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Operational considerations regarding the impact of variations in muscovite content in mine tailings on the flowability of cemented paste backfill

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Abstract

The detrimental effect of muscovite on the mechanical and rheological properties of cementitious materials is likely to be observed in cemented paste backfills (CPBs) made from muscovite-rich tailings. Once a CPB mix design is formulated with tailings containing a specific muscovite content, variations in muscovite content may present operational and performance challenges. This study assesses the impact of increasing muscovite content on the consistency (slump) and rheological properties (yield stress, flow index and viscosity at high shear rates) of CPBs prepared with varying solids contents by weight. Pure muscovite was added to tailings initially containing 15% muscovite by dry mass of tailings up to the maximum expected muscovite content (25%) at the mine site where the tailings were sampled. CPB mixtures were prepared in the laboratory with solids contents ranging from 68 to 72%, using tap water and 5% high early (HE) strength cement. The CPB mixtures underwent standard Abrams cone slump tests and triplicate rheological analyses.

For a given solids content of the CPBs, the results indicate that an increase in muscovite content reduces the slump while increasing the rheological properties mentioned earlier. This necessitates the addition of water to maintain a specific slump, which lowers the solids content and increases the water-to-binder (W/B) ratio, potentially compromising the mechanical strength. Results are discussed in evaluating the impact of the muscovite content on the pressure loss during CPB transportation in pipelines and in proposing a method for estimating both the amount of water required to maintain the target slump and the amount of binder required to maintain the initial W/B in the CPB.

Keywords: *cemented paste backfills, muscovite-rich tailings, slump, rheological properties*

1 Introduction

Mine backfilling is a standard practice in the comprehensive mine waste management strategies of many leading underground mining companies. This technique is essential for advancing the mining process, improving operational efficiency and reducing the environmental impact of surface mine waste. Consequently, mine backfilling has become a vital part of mining operations. Cemented paste backfill (CPB) provides features beyond the environmental benefits, including structural support to ensure mechanical stability and enhancing ore recovery rates, especially in cut-and-fill and longhole sublevel stoping methods (Mitchell 1989a, 1989b; Belem & Benzaazoua 2008).

CPB is prepared by mixing three primary components (tailings, binder and water) in specific proportions (Landriault 1995; Belem et al. 2003; Benzaazoua et al. 2004). The choice and ratio of each component influence both the transportability and strength development of CPB (Hassani & Archibald 1998; Belem et al. 2000; Benzaazoua et al. 2002).

Since binder is the most expensive component, its type and proportion (B_w, defined as the binder mass relative to dry tailings mass and generally ranging from 3 to 10%), must be carefully selected to meet specific

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strength requirements (Brackebusch 1995; Benzaazoua et al. 2003; Tarik & Yanful 2013). The mixing water, which can be fresh, lake or recycled process water, is adjusted to achieve a consistency that allows safe transport by gravity or combined pumping and gravity (Thomas et al. 1979). A CPB slump of 15 to 25 cm, as measured by the standard Abrams cone, is targeted for effective transport and backfilling (Landriault et al. 1997; Belem & Benzaazoua 2008). The Abrams cone slump test (ASTM International 2015) (ASTM C143) is a method of assessing the consistency or workability of cementitious materials, typically employed in the context of concrete and mortar. It involves the measurement of the vertical settlement (slump) of fresh material after the removal of a standard mould, thereby indicating its flowability. The water-to-binder (*W/B*) ratio of CPBs can vary based on the physical (e.g. particle size, density of solid grains, specific surface area), mineralogical and chemical properties of the tailings, which may fluctuate during mine operations, but typically ranges between 2.5 and 7 (Tariq & Yanful 2013).

So far, limited research has focused on the effect of tailings mineralogy on CPB's rheology, consistency and mechanical strength. In concrete and mortar studies, free muscovite, especially those from the mica group, are known to have a detrimental impact on rheological properties (Chi et al. 2024), consistency (Muller 1971; Danielsen & Rueslåtten 1984) and unconfined compressive strength (Mshali & Visser 2014; Khoshkbijari et al. 2020). Therefore, it is plausible that the presence of free phyllosilicates, particularly free muscovite, which is common in mines located in Quebec (Canada) (Benzaazoua et al. 2008; Ethier et al. 2018; Ouffa 2019; Amri et al. 2023), could also adversely impact CPB's rheological properties and strength. Poor rheological properties can increase energy demand for pumping and may even cause pipeline blockages. Menasria et al. (2025) evaluated muscovite's detrimental effect for CPBs prepared with a binder consisting of a mixture of 20% general use/Type I Portland cement and 80% ground granulated blast furnace slag of the total binder mass. This blended binder is commonly used for CPB preparation in backfilling operations at many mines in the Abitibi region (Quebec).

The purpose of this paper is to examine how the presence of free muscovite affects two key CPB properties – consistency and rheological behaviour – that are crucial for effective pipeline transport in CPBs prepared with high early (HE) strength Portland cement.

2 Materials and testing methods

This section presents the CPB ingredients, preparation and testing program.

2.1 Cemented paste backfill ingredients

Filtrated tailings were obtained from the CPB facility of a hard rock gold mine situated in the Abitibi region of Quebec, Canada. The muscovite incorporated into these tailings was prepared from a sampled pegmatite outcrop within the same region. The sampled muscovite underwent an extensive preparation process to ensure its purity. This process involved washing and sorting of raw muscovite sheets, followed by drying and separation from other mineral components (see Figure 1). Subsequently, the muscovite sheets were subjected to multiple stages of pulverisation to produce a fine powder.

