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Research Article

Effect of Desliming of Tailings on the Fresh and Hardened Properties of Paste Backfill Made from Alkali-Activated Slag

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Cemented paste backfill (CPB) allows environmental friendly management of potentially hazardous tailings generated from milling of nonferrous metal sulphide ores by placing such tailings into the underground mined-out openings. The components of CPB are tailings, water, and binders. These components significantly affect the physicomechanical, workability, and geotechnical properties of CPB. Ordinary Portland cement (OPC) is the commonly used binder for CPB operations. The effects of the tailings characteristics and OPC are extensively studied in the study area. The beneficial effect of the use of alkali-activated slags (AASs) on the mechanical and durability properties of CPB of sulphide-rich tailings has been recently reported. Therefore, this study especially focused on the effect of desliming of the tailings on the workability properties of sulphide-rich tailings CPB containing AAS besides hardened properties. In this scope, the water-retention capacities of full (FT) and deslimed tailings (DT) and the workability characteristics of CPB mixtures were studied. DT was found to decrease the water-retention capacity, leading to denser CPB mixtures. In addition, DT-AASs usage produced no adverse effect on the workability of fresh CPB materials. LSS-S (slag activated with liquid sodium silicate) improved the flowability of CPB mixtures owing to its dispersant effect. Desliming also modified the tailing properties by removing fine particles and improved the main geotechnical parameters of CPB.

1. Introduction

Cemented paste backfill (CPB) allows the placement of potentially hazardous materials into the mined-out underground openings. CPB is one of the most effective and environmentally friendly methods for the management of mineral processing tailings. In addition, CPB provides numerous operational, economic, and environmental advantages [1–7]. CPB consists of the entire gradation processing tailings (full tailings, FT), binders, and water in general. Each component significantly affects the quality and performance of CPB from the mixing stage to the end of service life underground [8–15].

CPB requires more than 15 wt.% fine particles (<20 μm) for water retention in its matrix to prevent segregation [16, 17] and to provide favorable consistency. Higher fines content is reported to increase the viscosity of CPB mixtures and the resistance against flow in a pipeline for a given water content [18]. Full tailings (FT) with high fines content retain more water and increase the porosity in the CPB matrix. CPB is produced from FT which may consist of high amount of sulphide minerals depending on the ore composition. In such a case, a high porosity (i.e., 30–50%) promotes air and/or water diffusion, leading to the formation of acid and sulphate through the oxidation of sulphide minerals (pyrite, in particular) in CPB [19]. In this case, CPB becomes susceptible to both internal and external acid and sulphate attacks [19–21]. Acid leads to the destruction/decalcification of hydration products such as C–S–H (crystalline calcium (CaO) silicate (SiO_2) hydrate (H_2O)) formed with the hydration of the binder, such as ordinary Portland cement (OPC), while sulphate precipitates in the form of gypsum and/or ettringite as a result of chemical reactions with portlandite (C–H: $Ca(OH)_2$: a hydration product) [22–24]. These reaction products (secondary gypsum, ettringite, and so on) cause durability problems [25, 26]. Mineral and

chemical additives [27–31], alkali-activated slags (AASs) [32, 33], and the use of deslimed tailings (DT) have been suggested to improve the strength and stability of CPB in the short and long term [8, 19, 21, 34].

CPB contains a large amount of water to provide the required consistency for material transportability [35]. The excess water can easily drain when DT is used. Therefore, the rate of strength gain of CPB when DT is used is reported to be faster than that of FT, since the former allows a denser cementitious matrix and microstructure (i.e., decrease in the void ratio, porosity, etc.) [19, 21]. DT is also reported to reduce binder consumption for the desired strength level [19] which is among the most important features of CPB applications.

