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Natural weathering as a surface crusting tool for tailings management

L'altération naturelle comme outil de formation de croûtes de surface pour la gestion des rési dus d'extraction

Umme Rima & Nicholas Beier

Department of Civil and Environmental Engineering, University of Alberta, CNRL/Markin Natural Resources Engineering Facility, Edmonton, Canada, umme@ualberta.ca

ABSTRACT: Canada's oil sands are one of the largest unconventional fossil reserves, constituting 81% of the world's total bitumen reserve and are considered world's third largest reserve after Saudi Arabia and Venezuela. Extracting bitumen from oil sands generates a waste slurry referred to as tailings. The abundant large volumes and the extremely low settling rates of tailings present a unique management concern for the mining industries. The objective of the research presented in this paper is to utilize freeze-thaw (Canadian weather) as a crusting tool in order to increase the surface strength of the tailings to support capping and reclamation. This paper also compares different tailings (oil sands, coal, and gold) management approach using seasonal weathering (multiple freeze-thaw cycles and evaporation) in order to understand the effects of seasonal weathering on the development of a surface crust. The results concluded that predicting the volume change behavior of the tailings deposits exposed to surficial seasonal weathering is quite challenging in Canada compared to Australian arid/semi-arid climate zone. However, the laboratory results also suggest that seasonal weathering in Canadian weather can facilitate surface crust for oil sands tailings deposits with an associated peak shear strength of more than 110 kPa, provided active water management is ensured.

RÉSUMÉ: Les sables bitumineux du Canada sont l'une des plus importantes réserves fossiles non conventionnelles, constituant 81% de la réserve mondiale totale de bitume et sont considérés comme la troisième plus grande réserve mondiale après l'Ara bie saoudite et le Venezuela. L'extraction du bitume des sables bitumineux génère des restes des boues de plus en plus nombr eux appelées résidus d'extraction. Les grands volumes abondants et les taux de décantation extrêmement bas des résidus d'ext raction entraînent une préoccupation de gestion unique pour les industries minières. L'objectif de la recherche présentée dans cet article est d'utiliser le gel-dégel (conditions météorologiques canadiennes) comme outil de formation de croûtes afin d'augmenter la résistance de surface des résidus pour soutenir le recouvrement et la réhabilitation. Cet article compare également différentes appro ches de gestion des résidus d'extraction (sables bitumineux, charbon, or) à l'aide de l'altération saisonnière (multiples cycles d e gel-dégel et évaporation) afin de comprendre les effets de l'altération saisonnière sur le développement de la croûte de surfa ce. Les résultats ont conclu que la prédiction du comportement de changement de volume des dépôts de résidus d'extraction e xposés à l'altération saisonnière de surface est assez difficile au Canada par rapport à la zone climatique australienne aride/se mi-aride. Cependant, les résultats du laboratoire suggèrent également que les intempéries saisonnières par temps au Canada pe uvent faciliter la croûte de surface des dépôts de résidus de sables bitumineux avec une résistance au cisaillement associée de plus de 110 kPa, à condition qu'une gestion active de l'eau soit assurée.

KEYWORDS: freeze-thaw, oil sands tailings, evaporation, strength, reclamation.

1 INTRODUCTION.

The volume change and shear strength behavior of tailings slurries are a function of gravimetric moisture content. Lowering moisture content or dewatering the tailings deposits is paramount to improve the strength and stability of any deposit. Finding ways to densify the deposit and improve the strength performance are imperative for stabilization, capping and reclamation of soft tailings deposits. The surficial mine waste deposits in arid or semi-arid regions around the globe are naturally subjected to surface crusting and desiccation and in turn support the placement of capping layer. On the contrary, soft tailings deposits in Canada, particularly in Western Canada are subjected to freezing weather conditions where the benefits of surface crusting due to evaporation are limited. Hence, finding cost effective, practical methods to manage the ever growing soft tailings accumulation and promote reclamation through the development of shear strength have long been a challenge for the mining industry, particularly for the oil sands industry.

