Enhancing Sustainability in Mining: CO_2 Reduction in Underground Mines Using Modern Paste Backfill Admixtures

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Abstract

Cemented paste backfill has become the standard in modern cut-and-fill and long-hole stoping mines globally. It has proven to be an efficient method in maximizing ore recovery while reusing up to 50% of the tailings for underground stope fill. To reach the required fill strength, paste backfill must incorporate a cementitious binder. The cost of this binder can account for up to 75–80% of the total backfilling cost. Therefore, reducing the binder content can generate substantial savings while reducing cement related CO_2 emissions. The loss in strength due to binder reduction can be compensated by paste backfill admixtures, which allow an increase in the paste solid content while maintaining a flowable paste. This study analyses cemented paste backfill mixes sourced from three different Canadian hard rock mines. Laboratory results validate significant binder reduction by changing the paste mix designs. The use of customized cement-reducing admixtures results in a paste solid content increase, ranging from 3–4%, which in turn, facilitates a total binder reduction of 14–26%. This binder reduction translates to a reduction in CO_2 eq/kg of paste, ranging from 4–26%.

Key words: paste backfill, admixture, binder/cement, underground, mining

Introduction

Modern mining operations have high standards of sustainability and must limit their environmental footprint. Some ways to achieve this is by proper waste and water management, reducing overall CO_2 footprint, and mitigating the effect of acid mine drainage problems of sulfide bearing tailings and waste rocks stored on surface. Furthermore, the inclusion of a circular economy approach for mines, particularly when they are mined underground, has become an important topic, where the re-use of the tailings takes the centre stage of the discussion. The implementation of paste backfill as a method for structural underground support while reducing the surface deposition of tailing has resulted in an effective way to address the circular economy of underground mines. Cemented paste backfill not only reduces up to 50% of the tailings volume stored on surface in tailing storage facilities but is mainly used to maximize underground ore recovery. To reach the specified paste strength requirements different dosages of binder are added, and depending on availability different types of binders are used. However, use of binder comes at a cost, which can make up to 75–80% of the operating cost of a paste backfill plant (Hassani and Bois, 1989; Potvin et al., 2005; Li et al., 2019).

Cement production is one of the largest source of CO_2 emissions in the industrial sector globally, accounting for 5–7% of all industrial CO_2 emissions. According to the 14th Edition of The Global Cement Report (2021) around 4,000 metric tonnes (MT) of cement are produced and consumed in the world. In Canada, it is estimated that around 10 MT of cement are consumed per year. Cement consumption by Canadian mines is important and most of the cement is used for backfilling, either as paste backfill, cemented rockfill or cemented hydraulic fill. Any reduction of cement consumption in backfill is not only economically interesting but also allows to achieve reduction of related CO_2 emissions from the purchased cement, reported as Scope 3 emissions of mining operations. Optimizing paste designs allows for reduction of cement consumption and hence reduction of related CO_2 emissions, while at the same time offering a reduction in backfilling operation costs. Over the past years, there has been a strong focus on exploring alternative binders to replace Portland cement fully or partially for environmental reasons.

Examples of supplementary cementitious materials used in Canadian mines are slag, fly-ash and other pozzolanic materials.

This paper presents a different approach. Rheology modifying chemical admixtures, known as super-plasticizers or water-reducing admixtures have been used in the concrete industry for decades. They allow to reduce the binder volume required to obtain the specified compressive strength by allowing a reduction of water from the total concrete recipe. This paper presents three case studies from different Canadian hard-rock mine sites where water-reducing admixtures were used to identify cement reduction potential in paste backfill. Associated CO_2 savings related to the reduced binder consumption are also presented in this paper.

Methodology

When developing and using water reducing admixtures for paste backfill, several aspects need to be considered. These aspects include the physical and chemical properties of the tailings, water chemistry and type of binder used. Complete understanding of the requirements on the paste backfill operations is critical prior to starting the mix-design optimization process. This includes the overall setup for backfilling, including filters, mixing equipment, and configuration of the reticulation system (pouring distance, time), etc. The improvements desired on the behaviour of the paste, will ultimately define, what type of admixtures will yield the highest benefits.

Mineralogy

The geological formation history, in particular the alteration history of a given ore deposit is reflected in the mineralogy of the tailings. Hence, special attention is given to the presence of certain alteration minerals such as phyllosilicates such as the clay minerals. Three mines operating in different geological conditions and belonging to different types of deposits were selected for this study. To evaluate the mineralogical composition of each tailing a Bruker D8 ADVANCE X-ray diffraction (XRD) apparatus was used. The parameters used were a 2θ angle range of 3–65°, a step size of 0.015° and a time/step of 1.0 s. The analyses were conducted in Sika's research laboratories in Zurich, Switzerland. The effect of the different deposit types and the mineralogy on the impact of water reducing admixtures in backfill materials has been studied by Erismann and Hansson (2021), and Arcila et al. (2023).