The effect of desliming on the strength and durability performance of CPB has been extensively investigated [8, 9, 19, 21, 22, 34, 36–38]. However, Ercikdi et al. [19] noted that desliming might affect unit operations such as transportation of CPB into underground voids. Therefore, in addition to mechanical and geotechnical properties, workability of CPB is of great importance when using DT. On the other hand, AAS has been reported to cause some workability losses on fresh concrete/mortar samples [39, 40] although this problem can be overcome by pozzolanic ultrafine mineral additions [41] or retarders [42–44].

Workability is frequently used to characterize some properties such as flowability, pumpability, and consistency of the materials containing hydraulic binders (e.g., fresh concrete) for mixing, transportation, and placement without allowing for any segregation. There are many factors that can influence workability such as type and shape of aggregate, solid content, binder type and dosage, water-to-cement ratio, activator type, concentration, and modulus ratio [45]. Slump test, compaction test, and flow test are usually used for the assessment of workability [46]. Slump test which is a simple, easy to perform and evaluate, cheap, and widely known method is extensively used by mine operators on-site to estimate material consistency as a good indication of flowability in terms of transportability of fresh CPB mixtures [18, 47–50]. Any change in the initial consistency of CPB material during transportation may require high pump pressures and can cause excessive friction and thus wear problems in pipes which result in high costs [51]. Therefore, workability is of great significance in practice for CPB applications [13, 52–55].

Although the use of AAS is reported in some underground mining applications in South Africa and Canada [56], there is lack of knowledge about the conditions of usage and performance (i.e., durability and workability) properties of the materials containing AAS. On the other hand, while FT is extensively used for backfilling of the mined-out underground voids, use of DT was reported in South African mines in order to prepare high quality CPB material [57]. However, there are relatively few studies dealing with the performance properties of CPB made from AAS [14, 58] and DT.

In [22], the authors studied the mechanical, durability, hydraulic, and microstructural properties of deslimed sulphide-rich tailings CPB in detail. They indicated that DT and AAS enhanced the strength gain, improved the microstructure, and decreased the effects of acid and sulphate attacks. However, they did not study the workability of fresh CPB mixtures and main geotechnical properties of fresh and hardened CPB materials made from of DT and AASs which are the focus of the current study. Since the workability of CPB materials is determined by the interaction between the solid (tailings, cement, slag) and liquid components (water, activators), the water-retention capacity of the tailings was firstly determined in this study. Afterwards, effect of desliming on the geotechnical properties of fresh CPB mixtures prepared from FT and DT using OPC and AASs combinations was studied. Some geotechnical parameters, i.e., water content and porosity levels of hardened CPBs over the curing period, were also studied.

2. Experimental Studies

2.1. Tailings and Binders. Full (FT) and deslimed tailings (DT) were utilized to investigate the coupled effect of using DT and alkali-activated slag (AAS) on the workability and some main geotechnical properties of CPB materials. FT was collected from the disc filter outlet of the paste backfill circuit while DT (coarse sized) was obtained simultaneously from the underflow after separation and removal of fine particles by hydrocyclone.

Ordinary Portland cement (OPC) and alkali-activated blast furnace slag (AAS) were used in order to investigate the effect of desliming on the workability of the fresh CPB mixtures and main hardened properties of CPB specimens. Liquid sodium silicate (LSS) and sodium hydroxide (SH) were used as activators. For the characterization of the materials used in the study, chemical (ACME laboratories in Canada using X-ray fluorescence and wet chemical analyses), mineralogical (TCMA (Turkish Cement Manufacturers' Association) labs in Turkey using X-ray diffractometer analysis), and physical properties of the binders were determined (Tables 1–2). Detailed characterization of the materials can be found elsewhere [22].

2.2. Water-Retention Tests on Tailings Materials. CPB is required to contain sufficient amount of water to achieve the desired consistency for its transportability from the paste plant to the underground openings. Tailings must have at least 15 wt.% material finer than 20 μm to retain enough water to form paste with the desired flow properties for its transportation through a borehole or pipeline [16]. In order to study the water-retention characteristics, each tailing and some amount of water were firstly mixed and prepared in duplicate (without binder addition) at slump consistencies of 8.0 ± 0.1 inch which were verified using the slump test in accordance with ASTM C143/C143M-12 [59]. After that, the procedure described by Ercikdi et al. [19] was followed to determine the water-retention capacities of the tailings where mean values of duplicate tests were presented in the results.