Figure 1 Separated sheets of muscovite ready to be pulverised into finely ground powder

A physical and mineralogical characterisation was conducted on both the pulverised muscovite and the tailings. The physical characterisation involved determining the grain-size distribution (GSD) curve, specific gravity (G_s) and specific surface area (S_s). The GSD analysis was carried out using a Malvern® Mastersizer laser particle size analyser. Figure 2 presents the resulting GSD curves for the tailings and the pulverised muscovite. To avoid altering the GSD curve of the tailings upon muscovite addition, significant efforts were made to ensure that the muscovite powder's GSD curve closely matched that of the tailings. In reality, muscovite is predominantly concentrated in the finer particle fractions. The primary objective of this GSD adjustment is to replicate the particle size distribution of the tailings, allowing the effect of muscovite to be assessed independently of GSD influences. Given the complexity of this process, we ultimately focused on achieving similar fractions of particles finer than 20 µm ($P_{20\mu m}$) for both materials, given that the rheology is primarily influenced by fine particles. It is, however, important to note that, as shown in Figure 2, matching the $P_{20\mu m}$ values does not necessarily gives identical GSD curves. Figure 2 also illustrates the GSD curve for a tailings-muscovite mixture containing 25% muscovite. This GSD curve was calculated analytically based on the GSD curves of the individual tailings and muscovite components using Equation 1 (Menasria et al. 2025).

$$P_{mix-d} = P_{T-d}(1-\alpha) + P_{M-d} \times \alpha \quad (1)$$

where:

P_{mix-d} = the particle fraction finer than diameter *d* in the muscovite-tailings mixture

P_{T-d} = the particle fraction finer than diameter *d* in the tailings

P_{M-d} = the particle fraction finer than diameter *d* in the muscovite

α = the ratio of the mass of muscovite incorporated into the tailings to the mass of dry tailings.

The ratio α in Equation 1 can be obtained with the Equation 2 (Menasria et al. 2025):

$$\alpha = \frac{\Delta M_{mu}}{M_{t-s}} = \frac{(X_f - X_i)}{1 - X_f} \quad (2)$$

where:

ΔM_{mu} = the amount of muscovite to be added to a mass of dry tailings M_{t-s} to achieve a given muscovite content X in the muscovite-tailing mixture

X_f , X_i = the target total muscovite content in the tailings-muscovite mixture and the initial muscovite percentage in the tailings (with $X_i < X_f$), respectively.

For X_i = 0.15 and X_f = 0.25, α = 0.133.

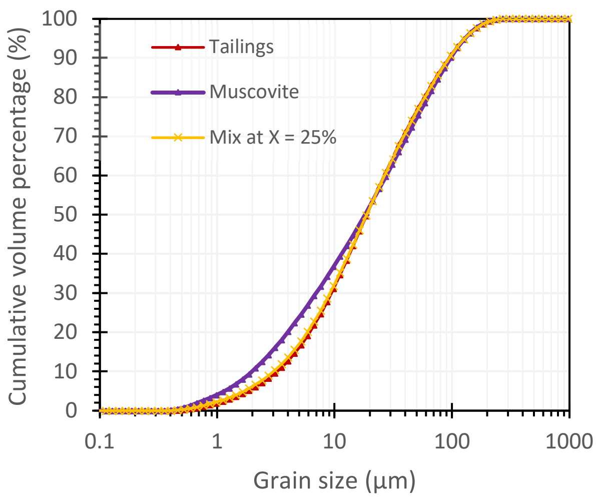

Figure 2 Grain-size distribution curves of the tailings, muscovite and tailings-muscovite mixture with 25% muscovite content

The resulting GSD curve of the mixture with the maximum expected muscovite content closely approximates that of the tailings alone. Table 1 presents the physical properties of the tailings and pulverised muscovite, including the diameters D_x (representing the diameter at which x% of the material passes on the cumulative GSD curve), the coefficient of uniformity (C_U), the coefficient of curvature (C_C), and the proportions of particles finer than 20 µm and 80 µm ($P_{20µm}$ and $P_{80µm}$, respectively).

The G_s of both the tailings and muscovite were measured using the helium pycnometer ULTRAPYC 1200e, while the S_s was determined using the Brunauer, Emmett and Teller (BET) method, with sample preparation carried out using the Micromeritics VacPrep 061 Sample Degas System. These results are also included in Table 1. It is worth noting that the G_s of muscovite typically ranges from 2.76 to 3.00 (Jahns & Lancaster 1950), and the value obtained in this study (G_s = 2.85) falls within this expected range.

The mineralogical compositions of both the tailings and the pulverised muscovite were determined using X-ray diffraction. As shown in Table 2, the results indicate that the tailings initially contain approximately 15% muscovite. Additionally, the analysis confirms that the pulverised muscovite consists solely of muscovite, without the presence of any other minerals. Given the fine-grained nature of the tailings, it is assumed that the muscovite within them exists as free muscovite.

Table 1 Physical characteristics of the tailings and pulverised muscovite

Parameters	Tailings	Muscovite
D_{60} (µm)	26.6	27.7
D_{50} (µm)	18.9	18.2
D_{30} (µm)	9.4	7.0
D_{10} (µm)	3.3	2.0
C_U (-)	8.2	13.9
C_C (-)	1.0	0.9
P_{20} (%)	51.7	52.3
P_{80} (%)	87	85
G_s (-)	3.0	2.85
S_s (m^2/g)	2.8	22.6

Table 2 Mineralogical composition (%) of the tailings and muscovite

Mineral	Tailings	Muscovite
Quartz	51.5	–
Albite	0.0	–
Muscovite	15.1	100
Augite	10.4	–
Clinochlore	6.2	–
Pyrite	12.6	–
Calcite	1.3	–
Gypsum	1.9	–

The binder utilised in this study is an HE strength Portland cement; a type predominantly used in mines situated in permafrost regions. Its primary advantage is generating an early heat release, which initiates the hydration process even under cold conditions. For all CPB mixtures, a binder ratio B_w of 5% was employed.