Particle size distribution (PSD)

The ore formation history has a direct impact on the comminution requirements of a given ore body to retrieve the ore. Milling of the ore and, if applicable, the desliming and scrubbing will impact the final particle size distribution of tailings. Particle size distribution analysis was done using the Sympatec HELOS laser diffraction instrument combined with the QUIXEL wet dispersing system. Particles were suspended in distilled water. The analyses were conducted in Sika's research laboratories in Zürich, Switzerland.

Uniaxial compressive strength (UCS)

Cemented paste backfill 3 × 6 in cylinders were cast following the C31/C31M-03a ASTM international (2022) standard and cured in a humidity chamber at 23 ± 2 °C and a relative humidity higher than 95%. Triplicate cylinders per breaking age were tested using the soil compression HM-5030 Master Loader testing machine with a maximum load cell capacity of 10 kN, following the C39/C39M ASTM international (2015) standard. The samples were tested after the specified curing times by the different mine sites (5, 6, 7, 14, and/or 28 days). The uniaxial compressive strength was measured for three different samples sets:

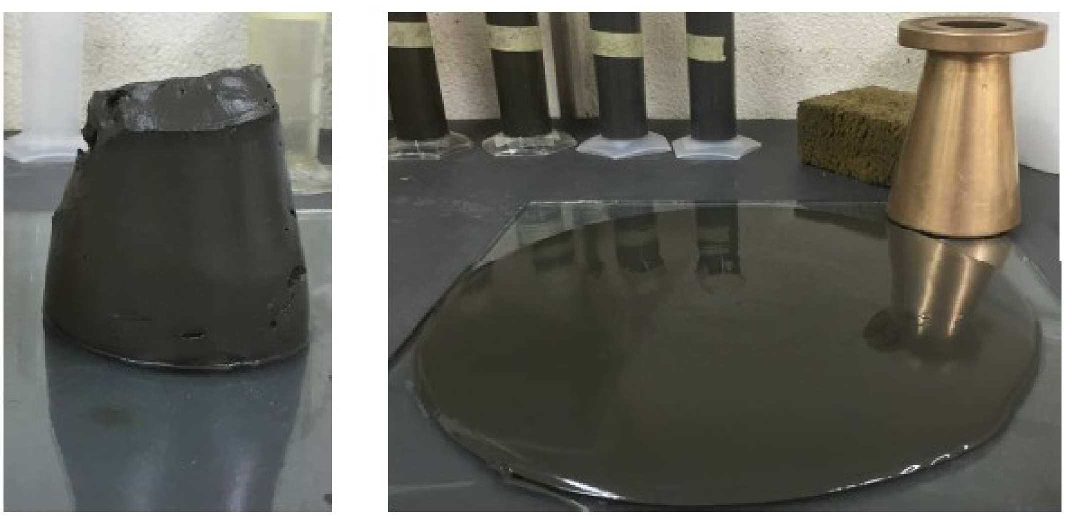
1. The mine reference mix prior to mix optimization.
2. The mix obtained after estimating the maximal water reduction potential when using water-reducing admixtures.

3. Samples after water and cement reduction to estimate the maximal percent cement reduction that can be achieved to return to a similar UCS as the reference mix.

Water/Solids content and solids content increase
Following the D2216-19 ASTM International (2019) standard for gravimetric water content or the paste solids content was calculated by drying a weighted paste sample at 110 ± 5°C. The difference in weight between the wet and dry sample represents the amount of water in the sample and the solid content can be calculated. The percent solids content gain was calculated by comparing the reference mix design solids content with the solids content of the maximal water reduced sample when using water-reducing admixtures. This maximal water reduction is based on the workability requirements of the mine, which is usually measured by a slump test using an Abrams slump cone or a Boger cylinder (Pashias et al., 1996).

Water-reducing admixtures
When targeting cement reduction using admixtures, the best suited admixture is usually identified by observing a significant rheological effect (ie, substantial increase of the slump-flow of the paste) when mixing it with the paste (Figure 1). The method to reduce binder through a water-reducing admixture works as follows: the water-reducing admixture allows for water reduction of the paste while compensating for the increase in shear yield stress resulting from the higher solids content (Silva, 2017; Sofra, 2017). The increased solid content results in an increase in the UCS, which in turn will allow to achieve cement reduction while meeting initial UCS and flowability requirements. Typical admixtures dosages are between 1–3% by dry mass of cement. To remain within an economic viable range, the savings from the reduced cement consumption should compensate the admixture cost. It is important to highlight two aspects when using a water-reducing admixture:

1.) Reducing water out of a paste mix can impact the workability over time. The workability needs to be sustained for the period specified by the mine and hence adjustments to the admixture composition may be required.
2.) There is a limit to water reduction due to an increased interaction between the particles when increasing the solids content of the paste. This will ultimately limit water reduction due to strongly increased shear stress, viscosity, and static and dynamic yield stress (Ouattara et al., 2017, Ouattara et al., 2018, Arcila et al., 2023)



(a) (b)

Figure 1. a) Mine mix-design reference slump without admixture, and b) plasticizing effect resulting from the addition of a water-reducing admixture to the reference mix-design.