2.3. Mixing Procedure and Workability Tests of Fresh CPB Materials. In this study, FT and DT, binders, and tap water were prepared in six different recipes using a Univex

Table 1: Physical, chemical, and mineralogical properties of tailings.

Chemical composition	Full tailings (wt.%)	Deslimed tailings (wt.%)	Physical properties	Full tailings	Deslimed tailings
SiO_2	13.16	10.43	Specific gravity (G_s)	4.09	4.32
Al_2O_3	4.81	2.46	Specific surface area (cm^2/g)	3662	1956
Fe_2O_3	48.41	53.93	D_{10} (μm)	2.14	14.98
MgO	1.13	0.91	D_{30} (μm)	7.65	29.62
CaO	1.83	1.28	D_{50} (μm)	19.21	45.24
Na_2O	0.19	0.18	D_{60} (μm)	28.52	54.23
K_2O	0.64	0.23	D_{90} (μm)	77.43	117.39
TiO_2	0.08	0.07	Coefficient of curvature (C_c)	0.96	1.08
P_2O_5	0.02	0.02	Coefficient of uniformity (C_u)	13.33	3.62
MnO	0.06	0.05			
Cr_2O_3	0.01	<0.01			
$BaSO_4$	2.54	2.02			
Loss on ignition	26.9	28.2			
Sulphide (S^{-2})	37.4	42.23			
Total S	38.52	42.76			
Pyrite content (FeS_2)	70.13	79.19			

Table 2: Chemical, physical, and mineralogical properties of binders.

Chemical composition	OPC (wt.%)	Slag (wt.%)	Physical properties	OPC	Slag
SiO_2	21.88	39.75	Specific gravity	3.07	2.89
Al_2O_3	4.74	10.91	Specific surface area (cm^2/g)	4120	4600
Fe_2O_3	2.90	0.80	Retained on 45 μm sieve (%)	2.17	4.15
CaO	65.0	38.02	Retained on 32 μm sieve (%)	7.48	9.60
MgO	1.40	5.92	Mineralogical composition (%)		
TiO_2	0.19	0.51	C_3S	50.42	–
Cr_2O_3	0.01	0.01	C_2S	27.76	–
Na_2O	0.39	0.32	C_3A	7.66	–
K_2O	0.75	1.19	C_4AF	8.83	–
MnO	0.12	1.54	Basicity index		
P_2O_5	0.06	<0.01		–	1.03
Free lime	1.04	–			
Loss on ignition	2.5	0.20			
SO_3	2.67	1.62			
Reactive SiO_2	–	39.10			

SRMF20 Stand model blender. CPB mixtures were prepared at 7 wt.% binder dosage on total dry solids basis. For AAS samples, the solid contents of the activators, i.e., SiO_2 and Na_2O, were considered for determination of binder content. Na_2O concentration of the activators was fixed at 8 wt.% by weight of the slag. The modulus ratio (SiO_2/Na_2O) of LSS was set to 1.0 with SH where optimal mechanical results were reached for CPB of sulphide-rich tailings [22]. Since the ideal slump of CPB material is between ~6.5 and 10.0 inches in most CPB applications [60, 61], the initial consistency of CPB mixtures was set to 8.0 ± 0.1 inches for this study. Based on the design and consistency conditions, the workability and the geotechnical properties of fresh CPB mixtures were obtained.