2.2 Cemented paste backfill mix preparation

The CPB mixtures were prepared using an OMCAN paste mixer, with the tailings load set at 4 kg. For the raw tailings containing 15% muscovite, control CPB mixtures were prepared with varying target solids contents (C_w) between 67 and 72%. For CPB mixtures where pure muscovite was added to the tailings to achieve muscovite contents of 17, 19, 21, 23 and 25%, CPB mixtures with solids contents of 68, 70 and 72% were studied due to a limited quantity of available muscovite. In total, 19 CPB mixtures were prepared. These variations in C_w aimed to produce a wide range of CPB slump values.

Considering the documented influence of specific mixing energy on the consistency and rheological behaviour of CPB (Dikonda et al. 2021a, b), it is imperative to provide the detailed mixing procedure employed for all CPB mixtures as shown in Figure 3. The binder was initially combined with half of the requisite water, after which the initial portion of tailings was added within 10 seconds. Subsequently, the mixture was stirred at 91 rpm for one minute. Following a brief 10-second interval during which the remaining tailings and water were added, the mixing process was continued at 91 rpm for a further three minutes. Subsequently, the mixing speed was increased to 116 rpm for 30 seconds, followed by a final high-speed phase at 282 rpm for two minutes. A pause was required between each speed change, which resulted in brief interruptions to the mixing process. In the case of CPB mixtures containing added muscovite, the appropriate quantity of muscovite powder was incorporated at the outset of the mixing process, along with the binder and water.

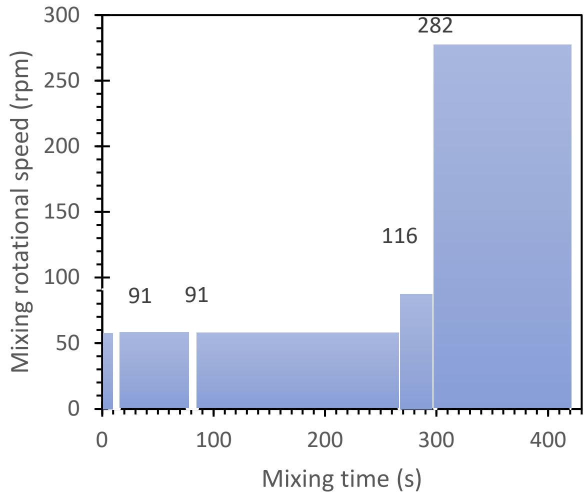

Figure 3 Mixing process

2.3 Slump and rheology testings

Once the mixing process was completed, the water content of a CPB subsample was measured to determine the measured solids content (C_w). A second sample was then used to determine the CPB density through the utilisation of a Baroid mud balance. This density is needed for determining the mass of the sample required for the rheological test, as indicated below. The remaining paste was subjected to a slump test in accordance with ASTM C143 (ASTM International 2015), utilising the standard Abrams cone, and subsequently underwent rheological analyses.

Rheological analyses of CPB mixtures were conducted utilising the AR2000 rheometer (TA Instruments, USA). Following calibration of the instrument, a flow mode procedure was devised and programmed in accordance with a defined sequence of steps. The experiments were conducted at a constant temperature of 20°C, which was maintained by a Peltier water-cooled temperature control system. Each CPB sample, with a volume of 28.72 cm^3, was placed in a 30 mm-diameter stator cylinder and subjected to shear using a four-blade vane geometry. Shearing was performed in two steps of 150 seconds each, covering shear rates ($\dot{\gamma}$) of 1 to 100 s^{-1} during the upward ramp and then 100 to 1 s^{-1} during the downward ramp. The vane geometry had a height of 42 mm and a diameter of 28 mm, resulting in a lateral gap of 1 mm between the vane and the cylinder wall. The distance between the base of the apparatus and the surface of the cylinder was set to 4 mm. Twenty pairs of values (shear rate $\dot{\gamma}$ and shear stress τ) were recorded at 7.5-second intervals to obtain both the rheogram $\tau(\dot{\gamma})$ and the dynamic viscosity curve $\eta(\dot{\gamma})$ simultaneously. The shear rate is determined by the rheometer software, which employs equations established by previous studies (Barnes & Carnali 1990; Nguyen & Boger 1985). The procedures were repeated on three samples. To ascertain the CPB's rheological properties, the flow and viscosity curves were subjected to fluid model fitting according to the procedures set forth in section 3.2. This research primarily focuses on the analysis of downflow curves. The phenomena such as thixotropy, dilatancy, and rheomalaxis were not explored in this paper.

3 Results

3.1 Effect of solids and muscovite contents on the slump

Figure 4 shows the results of slump tests on CPB mixtures with varying muscovite and solids contents. Observing Figure 4a, a clear negative linear correlation is noted between slump and solids content for a given muscovite content, for the actual range of solids content. Specifically, as CPB solids content increases, slump values decrease. Figure 4b reveals a further reduction in slump values with increasing muscovite content in CPB mixtures for a fixed solids content C_w. CPB mixes containing 15% muscovite gave slump values of 29.9 cm and 16.4 cm for C_w values of 67 and 72.4%, respectively. For mixes containing 25% muscovite, slump values were 22.7 and 13.1 cm for C_w values of 69.6 and 72.2%, respectively. For the samples with X = 15% and target C_w values of 70 and 72%, the slump values deviate from the main trend of the curves, appearing lower than those of subsequent points with higher muscovite content. This discrepancy arises because the actual measured C_w values for X = 15 and 17% are higher and lower than the target C_w values represented in the legend, respectively. On the one hand, the measured C_w values for X = 15% are 72.3 and 70.4% for the target C_w of 72 and 70%, respectively. On the other hand, measured C_w values are 69.2 and 71% for target values of 70%, and 72% for X = 17%, respectively (see Figure 4a).