The Athabasca oil sand deposits in northern Alberta, Canada, are considered to be the third largest proven reserve in the world that contain approximately 177 billion barrels of economically recoverable crude oil (AER, 2016). The current water based bitumen (crude oil) extraction process from the oil sands ore body generates about 1 m^3 of sand and 0.25 m^3 of a fluid waste byproduct, known as fluid fine tailings (FFT), per every barrel of recovered bitumen (Beier et al., 2016). The FFT, consisting of process affected water, sand, fines (particle size of less than 44 μm) and residual bitumen are typically stored in tailings impoundments/ponds because of the inability to release water out of these high water content tailings on-site (OSTC and COSIA, 2012; Sorta et al., 2013). At current and predicted bitumen production rates, the inventory of the tailings ponds is expected to grow over the next decade as the total fluid tailings volumes increased from 1075 million cubic meters (Mm^3) in 2014 to 1270 Mm^3 in 2019 (AER, 2020).The FFT deposited in the tailings ponds is considered non-trafficable with minimal shear strength (Sorta et al., 2012) that takes many decades to settle out due to extremely slow settling and consolidation rate. Hence, it is paramount to sufficiently dewater these FFT to gain shear strength and allow reclamation to occur (McKenna et al., 2016).

In order to address these issues, progress has been made to gradually shift from conventional tailings disposal to treated tailings discharge where different mechanical, physical and chemical methods have been implemented prior to disposal in order to improve the mechanical properties of the tailings (OSTC and COSIA, 2012). However, the treated tailings may not have the strength required to promote trafficable surfaces and hence, these tailings deposits are left to gain strength under self-weight consolidation and natural dewatering processes (OSTC and COSIA, 2012). Natural dewatering processes such as freeze-thaw, evaporation and desiccation have the potential to act as an additional dewatering step for tailings deposits where, freeze-thaw process promotes dewatering through the changes in macro and micro structure of the tailings fabric while evaporation promotes surface drying and cracking leading to surface desiccation (Proskin et al., 2012; Pham and Sego, 2014).

Since most of Canada experiences seasonal temperature variations leading to alternate freezing and thawing cycles, this paper will primarily evaluate the effectiveness of freeze-thaw dewatering as a crusting tool in tailings deposit surface. This paper will also compare different mine tailings and management approaches where seasonal weathering has been employed to develop surface crust.

2 EFFECTS OF SEASONAL WEATHERING ON DIFFERENT TAILINGS MANAGEMENT STRATEGIES

2.1 *Oil sands tailings*

The extensive research (Johnson et al., 1993; Proskin, 1998; and Proskin et al., 2012) conducted at both laboratory and pilot scales showed that the FFT subjected to multiple freeze thaw cycles promotes dewatering. However, the studies were predominantly limited to untreated FFT. The clay dominant fine particles in the ore are typically dispersed as a result of water based extraction process (Jeeravipoolvarn et al., 2005), thereby, contributing to the large volumes of FFT. The matrix of these high water content-fine particle suspensions can be altered by freezing the slurry. Within the frozen zone, localized moisture migration develops a three dimensional reticulate network of consolidated mineral peds and ice lenses (Proskin et al., 2012). Upon thawing, the consolidated peds formed during the freezing process and pure water from the thawed ice matrix develop a segregated profile where the peds settle and pure water reports to the surface (Proskin et al., 2012).

Since the freeze-thaw process is controlled by moisture migration/re-distribution, treated tailings (centrifuge cake, in-line thickened tailings and flocculated tailings) may be less impacted by the benefits of freeze-thaw process compared to FFT because of their lower initial moisture content (Johnson et al., 1993). Therefore, incorporation of atmospheric drying and active water management by means of mechanical channeling or decant structures may be required for subsequent dewatering (Beier et al., 2013). Certain tailings management strategies have incorporated evaporation in their commercial operation/ commercial scale demonstration in Canada, such as Suncor's tailings reduction operation (TRO) (Wells et al., 2011) and Shell's (known as Canadian Natural Albian Sands at present) atmospheric fines drying (AFD) (Dunmola et al., 2013) to promote subsequent additional dewatering from in-line thickened tailings (ILTT). The TRO process achieved dry landscape by employing thin lift drying (AER, 2018). Similarly, the AFD process employing three different tailings depositional approaches (thin lift deposit, thick lifts deposits and deep fines-dominated deposits) and exposed to environmental dewatering (freeze-thaw dewatering and evaporative drying) for two years achieved a strength gain of 5-25 kPa within the entire deposit, where evaporative drying and freeze-thaw dewatering contributed to a 22-23.5% and 4.5-8% gravimetric moisture content reduction (mass of water to the mass of solids in a given mass of soil/tailings) from its the initial treated FFT, respectively (Kolstad et al., 2016). Syncrude's large scale pilot test incorporating accelerated dewatering/ rim ditching with in-line flocculated FFT (known as ADW) is currently underway to investigate the effects of atmospheric drying (evaporation and freeze-thaw dewatering) and surface dewatering system (perimeter ditching/ lateral drain) (BGC and OKC, 2014). Overall, atmospheric drying through evaporation and freeze-thaw dewatering is currently considered an important component for the present and future oil sands fine tailings management, despite seasonal temperature fluctuations (BGC, 2010).