Global warming potential (GWP)
Table 1 presents the mean potential environmental or global warming impact (kg CO_2 equivalent) cradle-to-gate of 1 kg of water-reducing admixture and of the specific types of binder considered for this study. The values include the extraction and upstream production (A1), the transport to factory (A2) and the manufacturing (A3) of the products. The Global warming impact of high-range water reducing (HRWR) admixtures was extracted from the declared values for similar water-reducing admixtures from the environmental product declaration (EPD) for Sika Concrete admixture and cement additives in Canada commissioned by Sika Canada in June 2022.

For the different binders used in this study, the GWP was extracted from the EPD reports for each mine based on their corresponding cement manufacturer and production plant. For the General Use (GU) Portland cement, the Portland-Limestone (GUL) cement with up to 15% limestone, and High Early (HE) cement GWP were extracted from the Holcim-Lafarge EPD issued in July 2022. For the slag cement it was extracted from the Slag Cement Association issued in July 2021. All this EPD were developed in compliance with the ISO 14025:2006 and ISO 21930:2017.

Table 1. Cradle-to-gate (A1-A3) values for 1 kg of water reducing admixture and the different types of binders used in this study.

Component	**Global warming impact (kg CO_2 eq / MT*)**
Water-Reducing Admixture	1360
Portland General Use Cement (GU, type I/II)	928
General Use Limestone (GUL, Type IL)	830
High Early (HE type III)	922
Slag Cement	143

*MT: Metric Ton.

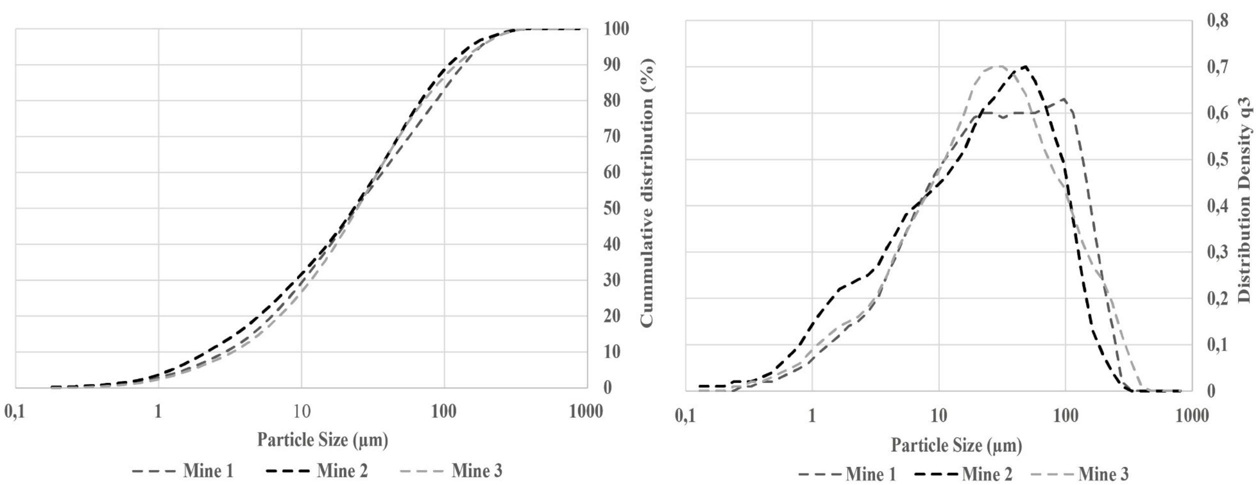
Tailings Characterisation

Table 2 presents the XRD results for the three tailings studied. Mine 1 shows a major difference in mineralogy, with a high sulfide concentration (33 wt%) and lower phyllosilicates content (12 wt%). Mines 2 and 3 have similar mineralogical compositions. Both have a considerable amount of phyllosilicates (23–27 wt%). Mine 2 has a more mafic composition with lower amounts of quartz and including some amphibole (actinolite). The three mines are constituted by > 50 wt% of inert minerals, ie, quartz and felspars. The phyllosilicate minerals present are micas (muscovite and biotite) and chlorites, mineral groups that do not swell in the presence of water. Additionally, no clay minerals were detected. The specific gravity of the tailings was 2.97, 2.91 and 2.78 for Mine 1, Mine 2 and Mine 3, respectively.

The particle size distribution of the three tailings studied, show a similar cumulative distribution curve (Figure 2a), which is also confirmed by the comparable percentage passing 10 and 20 µm, with approx 30% passing 10 µm and approx 46% passing 20 µm. The volume percent passing 20 µm is shown (Table 3), as it reflects the amounts of fines in the tailings which is an important factor for paste behaviour in the reticulation system (Landriault and Primeau, 2013). Mine 1 shows a more heterogenous distribution density of the particles, with a broader range on the highest concentrations of particles showing a plateau between approx 20–100 µm (Figure 2b). Mine 2 and Mine 3 have a clear peak and have their highest concentration at approx 50 and 30 µm, respectively.

Table 2. XRD mineralogy results from the three mine sites from this study.