According to White & Pichler (1959), muscovite can absorb up to 350% of its mass in water. In CPBs containing muscovite, the water absorbed by muscovite counts for evaluating the solids content C_w but is not available to contribute to the mixture's fluidity. As a result, the slump decreases when muscovite content increases for the same solids content or water content.

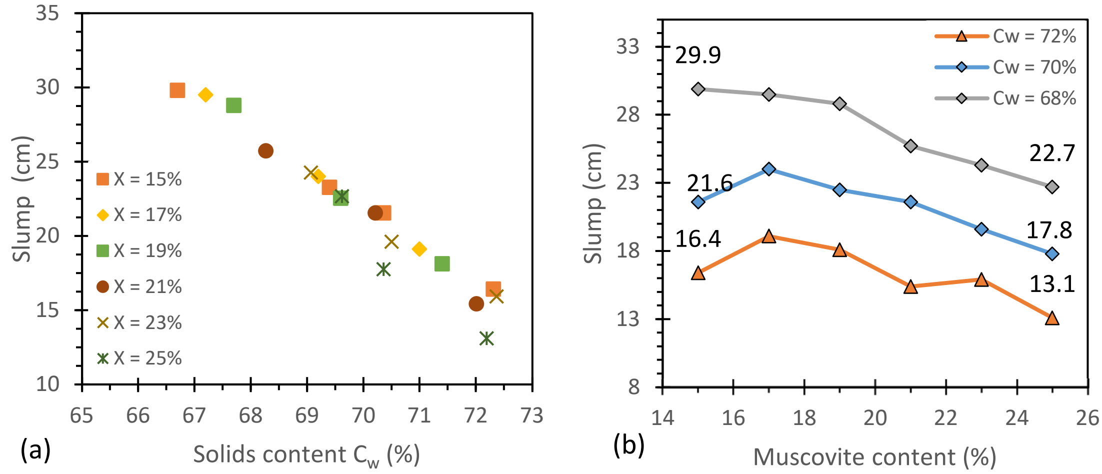

Figure 4 (a) Impact of solids content on the cemented paste backfill slump for varying muscovite content; (b) impact of varying muscovite content on the slump for different target solids contents

3.2 Effect of solids and muscovite contents on the rheological properties

Figure 5a shows typical flow curves or rheograms $\tau(\dot{\gamma})$ resulting from rheological tests carried out using the continuous ramp down flow method on different CPB recipes prepared at $C_w = 72\%$. For both types of tailings, these rheograms show an increase in shear stress for a given shear rate as the muscovite content, X, in these mixes increases. For example, at an arbitrary shear rate of about 26 $^{s-1}$, the shear stress increased from 95.6 to 160 Pa as *X* increased from 15 to 25% for CPB prepared at $C_w = 72\%$. This trend was also observed for the other solids contents. Figure 5b displays typical curves of dynamic viscosity, $\eta(\dot{\gamma})$, obtained from rheological tests using the same testing procedure, applied to CPB samples prepared at C_w of 72% while varying the muscovite content in the mixtures. For these solids contents, viscosity values decreased as shear rate increased. At the highest shear rate tested in this study (95 s^{-1}), the viscosity curves had not yet levelled off to the horizontal asymptote, $\eta\infty$, as defined in Equation 4. Additionally, as shown in the rheograms, dynamic viscosity at a specific shear rate increased with higher muscovite levels in these mixtures. For example, at a shear rate near 26 s^{-1}, dynamic viscosity rose from 4.1 to 6.1 Pa.s as muscovite content increased from 15 to 25% for CPB prepared at 72% solids.

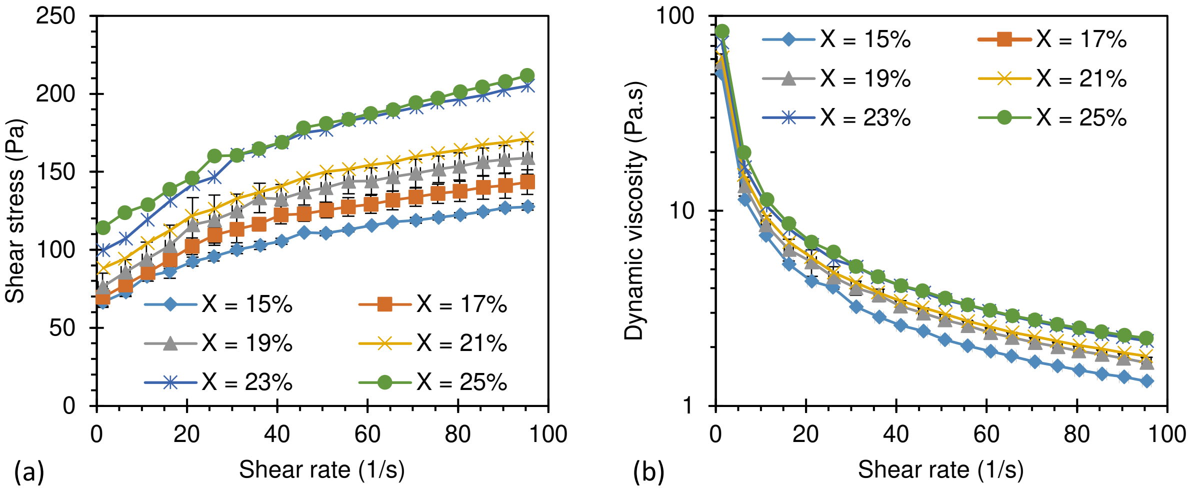

Figure 5 Influence of the muscovite content *X* (%) on typical rheograms (a) and viscosity curves (b) for cemented paste backfill mixtures at a fixed solids content of 72%

All the rheograms and dynamic viscosity curves obtained in this study were analysed by fitting rheological models. This approach allowed the determination of key rheological properties and the evaluation of relationships between these properties and variations in muscovite content and solids concentration.