Workability tests were performed during 2 hours according to ASTM C143/C143M-12 [59]. These tests allowed the assessment of the flowability behavior of fresh CPB materials prepared with OPC, LSS-S, and SH-S. Duplicate simple slump tests with a standard cone were performed on the fresh mixtures at the predetermined time intervals (0, 30, 60, 90, 120 min). During the slump tests, the remaining CPB material in the bucket was mixed thoroughly to prevent the settling of the tailings particles and the stiffening of the mixture. The mean slump values at the corresponding time intervals were used in the presentation of the results.

2.4. Determination of Main Geotechnical Parameters of Hardened CPBs. For the assessment of the effect of desliming and AAS interaction on the geotechnical properties (i.e., total porosity and gravimetric water (wt.%) content) of hardened CPB specimens (CPBs), 72 samples were prepared in duplicate for each recipe at 14, 28, 56, 112, 224, and 360 days of curing. Thereafter, CPB specimens were sealed in plastic bags and subjected to curing in the curing room at $20 \pm 1^{\circ}C$ and $85 \pm 1\%$ humidity. For the determination of the final gravimetric water content, some CPB specimens were collected and oven-dried for 36 h at $50^{\circ}C$. The mercury intrusion porosimetry (MIP) tests were carried out on the representative samples of fractured CPB specimens at 14, 56, and 360 days in order to evaluate the effect of desliming on the total porosities of CPBs. MIP tests were performed according to ASTM D4404-10 [62] under pressure ranging from 0 to 414 MPa.

3. Results and Discussion

3.1. Effect of Desliming on the Physical and Chemical Characteristics of the Tailings. FT and DT were seen to include the required amount of fine particles (greater than 15 wt.%) for CPB mixtures in order to provide the desired consistency according to the fineness contents (−20 μm) (51 wt.% for FT and 16 wt.% for DT). Due to the removal of fine particles and clay minerals by desliming, SiO_2+Al_2O_3 content and the specific surface area (cm^2/g) of the tailings were observed to decrease by 28.27% and 46.59%, respectively. Additionally, as an indication of the concentrated coarser particles and denser minerals, i.e., pyrite, during desliming process, the amount of sulphidic minerals was seen to increase, thereby increasing the specific gravity (G_s) of the tailings (Table 1).

Pyrite was observed to be the predominant mineral in FT and DT based on the mineralogical compositions of the tailings from XRD analysis where quartz, albite, barite, dolomite, calcite, ferroactinolite, kaolinite, and illite were also detected in the tailings (Figure 1). Among these components, kaolinite and illite are nonswelling clay minerals. Kaolinite is composed of model sheet units of silica tetrahedra and alumina octahedra, called a 1 : 1 layer mineral, while illite is a 2 : 1 layer mineral consisting of two silica tetrahedra units enclosing one octahedral alumina unit. Al–OH linkages located at the surface of such clays are reported to play an important role in the water adsorption process [63].

3.2. Effect of Desliming on the Water-Retention Characteristics of the Tailings and the Properties of Fresh CPB Mixtures. Water-retention characteristics of a cemented paste backfill material (CPB) are unique due to the colloidal properties of the fine particles where colloidal electric charge forms bonds with water molecules. Therefore, water-retention properties significantly affect the rheology/workability of CPB [64]. Figure 2 illustrates that desliming reduces the water-retention capacity of the tailings. Water-retention capacity of DT was 11.66 times less than FT. This substantial reduction in water retention was concomitant with the removal of fine alumina-silicate minerals (i.e., kaolinite and illite) by desliming as indicated by the lower $SiO_2 + Al_2O_3$ content of DT (Table 1). Water absorption capacity of a mixture of kaolinite and illite (Figure 1) is reported to be in the range of 70 to 100% by weight of dry clay [65]. Illite is also reported to take up more water than kaolinite owing to its structure in 2 : 1 sheet of units made up of silica and alumina [63, 66].