Mineral	Mine 1 (wt%)	Mine 2 (wt%)	Mine 3 (wt%)
Quartz	43.0	31.3	55.8
Pyrite	32.9	Traces	
Pyrrhotite		5.9	
Muscovite	3.9	8.3	14.2
Biotite		10.3	
Chlorite	8.2	8.9	8.5
Dolomite			7.4
Microcline		11.7	
Albite	9.6	9.7	11.6
Anorthite		3.1	
Actinolite		9.2	
Magnetite		1.7	2.6
Gypsum	2.4		
Total Phyllosilicates	**12.1**	**27.5**	**22.7**



(a) (b)

Figure 2. a) Cumulative particle size distribution curves, and b) frequency distribution of the different particle sizes of the three mine tailings.

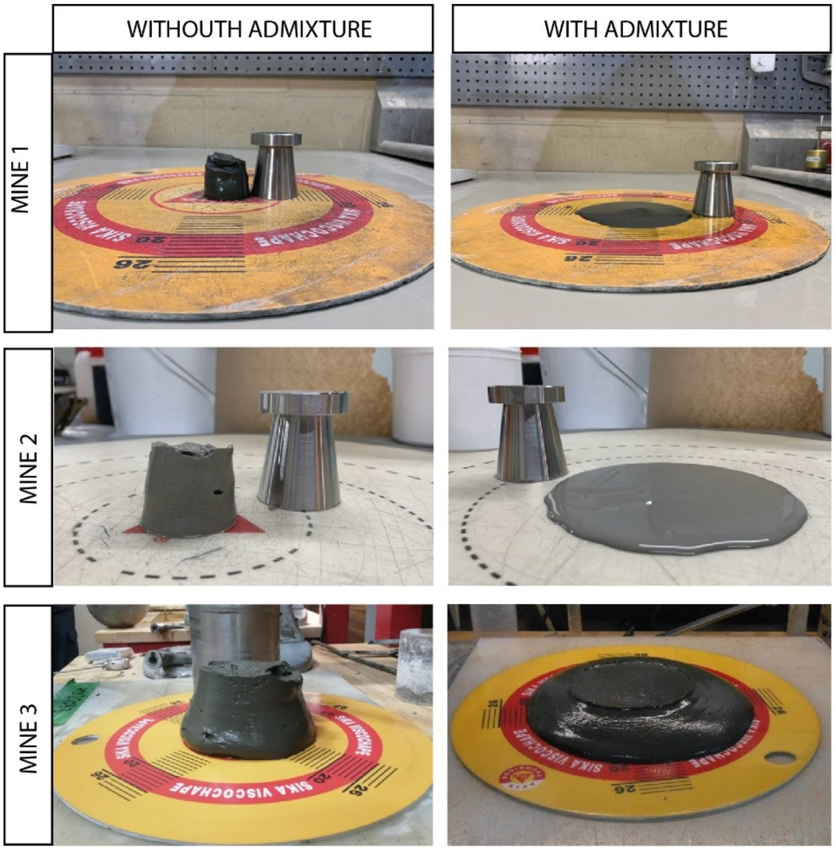
Table 3. Summary of the %- of tailings particles passing the 20 µm sieve for the three mines sites.

Mine Name	Mine 1	Mine 2	Mine 3
%-Passing 20 microns	46.1	46.9	44.7

Results

Admixture identification, water reduction and cement content optimization

The left side of Figure 3 shows the reference mix-design and reference slump for the three mine sites as tested in the laboratory. The initial paste solids content ranges from 71–74%. The paste specific gravity for Mines 1, 2, and 3 before water reduction is 2.0, 1.8 and 1.95, respectively, with a 7.5'' (approx 19 cm), 8'' (~ 20 cm) and 7'' (~ 18 cm) slump (Abrams Cone). The cement content in the paste mixes for the three case studies ranged from 4.2–5.3%. The three different mines used the following cement types: 1) a blend of 80% slag and 20% GU, 2) a blend of 90% slag and 10% GU, and 3) 100% HE type cement.



SOLID CONTENT	BINDER CONTENT	BINDER TYPE	ADMIX. DOSAGE
73 %	4.2 %	S:80% GU:20%	2.4%
71 %	4.6 %	S:90% GU:10%	2.0%
74 %	5.3 %	HE:100%	1.2%

Figure 3. Comparison of the reference mix design on the left and the mix with the water-reducing admixture on the right. The mix design of the different mines is shown in the table on the right.

Based on the mineralogical composition of the tailings and interaction with the water-reducing admixtures, customized admixtures were developed for the three mines sites. The right side of Figure 3 shows the plasticizing effects achieved for each paste. Admixture dosage ranges from 1.2–2.4% by dry mass of cement (mass of cement calculated based on the mass of dry tailing). This strong plasticizing effect is essential to achieve water reduction. With the addition of the water-reducing admixture, it was possible to increase the total paste solids content in the range of 3–4% (4% for Mine 1, 4% for Mine 2, 3% for Mine 3) while maintaining workability similar to the reference mix. This increase in solid content resulted into a significant increase in compressive strength and greatly impacted the compressive strength development (Figure 4). The difference between both strength development curves increases at higher curing ages.

