Input from the team, open mindedness and flexibility were key as to work through some of the challenges in developing this solution and we look forward to continuing to advance this work in the hopes it can become a valuable asset for the site.

References

Landriault, D & Goard, B 1987, 'Research into high density backfill placement methods by the Ontario Division of Inco Limited', *CIM Bulletin*, vol. 80, no. 897, pp. 46–50.

Stone, D 2014, 'The evolution of paste for backfill', in Y Potvin & T Grice (eds), *Mine Fill 2014: Proceedings of the Eleventh International Symposium on Mining with Backfill*, Australian Centre for Geomechanics, Perth, pp. 31–38, https://doi.org/10.36487/ACG_rep/1404_0.3_Stone

Tenbergen, RA 2000, 'Paste dewatering techniques and paste plant circuit design', *Proceedings of the 7th International Conference on Tailings and Mine Waste '00*, Fort Collins.