2.2 *Coal tailings*

Research (Beier and Sego, 2009; Stahl and Sego, 1995) carried out at the Coal Valley mine in Canada to investigate the effect of freeze-thaw dewatering on coal tailings indicates that this process has the potential to transform fine coal tails to a state of weak soil with a measurable shear strength. Freezing and subsequent thawing of the frozen tailings continued for four to five cycles in the laboratory resulted in 5 to 9 times increase in surficial shear strength compared to the never frozen tailings (Stahl and Sego, 1995), provided adequate drainage is incorporated. When coupled with evaporation, evapotranspiration and fibre reinforcement from plants, the seasonal weathering has a potential to overall provide sufficient stability to implement dry landscape reclamation (Stahl and Sego, 1995).

Stability assessments of other coal tailings deposits at New Acland Coal Mine and Ulan Coal Mine in Australia confirmed the formation of about 1 m of surface crust prior to the commencement of capping (Williams and King, 2016). The desiccation and surface crusting of these deposits are attributed to the contribution of solar and wind drying associated with the warm climate of Australia (Williams and King, 2016), although the number of years (it was mentioned as "some years") exposed to the seasonal weathering was not reported. The authors mentioned that the upper part of the tailings surface was well desiccated and the shear strength in the surface ranges from 15 kPa to 40 kPa ahead of capping.

2.3 *Thickened gold tailings*

Extensive laboratory research, field trials and numerical predictions (Simms et al., 2017; Fisseha et al., 2010; Dunmola and Simms, 2010) were implemented to study the effects of evaporation from the thickened gold tailings at the Bulyanhulu gold mine in Tanzania. Gold tailings are predominantly sand and silt sized (Bussiere, 2007) and thus the particle sizes are relatively coarser compared to the coal and oil sands fine tailings. Promoting evaporation from the tailings for 15-20 days was found to improve densification and strength gain by reducing the gravimetric moisture content from 38% to 5-13% (Simms et al., 2017; Dunmola and Simms, 2010). Therefore, maximizing strength gain due to evaporation is of less concern for these tailings deposits. However, excess evaporation from these acid generating hypersaline thickened tailings deposit can have an adverse effect since desaturation can consequently increase the probability of acid generation along with densification (Simms et al., 2017). In addition to this, the accumulation of salts was found to suppress the evaporation and lower the shear strength gain (Dunmola and Simms, 2010). Therefore, predicting evaporation rate is considered one of the major parameters for the engineers to optimize deposition planning (Simms et al., 2017; Dunmola and Simms, 2010).

2.4 *Metal mine tailings*

Evaporation/atmospheric drying greatly contributed to the desiccation of the Cannington Metal Mine (silver, lead and zinc) tailings located in Queensland, Australia, thus confirming that evaporation is a useful process for mining operation in order to dewater their tailings. The semi –arid climate zone results in a heavily desiccated tailings surface by exposing to atmosphere for four consecutive years (Williams et al., 2015). Similar to the gold tailings, the sandy silt to silty sand sized particles of this site also contributes to the desiccated surface crust and stability (Williams, 2016).