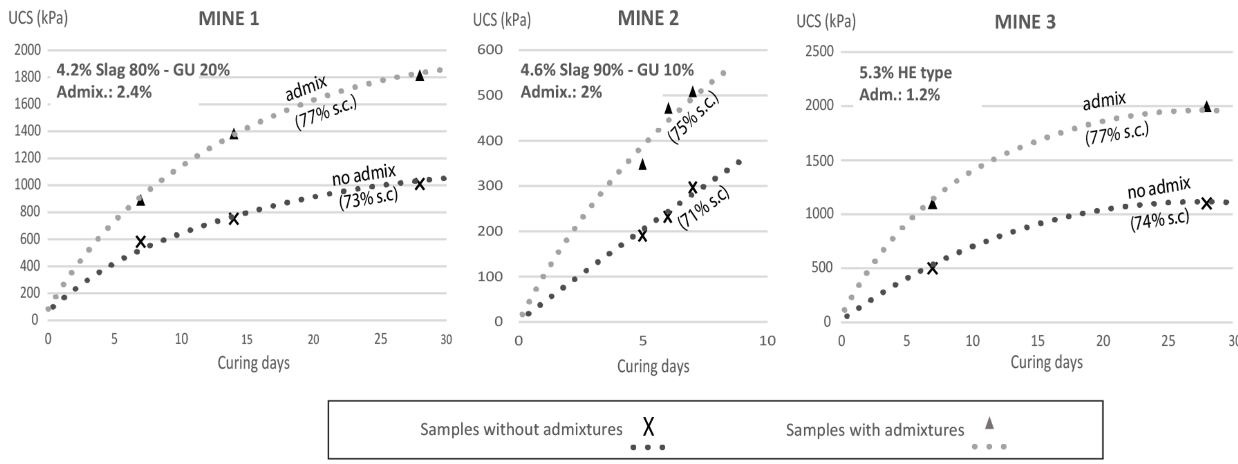


Figure 4. Compressive strength development with and without water-reducing admixture after reducing as much as possible water while maintaining similar workability to the reference mix without admixture.

The subsequent step involves reducing the cement content to restore the compressive strength back to the strength of the reference mix for each mine. This systematic optimization process is presented in Figure 5. The 7 days results were used as a comparison as all three mine sites studied had 7 days in their quality control program. The compressive strength gain between the reference mix (REF) versus the mix with the water-reducing admixture (WR) after water-reduction ranged between 53–120%. The UCS results after cement reduction (CR), were back to similar strength than those of the reference mix design. The cement reduction achieved for these mines ranged between 14–26% (Figure 5; Table 4). Hence, the calculation shows that for every 1 kg of admixture used in Mines 1, 2, and 3, the potential reduction in cement content amounts to 9.5 kg, 13 kg, and 21.5 kg, respectively.

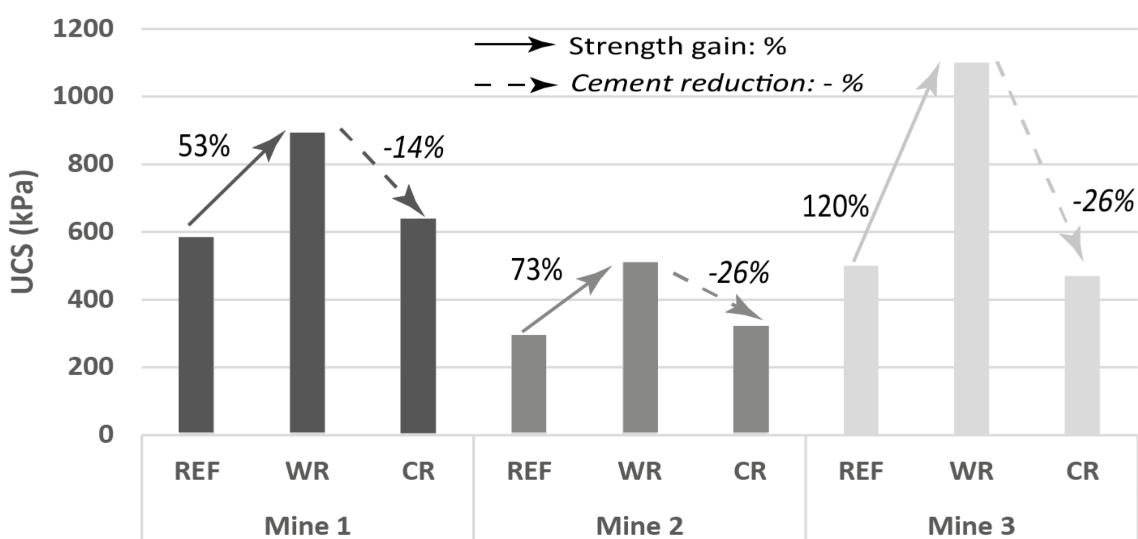


Figure 5. The 7 day compressive strength results for the three mines sites, including the reference mix design (REF, no admixture), the paste with the water-reducing admixture and reduced water content (WR), and for the paste with the water-reducing admixture, water content reduced, and cement content reduced (CR).