The typical rheograms in Figure 5a exhibit a discernible pattern that broadly aligns with the Herschel–Bulkley rheological model represented by Equation 3 (Herschel & Bulkley 1926):

$$\tau = \tau_0 + k\dot{\gamma}^n \quad (3)$$

where:

$\dot{\gamma}$ = the shear rate (s^{-1})

τ = the shear stress (Pa)

τ_0 = the yield stress (Pa) (the intercept of the flow curve with the y-axis)

k = the consistency index ($Pa.s^n$)

n = the flow index (-).

Fluids display shear thickening, Bingham and shear-thinning behaviours when $n > 1$, $n = 1$ and $n < 1$, respectively.

Additionally, the viscosity curves in Figure 5b are fitted to the Cross model, as shown in Equation 4 (Cross 1965):

$$\eta = \eta_\infty + \frac{\eta_0 - \eta_\infty}{1+(k_c \dot{\gamma})^{n_c}} \tag{4}$$

where:

η = the dynamic viscosity (Pa.s)

η_∞ = the infinite rate dynamic viscosity (Pa.s) (this parameter provides insights into the fluid's behaviour at high shear rates)

η_0 = the zero rate viscosity (Pa.s)

k_c = a constant

n_c = a flow index specific to the Cross model.

The quality of the fit between the experimental and modelled curves was evaluated using the standard error (SE) computed by the software based on the least squares method (refer to Equation 5). As indicated in the TA instrument manual, an SE value below 20‰ is deemed acceptable (TA Instrument 2004).

$$SE(‰) = \left[\frac{\left(\sum \frac{(x_m - x_c)^2}{(N-2)} \right)^{0,5}}{Range} \times 1,000 \right] \tag{5}$$

where:

x_m = the experimental value

x_c = the value predicted by the rheological model

N = the total number of measurements

Range = the difference between the highest and lowest measured values.

Figure 6 illustrates the impact of solids content on the yield stress for different muscovite proportions. For mixtures containing 15% muscovite, the yield stress is 31.7 and 129.1 Pa at C_w values of 69 and 72.2%, respectively. For mixtures with 25% muscovite, the yield stress increases to 80.5 Pa and 174.6 Pa at C_w values of 70 and 73.3%, respectively.

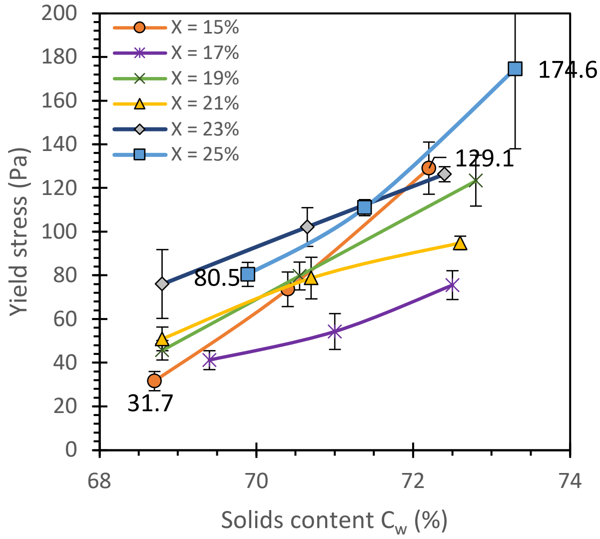

Figure 6 Influence of the solids content on the yield stress of cemented paste backfill with different muscovite contents

Figure 7a shows the impact of muscovite content on the yield stress τ_0 for solids contents C_w of around 68, 70 and 72%. One observes a clear increase in yield stress with a trend close to a quadratic function (second-degree polynomial function). For instance, τ_0 increases from 32 to 81 Pa, from 74 to 111 Pa and from 129 to 175 Pa when the muscovite content varies From 15 to 25% for $C_w \approx$ 68, 70 and 72 %, respectively.

Figures 7b and 7c show the impact of muscovite content on the flow index, n, and Cross infinite dynamic viscosity, η_∞, respectively. For solids contents of around 68 and 72%, these two parameters increase slightly with the muscovite content; the CPB remains, however, with a shear-thinning behaviour (n < 1). In Figure 7b we notice an increase of the values of flow index from 0.33 to 0.57, from 0.46 to 0.7 and from 0.66 to 0.95 when the muscovite content varies from 15 to 25% for $C_w \approx$ 68, 70 and 72 %, respectively. In the case of Figure 7c we observe an increase of the infinite viscosity going up from 0.02 to 0.33 Pa.s, from 0.41 to 0.71 Pa.s and from 1.24 to 1.76 Pa when the muscovite content varies from 15 to 25% for $C_w \approx$ 68, 70 and 72%, respectively.

The impact of muscovite on rheological properties and slump trend is generally consistent (albeit with some exceptions at lower muscovite contents and lower overall solids concentrations). It should be recalled that increasing values of yield stress, flow index and infinite viscosity result in increasing pressure loss and pumping energy requirements (Paterson et al. 2004; Swamee & Aggarwal 2011).