3 MATERIALS AND METHODS

The current study presented in this paper utilized two types of treated oil sands tailings: a). centrifuged tailings (initial moisture content = 89%) generated from centrifuge after treating FFT with polymer flocculant and coagulant and b). ILTT (initial moisture content = 122%) generated from injecting polymer flocculants into the FFT containing transfer pipeline, which was deposited into the containment area for subsequent further self-weight dewatering.

The laboratory research in this study was conducted in two phases. First phase included subjecting the treated tailings to five consecutive freeze-thaw cycles followed by a single drying-wetting cycle. Second phase included five alternating freeze-thaw and drying-wetting cycles, where each freeze-thaw cycle was followed by ambient drying cycle prior to and after a rainfall event. For the freeze-thaw testing, one dimensional closed system freezing tests were carried out in freezing cells inside a walk-in freezer whereas, evaporation tests were undertaken under the ambient temperature (~20°C) of the laboratory. The undrained shear strength was measured using a benchtop vane shear apparatus according to the ASTM (2016) standard D4648/S 4648M-16. A vane (width and height of 12.5 x 12.5 mm) was inserted into the sample to their full length such that the top of the vane was level with the sample surface. The vane was rotated at a uniform rate of 60°/minute until the sample failed and the torsional force required to cause shearing was calculated using the calibration data provided with the vane device. The detailed procedure was documented in Rima and Beier (2018a and 2018b).

4 RESULTS

Table 1 summarizes the index properties of different tailings deposits around the world. It shows different tailings deposits having different ranges of particle sizes and consistency limits that are expected to affect the dewatering and strength properties of these tailings. As shown in the Table, oil sands tailings are the finest grained materials with higher consistency limits followed by the coal tailings from the Coal valley mine, Canada. Coal tailings from the New Acland mine and the base metal mine tailings are relatively coarser grained materials (either silt or silty sand) with the lower consistency limits that indicate lower compressibility and lower water adsorption.

Figure 1 shows the effects of freeze-thaw cycles on the undrained shear strength at the near surface of coal tailings (initial moisture content ranges from 83 to 102%, as reported in Beier and Sego (2009)) and treated FFT (initial moisture content ranges from 89 to 122%). The peak undrained shear strength after four/five cycles increased from a negligible value to about 5 to 10.5 kPa at the surface.

Figure 2 depicts how evaporation can dominate over freeze-thaw dewatering process in treated oil sands tailings samples over time. The investigated treated tailings samples (centrifuged tailings and ILTT) subjected to different temperature gradients were only compared here since the identical tailings samples with and without evaporation component were unavailable in the previous published literature.

Table 1. Summary of key properties of tailings

Type	Name	*LL*[1]	*PL*[2]	*Clay fraction*[3] *(%)*	*Fines fraction*[4] *(%)*
Oil sands tailings	Shell AFD	NA[5]	NA[5]	21-22	90-100
	Syncrude centrifuge	57	26	52	92
	Syncrude ADW	62	23	70	96
Coal tailings	Coal Valley mine	54	31.5	45	98
	New Acland mine	41	17	0	12
Gold tailings	Bulyanhulu mine	23	20	5	45
Metal mine tailings	Cannington mine	14-16	Non-plastic	3-7	40-70

[1]LL = Liquid limit
[2]PL = Plastic limit
[3]Clay fraction = Particle sizes finer than 0.002 mm
[4]Fines fraction = Particle sizes finer than 0.075 mm
[5]NA = Not available

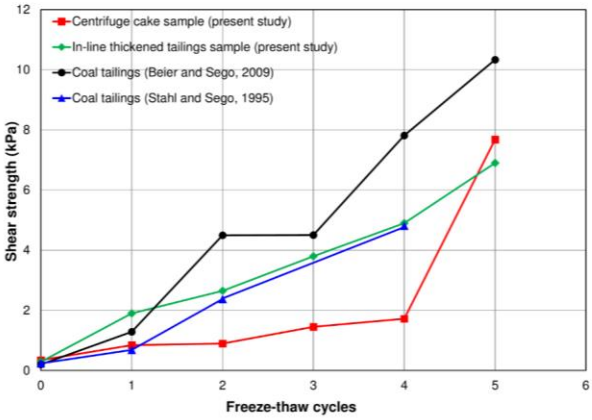

Figure 1. Effects of freeze-thaw cycles on the undrained shear strength of fine coal and oil sands tailings