Table 4 summarizes the optimization in solids content and in cement reduction for the 3 mines studied, for which:

- Mine 1 with a cement content of 4.2%, using an 80% slag and 20% GU blend, required a dosage of 2.4 wt.% (by dry mass of cement) of admixture. This led to a reduction in water, resulting in an increase in solids content from 73% up to a maximum of 77%. The cement content was reduced from 4.2% to 3.6%, which corresponds to a 14% decrease.
- Mine 2 with a binder content of 4.6%, using a 90% slag and 10% GU blend, a dosage of 2 wt.% (by dry mass of cement) of admixture was necessary. This contributed to a solids content increase from 71% to 75% while reducing the cement content from 4.6% to 3.4%, representing a 26% decrease.
- Mine 3 with a binder content of 5.3%, using 100% HE, and admixture dosage of 1.2 wt.% (by dry mass of cement) was required. This allowed us to increase the solids content from 74% to 77% and made possible to reduce the cement content from 5.3% to 3.9%, which is equivalent to a 26% decrease.

Table 4. Impact on the admixture dosage used on the paste solids increase and binder reduction for the three mines

Mine #	Paste Solids without admixture	Paste Solids with admixture	Admixture Dosage	Cement type	Initial cement	Final cement	Cement reduction
	%	%	wt.%		%	%	%
1	73	77	2.4	S: 80% GU: 20%	4.2	3.6	- 14.3
2	71	75	2.0	S: 90% GU: 10%	4.6	3.4	- 26.1
3	74	77	1.2	HE : 100%	5.3	3.9	- 26.4

Global warming potential of the optimized cemented paste backfill mixes

Table 5 presents the kilogram of CO_2 equivalent per metric ton of each of the specific combination of cement type used at the mines studied. These values were calculated using the values reported in Table 1, extracted from the environmental product declarations (EPD's) reports. It is interesting to note that slag cements have a much lower CO_2 footprint than regular Portland cements due to the reduction of the raw material-related CO_2 emissions (Osmanović et al., 2014) and the nearly 90% lower energy consumption during production (Prusinski et al. 2011). Slag blends, as used in Mine 1 and Mine 2, have a low carbon footprint of 298 and 225 kg CO_2eq/MT. The difference between the carbon footprint of Mine 1 and Mine 2 originates from the different slag content in the binder mix. Mine 1 has 80% slag and Mine 2 has 90% slag in the cement mix. Mine 3 has the highest carbon footprint as it uses 100 % Type HE cement, which has a carbon footprint of 922 kg CO_2 eq/MT.

Table 5. Carbon footprint in kg CO_2 eq/MT for the different cement types used for the three mines studied. The transportation distance and its carbon footprint are not included in these calculations.

Mine #	Cement type	Cement Carbon Footprint (kg CO_2 eq/MT)
1	S: 80% GU: 20%	295
2	S: 90% GU: 10%	225
3	HE: 100%	922

Table 6 presents the global warming potential values of the reference mix and compares it with the GWP of the optimized paste mix using water-reducing admixture (water and cement reduced). Figure 6 shows that Mine 1 and Mine 2 have a carbon footprint of 12.4 and 10.4 kg CO_2 eq/MT of paste, respectively, and with the cement optimization it is possible to reduce to 11.8 and 8.6 kg CO_2 eq/MT of paste, respectively. This represents a carbon footprint reduction per tone of paste of 4% for Mine 1 and 17% for Mine 2. The paste of Mine 3 has 4–5 times higher initial carbon footprint compared to the other two mines due to the different binder used (HE-type cement), with 48.9 kg CO_2 eq/MT of paste. After optimization, the carbon footprint is reduced to 36.2 kg CO_2 eq/MT of paste, which represents a 26% reduction of the mine operation carbon footprint when using admixture.

Table 6. GWP calculations comparing the carbon footprint without admixture versus the optimized mix using admixture.

Mine	Cement Type	GWP Cement	GWP Admix	Dosage Admix	Initial Cement Dosage	Cement reduction	GWP NO ADMIX	GWP WITH ADMIX	GWP Operation reduction
		kg CO_2 eq. / MT	kg CO_2 eq. / MT	% bwoc	%	%	kg CO_2 eq. /MT of paste*	kg CO_2 eq/MT of paste**	%
1	S:80% GU:20%	295	1360	2,4%	4,2%	14%	12,4	11,8	4%
2	S: 90% GU:10%	225		2,0%	4,6%	26%	10,4	8,6	17%
3	HE: 100%	922		1,2%	5,3%	26%	48,9	36,2	26%

*Accounts for the GWP cement
**Accounts for the GWP reduced cement + dosage admixture used