Water-retention capacity is significantly affected by the particle size distribution and mineral composition in terms of fine particles and clay minerals as mentioned above, respectively. Therefore, the greater water-retention capacity of FT was ascribed to the higher amount of finer particles having also higher specific surface area. This means that more water is required to wet the surface of the fine particles for a desired consistency [21, 66]. Desliming was determined to reduce the specific surface area of the tailings with a resultant decrease in water-retention capacity. Water-retention tests also indicated higher drainage of excess water from the coarse tailings, as expected. In [67], it was reported that a faster rate of removal of excess water from a stope through adjacent walls or barricade improved the stability of the backfilled material. It can be concluded that the reduced amount of finer particles by desliming leads to higher settling capacity which improves the properties of paste backfill material. In this way, it also decreases the potential pore water pressures on barricades in practice [68].

Owing to the lower water-retention capacity and the higher sulphide mineral content after desliming, DT was seen to increase the solid contents of CPB mixtures by 5–7 wt.% and hence the pulp density (g/cm^3). This suggests that DT enables the transfer of higher amount of sulphide minerals into the underground voids. Furthermore, desliming of the total tailings was also observed to lower the water content by 22.98 wt.%, 17.69 wt.%, and 19.55 wt.% and reduce the water-to-cement ratios by 28.28%, 21.76%, and 24.19% for OPC, LSS-S, and SH-S samples, respectively (Figure 3). The details of the data for Figure 3 can be found elsewhere [22].

The above parameters affected by the characteristics of the tailings directly influence the rheology/workability of CPB [69]. Additionally, these findings simply show that the percentage of water retention/adsorption by finer tailings particles is a function of particle size distribution and specific surface area. In other words, these results suggest a considerable potential for refinement on geotechnical properties (i.e., denser CPB material with lower porosity), and more compact structure corresponding to a decreased porosity by approximately 15–20% [70]. On the other hand, higher water-retention capacity was reported to give greater total porosity and higher void ratio [8, 19, 21].

3.3. Effect of Desliming on the Workability Properties of CPB. The change in slump levels during two-hour period of fresh paste backfill mixtures of FT and DT is shown in Figure 4. Slump levels of fresh CPB mixtures were observed to increase compared to the initial levels owing to the generation of hydration gel products for all binders as a result of the advance of hydration. DT mixtures resulted in a bit lower slump levels than those of FT mixtures, which can be attributed to the reduction in interparticle distance [58]. In other words, particle interaction increases as the solids concentration increases, which makes DT mixtures more viscous due to the granuloviscous effects. On the other hand, higher slump levels for FT mixtures can be ascribed to the higher fines contents as a consequence of the increase of hydrodynamic and electroviscous effects. The authors of [71] reported that the design parameters had an influential effect on the rheology of CPB. In [69], the authors found that flowability decreases as the hydration progresses, which is not beneficial for transportation of CPB materials. In [72], it was reported that higher solids content resulted in lower CPB material consistency concordant with the findings of this study. In [73], it was found that increasing the content of finer tailings decreased the flowability (transportability) at a given water-to-cement ratio, while Clark et al. [18] noted that fresh CPB mixtures of FT are easier to transport at a given slump.