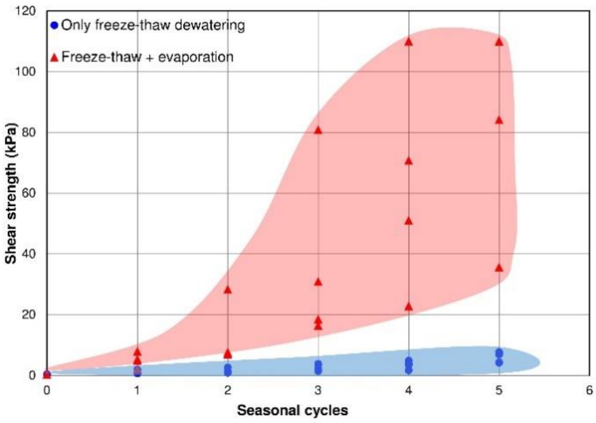

Figure 2. The effects of evaporation/drying on treated oil sands tailings

The result shows that the evaporation had profound impact on oil sands tailings sample. The volume changes subsequent to only freezing and thawing is minimal and hence, the shear strength ranges from 5-8 kPa at the surface (denoted by blue boundary). Conversely, the combined freeze-thaw-drying cycles result in high volume changes and subsequent shear strengths of 35-110 kPa. The treated FFT sample that experienced the shear strength of >100 kPa developed a surface crust of about 2 cm. However, the underlying tailings below the surface crust was very soft and weak, although the shear strength below was not measured in the laboratory.

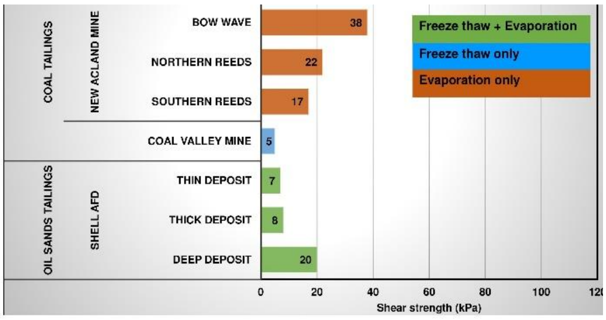

Figure 3. The effects of natural weathering on the surficial strength of different tailings deposits around the world

Table 2. Sources of index properties and shear strength data

Data	*Source*
Cannington metal mine, Australia	Williams et al., 2015
Bulyanhulu gold mine, Tanzania	Simms et al., 2017; Dunmola and Simms, 2010
Ulan coal mine, Australia	Williams and King, 2016
New Acland coal mine, Australia	Shokouhi et al., 2014; Williams and King, 2016
Coal Valley mine, Canada	Stahl and Sego, 1995; Beier and Sego, 2009
Shell AFD, Canada	Kolstad et al., 2016
Syncrude centrifuge, Canada	Rima and Beier, 2018a
Syncrude ADW, Canada	Present study

Figure 3 shows the contribution of seasonal weathering in strength gain of different tailings deposits at the surface around the world. The strengths of gold tailings at the Bulyanhulu mine and metal mine tailings (silver, lead and zinc) at Cannington Metal Mine were reported here as 100 kPa since these were reported as stiff and well-desiccated surface prior to capping (Simms et al., 2017; Williams et al. 2015). Simms et al (2017) reported that the thickened gold tailings surface subjected to 15/20 days of exposure of atmospheric drying resulted in moisture content from 38 (corresponding to a solids content of 72%) to 5-13% (corresponding to solids content of 88 to 95%). At such a high solids content, it is expected to achieve a well-desiccated surface and hence, the peak strength was reported here corresponding to a strength of 100 kPa. Similarly, Williams et al. (2015) reported that the vane shear strength data in the upper 4 m of Cannington mine site were unavailable due to the difficulties in testing a stiff desiccated crust. Nevertheless, the tailings samples in the present study were not compared in this data chart. Only the field deposit strengths were shown here to have a better understanding of the impact of climate. The data sources are summarized in Table 2.