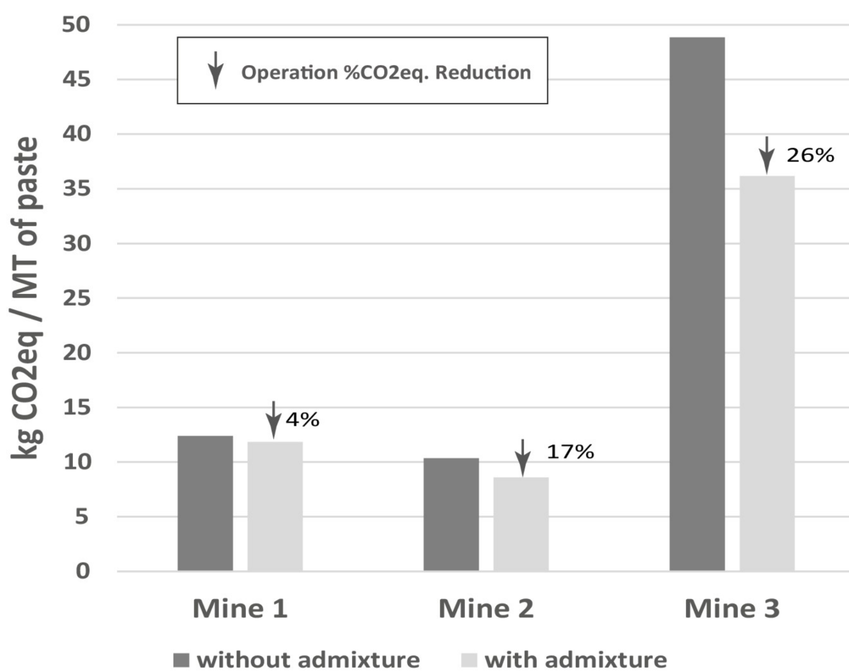


Figure 6. Carbon footprint in kg CO_2 eq/MT paste of each of the mines without and with admixture. The percentage in the arrows represent %CO_2 eq reduction of the mine operation footprint when using water-reducing admixtures.

Discussion

The three case studies have shown that each kg of admixture has the potential to replace between 9.5–21.5 kg of cement from every ton of paste produced. Cement reduction of 26% as observed for Mine 2 and Mine 3 will allow for significant cost savings (cement reduction, strongly reduced transported overall volumes) for a paste backfill operation as well as a significant positive effect on the CO_2 footprint of a given paste plant and overall mining operations. It must be noted, that CO_2 emissions related to the binder transport have not been calculated for these three mine sites. Depending on the location of the mine site, the impact on the CO_2 emissions could be significantly higher than those presented in Table 6.

Global warming potential reduction is particularly interesting when comparing Mine 2 and Mine 3. Despite the difference in cement type used (90% slag blended with 10% GU for Mine 2 and 100% HE Portland cement for Mine 3), the carbon footprint reduction is significant for both sites. The effectiveness of the admixture is playing a decisive role to achieve significant cement reduction for a given paste. The admixture was particularly effective on the paste of Mine 2 and Mine 3, and less so for Mine 1. It is unclear what resulted in the lower cement reduction for Mine 1 despite choosing an admixture which had a very strong rheological impact on that paste. However, the large 4% solids content increase only resulted in a 53% UCS gain. The hypothesis proposed is that it could be a combination of an overall low cement content in the mix, water chemistry, the occurrence of large amount of pyrite in the mix as well as gypsum. In the presence of water and air, pyrite oxides produce sulphate ions (SO_4^{2-}), acidifying the paste. The adverse impact of sulfate ions on compressive strength arises from the synergistic effects of several factors:

(i) the absorption of sulfate ions by calcium silicate hydrate (C-S-H) bonds, leading to the formation of lower-quality bonds;
(ii) the generation of expansive minerals, such as gypsum and ettringite, which cause a coarsening of the pore structure within the cementitious mix, consequently diminishing the yields in strength development;
(iii) ettringite inhibits the process of cement hydration, resulting in prolonged setting times and a reduced production of hydration products (Li and Fall 2015). The acidity within the paste is undesirable, as C-S-H bonds are broken by it, lowering the strength of the cementitious mix (Ercikdi et al. 2017).

A more in-depth study would be required to define the exact cause.

From laboratory work, it was observed that the solids content of the tailings can be increased by 3–4 % using the water-reducing admixture while maintaining similar workability compared to the reference mix. This increase in solid content resulted in an increase in the uniaxial compressive strength, allowing to reduce the cement content by 14–26%. With a view towards the required admixture dosage to reduce water and cement, the slag blends seem to require a generally higher dosage (> 2% by dry mass of cement) compared to the Portland HE-type cement (1.2% by dry mass of cement). Because of the natural compatibility between the admixture and the cement, it is known that the higher the cement content, the lower the dosage of admixture required and the higher the cement reduction potential (Erismann and Hannson, 2021). Mine 1 has the lowest cement dosage and required the highest dosage of admixture of 2.4% by dry mass of cement. The higher admixture dosage for Mine 1, coupled with lower cement reduction is limiting the impact of the admixture on the overall CO_2 reduction for this paste.