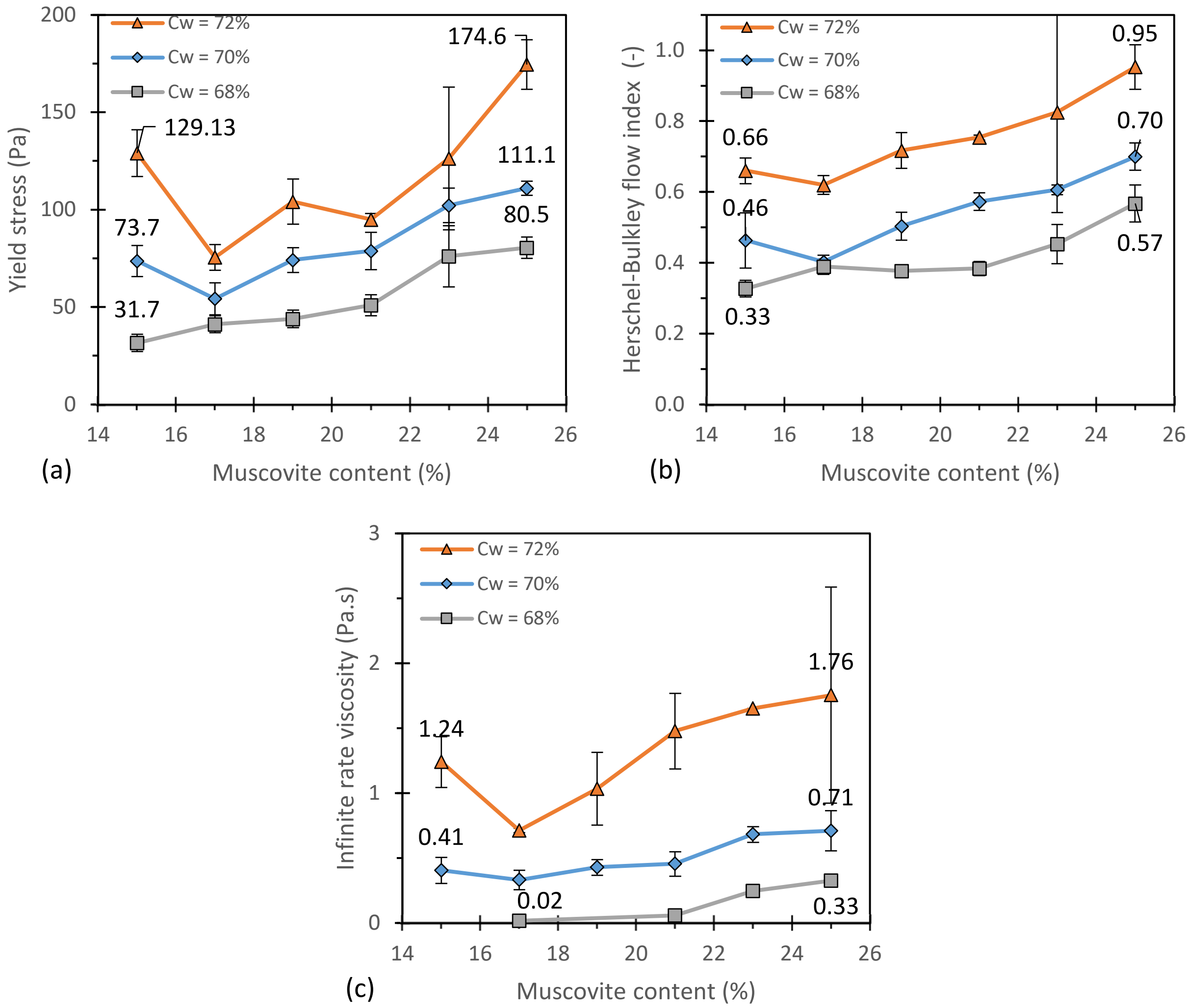

Figure 7 Influence of muscovite content on the rheological properties of cemented paste backfill mixtures for different solids contents on: (a) the yield stress τ_0; (b) the low index n; (c) the Cross infinite rate viscosity η_∞

4 Discussions

4.1 Effect of muscovite on linear pressure during cemented paste backfill transport in the pipeline

The results presented in Figure 7 illustrate the effect of muscovite content on rheological properties. It would be interesting to conduct a preliminary evaluation, using analytical solutions, of the impact of these rheological property variations on pressure loss during CPB transport in the pipeline. While both linear and singular pressure losses influence CPB transport in pipelines, the emphasis here is placed on linear pressure loss, which can be estimated using the following equation (Paterson et al. 2004):

$$J = \frac{\Delta P}{L} = \frac{4\tau_w}{D} \quad (6)$$

where:

J = the linear pressure loss (Pa/m)

ΔP = the pressure loss (Pa) over a pipe length L (m)

τ_w = the wall shear stress (Pa)

D = the pipe diameter (m).

For a Herschel–Bulkley fluid, the wall shear stress τ_w can be approximately linked to the mean flow velocity under laminar flow conditions by the following equation (Paterson et al. 2004):

$$V = \frac{Dn}{2\tau_w^3}\left(\frac{1}{K}\right)^{\frac{1}{n}}(\tau_w - \tau_o)^{\frac{n+1}{n}}\left[\frac{(\tau_w-\tau_o)^2}{3n+1} + 2\tau_0\frac{(\tau_w-\tau_o)}{2n+1} + \frac{\tau_0^2}{n+1}\right] \quad (7)$$

where:

V = the mean flow velocity (m/s)

τ_0 = the yield stress (Pa)

K = the consistency index (Pa.s^n)

n = the flow index (-).

When the target flow velocity *V* is known (based on the backfill tonnage and pipe diameter), Equation 7 can be solved iteratively to determine the value of τ_w, ensuring that the calculated velocity aligns with the target flow velocity. The obtained value, τ_w, is subsequently used in Equation 6 to estimate the linear pressure loss, J. This exercise was conducted for CBPs with solids contents C_w of 68 and 72%, and muscovite content *X* increasing from 15 to 25%, using the rheological properties provided in Table 3 and considering typical pipe diameters *D* (100, 125, 150 and 200 mm) and flow velocity *V* (0.1, 0.5, 1 m/s). Results are presented in Figure 8.