4 DISCUSSION

Table 1 shows the index properties of all the different types of tailings discussed in this paper. Among all these tailings, oil sands tailings primarily consist of clay minerals that are highly negatively charged particles and highly affected by the changes in grain size distribution, clay content, solids mineralogy, and pore water chemistry (Mitchell and Soga, 2005). On the contrary, coal, gold and base metal tailings have either sand or silt as their predominant minerals (Williams et al., 2015; Bussiere, 2007). All these variables can substantially impact the shear strength of tailings (Mitchell and Soga, 2005).

Figure 1 shows the effects of freeze-thaw cycles on the surficial shear strength of three types of fine tailings: coal tailings and two types of oil sands tailings. The two types of treated oil sands tailings compared here were: centrifuge cake and in-line thickened tailings. The clay fractions of these tailings (coal, centrifuge cake and ILTT) were measured to be 45 (Beier and Sego, 2009), 52 and 70% by weight, respectively, which indicates that these tailings are fine grained. All these fine grained tailings subjected to below freezing temperatures develop high negative pore pressures/ suction that cause water migration towards the freezing front, feeding a growing ice lens (Andersland and Ladanyi, 2004). The warmer temperatures during the spring and summer result in thawing these frozen tailings and unlocking the benefits of thawed ice matrix developed during freezing by facilitating the settlement of heavier soil peds and release of thawed water and overall dewatering and strength gain (Stahl and Sego, 1995).

However, the magnitudes of dewatering (measured as "thaw strain' that refers to change in height after thaw divided by the frozen height of sample) and shear strength are predominantly governed by initial moisture/ solids contents (Johnson et al., 1993), mineral compositions, grain size distribution (Stahl and Sego, 1995), pore water chemistry (Proskin et al., 2012), freezing rate (Proskin, 1998), and temperature boundary conditions (Proskin, 1998). Since oil sands particles are highly negatively charged clay particles and net negative charges are the primary factor in controlling clay dispersion, the prevalence of clay fractions compared to the coal fine tailings (predominantly silty sized fractions, as reported by Beier and Sego (2009)) can have some impact on lower strength gain as evident in the Figure 1.

Figure 2 shows the effects of evaporation/ atmospheric drying on the investigated treated oil sands tailings samples. Centrifuge cake samples subjected to three different temperature gradients (0.083, 0.056 and 0.028°C/mm) and ILTT sample subjected to a temperature gradient of 0.028°C/mm were studied for this purpose. All these samples were exposed to similar atmospheric drying conditions under ambient temperature of the laboratory (~20°C). As expected, incorporating evaporation greatly enhanced the shear strength (about 10 times compared to the freeze-thaw dewatering alone).

Evaporation is desirable in mining operation as it promotes surface cracking and desiccation through the exposure of underlying tailings with lower suction (Johnson et al., 1993). The extent of cracking is predominantly dependent on the initial moisture contents, mineralogy, pore water chemistry and physical boundary conditions (Vogel et al., 2005). Therefore, it is anticipated that the two investigated treated tailings having differences in moisture content, mineralogy and pore water chemistry will respond differently to evaporation/ atmospheric drying. The centrifuge cake resulted in a surficial strength of >100 kPa and developed a surface crust while the ILTT sample under similar freezing temperature gradient and similar atmospheric conditions resulted in a surficial strength of 84 kPa with no distinguishable crust. Although, the strength values of both of these samples suggest a consistency of stiff soil, the formation of a surface crack has a larger impact on tailings reclamation process. On the contrary, identical samples (centrifuge cake in this case) under similar atmospheric drying conditions would be expected to behave similarly for gaining shear strength and developing surface crust. However, the interesting fact is the identical tailings samples can respond discordantly to the atmospheric drying if the boundary conditions in the previous freeze-thaw cycles are kept different. In the present study, centrifuge cake subjected to three different freezing temperature gradient while freezing and prior to atmospheric drying, resulted in distinctive strength values. Samples subjected to lower temperature gradient (0.028°C/mm) resulted in a formation of a surface crust while higher gradient (0.083°C/mm) sample behaved like a slurry. The detailed results are documented in Rima and Beier (2018b). Therefore, it can be implied that although the effects of freeze-thaw on strength gain can seem marginal, this process can help accelerate the strength gain during evaporation process. The cracks developed during previous drying cycles or the shrinkage developed during previous freeze-thaw cycles contribute to the easier penetration of advancing ice front during the subsequent freezing period (Sanchez Sardon, 2013). As a result, more water is expected to be drawn from the underlying tailings causing relatively higher dewatering and strengthening.