For the three sites studied, the average cement- and CO_2-reduction potential were calculated (Figure 7). The average capacity of the mills from the sites studied is of 6,000 tons of ore per day. The resulting backfill capacity is estimated around 3000 tons per day (50% of mill capacity). Using the average cement content of 4.7%, and a paste plant availability of 70% (255 days), their yearly average cement consumption is 36,000 tons of slag cement with maximum 20% GU (295 kg CO_2 eq/MT), so the resulting

GWP would be approx 10,600 MT CO_2 eq/mine. If an average cement reduction of 20% is achieved, this would represent a saving of 7,200 tons of cement or 2,100 MT CO_2 equivalent per year. To attain this cement reduction, an estimated average admixture dosage of 1.8% by dry mass of cement would be required, which would represent 650 MT of admixture per year with an 880 MT CO_2 equivalent emission/year/site. Therefore, the combined effect of cement reduction and using an admixture could reduce approximately 1200 tons CO_2 eq/site /year. This calculation does not include the carbon emissions related to transport to the specific mine sites. However, considering the respective volumes of cement and admixture, the transportation of 7200 tons of cement substituted by 650 MT of admixture should have a positive impact.

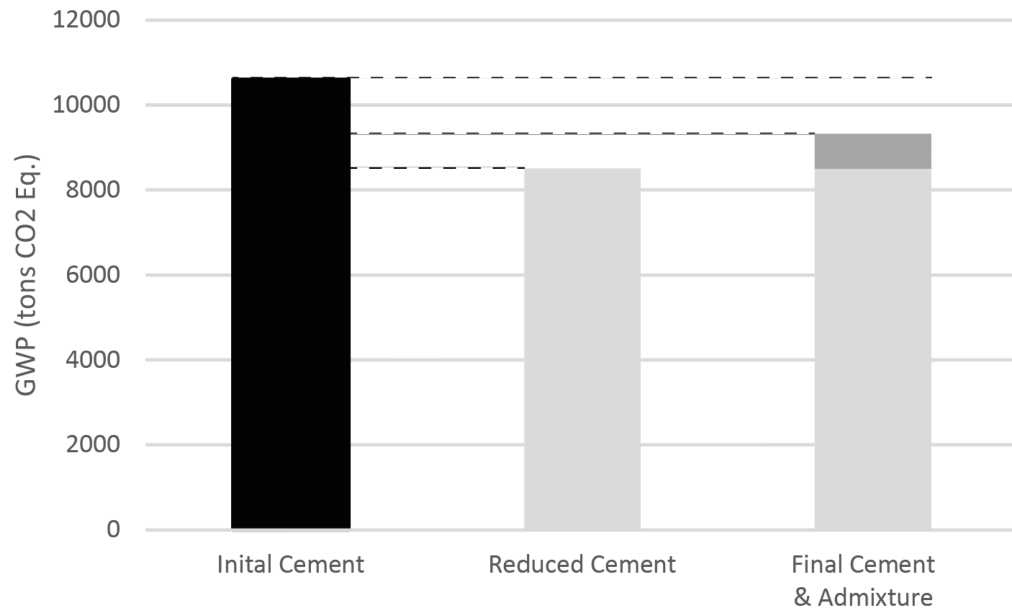


Figure 7. Theoretical average optimization of the Global Warming Potential of the mine sites. On the left, GWP associated with initial cement consumption (no cement reduction). In the middle, GWP associated with reduced cement content in backfill materials. On the right, GWP associated with the reduced cement content in backfill materials with the addition of the GWP of the water-reducing admixture.

Extensive use of slag blend cements in Canadian mines have contributed to reduce the mining industry GWP associated with their cement consumption as the CO_2 intensity is significantly lower for slag blend cements compared to Portland cements. However, the demand for such slag-binder, due to its positive qualities for backfilling operations, is currently much higher than the available quantities. Their availability is also being affected by the transition of the iron smelters from blast furnace-basic oxygen furnace (BOF) technology to direct reduced iron-electric arc furnace (EAF). This transition reduced their carbon emissions drastically but produces a slag with reduced pozzolanic reactivity. As a result, the prices of the slag have increased substantially over the past years. The identification of other types of pozzolanic binders with low GWP is being globally researched. In Canada and elsewhere, the cement producers are shifting away from pure Portland GU-type cements and transitioning to GUL-type cement. This cement contains up to 15% limestone by mass and further reduces the global warming potential from 928 to 830 kg CO_2 eq/MT, which is a 10% carbon footprint reduction (Table 1). Admixtures have proven their effectiveness for a range of binder systems and will play a critical role in addressing the carbon emissions for cementitious materials such as cemented paste backfill, cemented rock fill and cemented hydraulic fill, just as they currently do for any conventional cementitious material (concrete, grouts, mortars, etc.). The use of admixtures is not only environmentally but also economically interesting.

Conclusion

The three gold mines studied underscore the significant potential of water-reducing admixtures in optimizing paste backfill operations. Results from this study showed that 1 kg of admixture can replace between 10–20 kg of cement. The increase in the solid content achieved, using a water-reducing admixture allowed to increase the strength by 53 to 20%, which in turn allowed to reduce the cement content by 14 to 26%. This reduction in the cement content results on a carbon emission reduction per ton of paste between 4 to 26% CO_2 equivalent depending on the binder reduction achieved and the type of cement used. It was estimated that the use of admixture could reduce approximately 1200 tons CO_2 eq/year/mine. The key to a more sustainable paste plant is the use of slag or pozzolan blend cements combined with an optimized mix design using admixtures.

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