Table 3 Parameters used to estimate the linear pressure loss

X (%)	C_w (%)	ρ (kg/m³)	τ_0 (Pa)	k (Pas^n)	n (-)
15	68	1,801	31.66	9.37	0.33
25	68	1,799	80.50	5.19	0.57
15	72	1,904	129.13	7.42	0.66
25	72	1,877	174.60	2.68	0.95

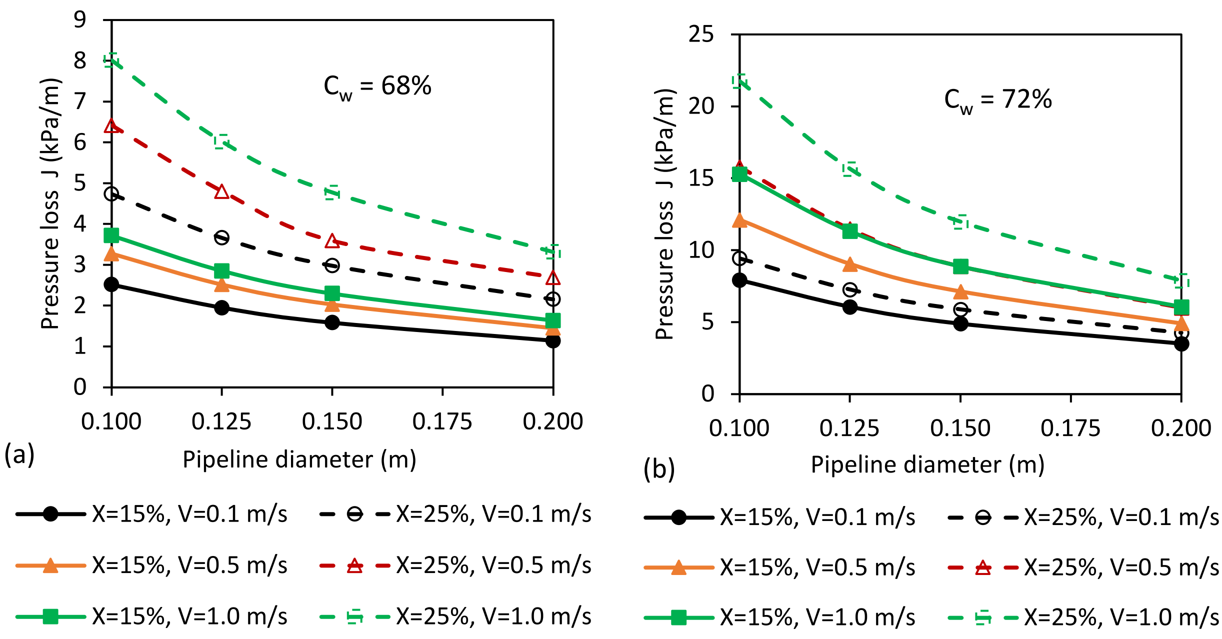

Figure 8 Impact of pipe diameter (D), flow velocity (V) and muscovite content (X) for cemented paste backfill prepared at a solids contents (a) C_w = 68% and (b) C_w = 72%

Figures 8a and 8b show the estimated pressure losses for CPBs prepared at solids contents C_w of 68 and 72%, respectively, when the muscovite content *X* increases from 15 to 25%. As expected, pressure losses decrease with increasing diameter (see Equation 6) for a given flow velocity. Conversely, pressure losses increase with flow velocity for a given pipe diameter. For example, for *V* = 1 m/s, and *D* = 0.1 m, estimated pressure losses increase from 3.7 to 8.0 kPa/m for CPB at C_w = 68% (see Fig. 8a), and from 15.3 to 21.8 kPa/m for CPB at C_w = 72% (see Fig. 8b) as muscovite content increases from 15 to 25%. These differences in the pressure loss at *X* = 15% and *X* = 25% can be significant for the required pumping pressure over long CPB distribution distances.

4.2 Effect of muscovite on the water requirement of cemented paste backfills

When the CPB mix design is based on tailings with minimal muscovite content, maintaining a target slump to ensure smooth backfill transport may become challenging as free muscovite content in the tailings increases unless extra water is added or the solids content is reduced. Figure 9 illustrates the relationship between the solids content and the muscovite content in CPB mixtures with respect to achieving a specific slump. It can be observed that for a given slump, an increase in the muscovite content in the CPBs results in a reduction in the required solids content. To maintain a 20.3 cm slump for example, the CPB solids content for a given muscovite content *X* ($C_{w\text{-}X}$) must decrease from $C_{w\text{-}X_i}$ = 70.8 % to $C_{w\text{-}X_f}$ = 70% as the muscovite content increases from X_i = 15% to X_f = 25%.

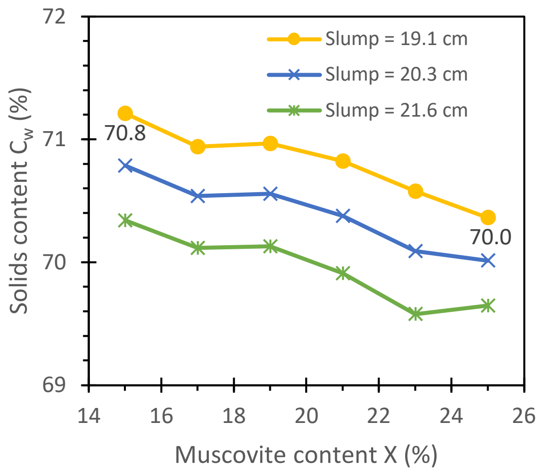

Figure 9 The effect of muscovite content on the solids content required to maintain a given slump criterion

Reducing the solids content would require adding extra water to the CPB mixtures. The amount of extra water to be added (ΔM_w) can be estimated by Equation 8:

$$\Delta M_w = M_{w-Xf} - M_{w-Xi} \quad (8)$$

where:

M_{w-Xf} = the mass of water in the CPB mixture at muscovite content X_f

M_{wi-X} = the initial mass of water in the control CPB with a muscovite content X_i (set at 15% here), both calculated for the same slump value.