Figure 3 shows the chart of undrained peak shear strength of various mine tailings deposits prior to capping. Evaporation depends on various local climatic and environmental factors such as solar radiation, wind speed, air temperature, ground temperature and relative humidity (Lahaie et al., 2010). Oil sands tailings deposits are typically discharged at water contents (water contents range between 90-130% for the investigated tailings) well above the liquid limits (liquidity index of 2~3). Coal tailings from the Coal Valley mine are also categorized as fine grained tailings deposited at a liquidity index of 2.3 to 3 (moisture content varies between 83~102%, as reported in Beier and Sego (2009)). Both of these tailings create non-trafficable deposits and hence, evaporation can contribute to an enhanced dewatering. On the contrary, the metal mine and gold tailings were deposited into the impoundments at lower initial moisture contents of 54% (liquidity index=3.6) and 40% (liquidity index=7) at the Cannington metal mine and Bulyanhulu gold mine, respectively (Simms et al., 2017; Williams et al., 2015). However, both of these tailings contain smaller amounts of clay/ no clay (as shown in Table 1) thus impacting liquidity index. Therefore, gaining strength and forming surface crusts in these tailings due to atmospheric drying are relatively less challenging compared to the fine tailings deposits. The semi-arid climate in Australia and Tanzania further facilitates desiccation and cracking for these tailings. However, an optimal rate of drying is paramount in order to ensure that contamination from mine effluent does not adversely affect the environment such as acid generation (Fisseha et al., 2010). Therefore, the thickness of the deposited layer and deposition approach are important for the tailings management.

On the contrary, fine grained tailings such as coal and oil sands tailings (as shown in Figure 3) will lack strength adequacy without capping/ soil cover. Even in a semi-arid zone like Australia, the strength gain due to atmospheric drying was not adequate enough to allow for a trafficable deposit without capping. The New Acland and Ulan coal mines in Australia experienced surface desiccation but the depth and shear strength of the surface crust were limited because of the marginal effects of solar and wind drying below 1 m depth and some reversal in shear strength due to subsequent deposition of fresh tailings on the desiccated crust (Williams and King, 2016). In Canada, relying on evaporation for fine tailings management is even more challenging due to the colder climate and shorter duration of summer. As evident in Figure 2, the combination of freeze-thaw-drying cycles was employed as a dewatering tool and it showed promising results, provided adequate water management (lateral drain, decant structure etc.) is ensured.

5 CONCLUSIONS

This paper provides an overall study of different mine tailings across the world and how seasonal weathering are employed to support the reclamation outcomes for mine closure. Each of the deposits are different due to the differences in geological origin, weather and site conditions and hence, site specific adaptive management need to be established to limit the accumulation and containment of tailings. The small scale laboratory test results of the investigated treated oil sands tailings indicate that freeze-thaw dewatering coupled with evaporation and active water management has a potential to have a substantial impact on developing surface crust (shear strength of >100 kPa). When compared to different tailings (coal, gold, metal), oil sands tailings management proved to be the most challenging due to their extreme slow consolidation rate and the lower hydraulic conductivity of these fine grained tailings deposit. Apart from climatic factors, subsequent dewatering and transforming the state of the slurry from a viscous liquid to a plastic solid, and then to a brittle solid are highly sensitive to mineralogy. When comparing shear strengths and dewatering as a function of mineralogy under the similar atmospheric conditions, the finer tailings deposits (coal tailings as compared to gold tailings in Australia) recorded lower strength gain due to the atmospheric drying. As expected, similar tailings deposits (coal tailings in Australia vs Canada) that enjoy the benefits of higher evaporation, will experience higher dewatering and shear strength. Based on the laboratory study, the oil sands tailings samples even from the same tailings deposit responded very differently to atmospheric drying when subjected to different frozen temperature gradients. Overall, the results indicate site specific conditions should be a key consideration for the tailings management/ planning team.

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