An explicit equation expressing ΔM_w in terms of X_i, X_f, $C_{w\text{-}Xi}$, $C_{w\text{-}Xf}$ and $M_{t\text{-}Xf}$ (the total CPB mass at a muscovite content of X_f) is currently being developed. $\Delta M_w/M_{t\text{-}Xf}$ gives the amount of water to be added per unit mass of CPB.

Figure 10a illustrates the amount of water required to sustain a given slump level calculated with Equation 8. It can be observed that as the muscovite content in the CPB increases, the amount of water needed also rises, reaching approximately 38 kg of water/t of CPB for the maximum of 25% muscovite content for a slump of 19.1 cm.

However, adding water increases the initial *W/B* ratio, leading to a relative decrease in the mechanical strength of the CPB after curing. To maintain the original *W/B* ratio established during CPB design, additional binder would need to be added. The required binder quantity (ΔM_B) can be calculated using Equation 9:

$$\Delta M_B = \frac{\Delta M_w}{W/B} \quad (9)$$

where:

ΔM_w = the mass of water to be added to the CPB mixture to maintain a given slump as the muscovite content in the mix increases (see Equation 8)

W/B = the original water-to-binder ratio.

Figure 10b shows the amount of binder required to preserve the initial *W/B* ratio as a function of muscovite content in the CPB mixtures. It is evident that an increase in muscovite content in the CPB leads to a greater mass of binder needed, reaching up to approximately 4.3 kg/t of CPB for a muscovite content of 25% and a slump of 19.1 cm. It is preferable that the added binder amount ΔM_B does not alter the solids content or *W/B* ratio, thereby preserving the rheological properties and consistency of the CPB. Otherwise, the effect of the binder addition on these properties should be considered. An ongoing complementary study on the effect of muscovite on mechanical strength will determine whether this additional binder can compensate and achieve the desired compressive strength.

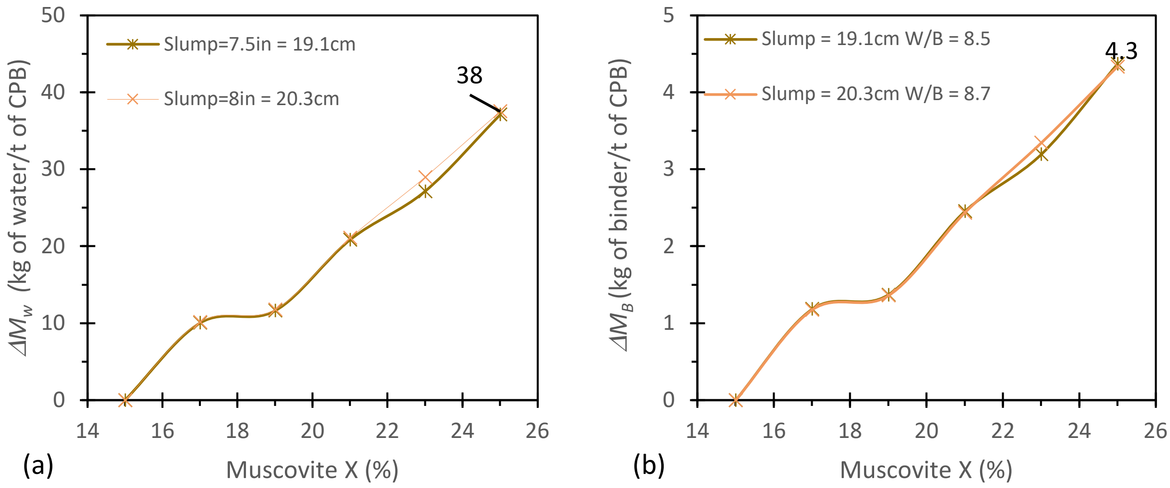

Figure 10 Impact of muscovite on: (a) the mass of water to be added to the cemented paste backfill mix to maintain a given slump; (b) the mass of binder to be added to cemented paste backfill to maintain the initial W/B

The solution proposed above, consisting of adding binder to CPB, may not be economically viable due to the high binder costs. It would probably be conservative to design the initial CPB recipe with tailings containing the highest expected muscovite content in the hope that this would not incur significant additional costs when the muscovite content decreases.

For the tailings studied, a CPB containing 25% muscovite should be prepared with a solids content C_w of 70.4% to achieve a design slump of 19.1 cm (see Figure 9). If the muscovite content decreases to 15%, a solids content of 71.2% would be sufficient to maintain this 19.1 cm slump (see Figure 9). In this case, water would need to be removed, which would increase the *W/B* ratio. This allows for the option of reducing the binder amount to maintain the original *W/B* ratio, following the procedure described above.

5 Conclusion

This study investigated the effects of varying muscovite content in CPBs incorporating HE strength Portland cement on slump and rheological properties. The key conclusions from the results are as follows:

- For a constant solids content, an increase in muscovite content generally decreases slump while increasing rheological properties and pressure losses. To achieve the desired fluidity or meet a specific slump criterion, additional water may be required in the CPB mixture. This adjustment increases the water-to-binder (*W/B*) ratio while maintaining a constant binder percentage, which could reduce mechanical strength.
- The findings from this research provide valuable guidance for estimating the amounts of water and binder needed in the CPB mixture to ensure sufficient fluidity while maintaining the target *W/B* ratio established during CPB formulation.
- In practice, it is recommended to formulate the CPB recipe from the beginning using tailings with the highest anticipated muscovite content.

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