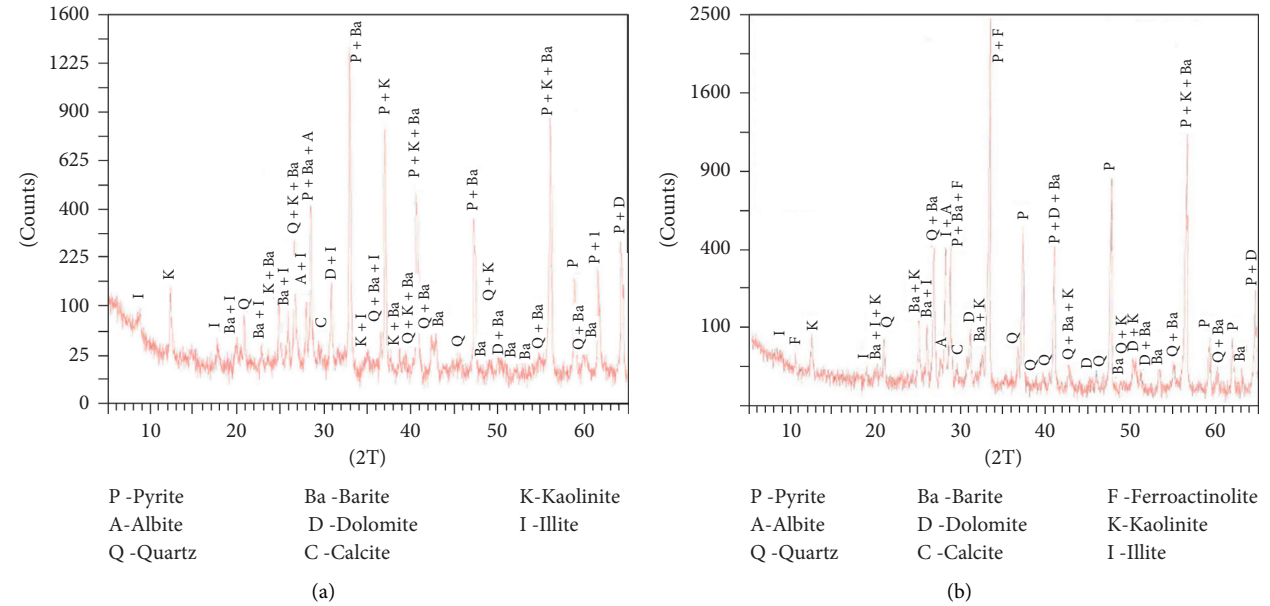


Figure 1: Mineralogical compositions of FT (a) and DT (b).

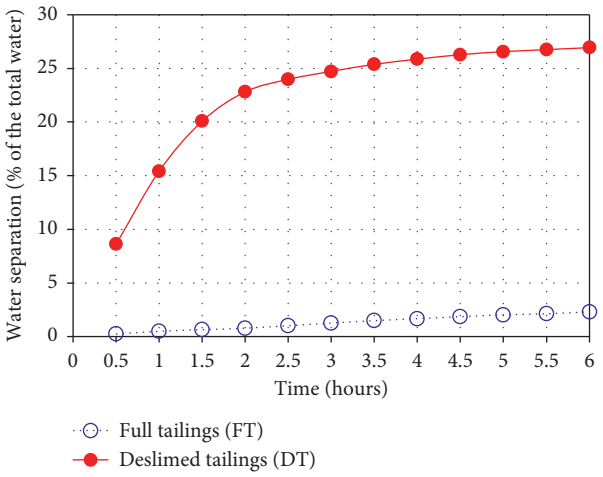


Figure 2: Water-retention characteristics of the tailings.

Slight reduction in workability (about 2%) was observed for OPC/DT and SH-S/DT mixtures after the first hour, where the workability levels were still higher than the initial values. This can be ascribed to the different hydration kinetics and mechanism, and properties of C–S–H products of AAS and OPC. SH-S is a depolymerization process from one to seven days and a polymerization process from 7 to 28 days, while LSS-S hydration can be regarded as a polymerization process. In addition, at a constant Na_2O content, SH-activated slag was reported to yield the shortest induction period and the highest accelerated hydration peak since pH of SH solution is higher than other Na-containing compounds. Besides, heat evolution curve during the hydration of SH-S was observed to be similar to that of OPC [46].

LSS was observed to have a fluidizing effect leading to the highest slump levels and it produced the highest workability for both tailings types (Figures 4 and 5). This can be attributed to the dispersion capability of silicate anions since it prevents the mineral pulp from agglomeration and settling out [74]. Jiang et al. [58] found and reported that the addition of alkali activator (sodium silicate + sodium hydroxide) reduces the Zeta potential of slag particles with the tailings yielding higher workability. Therefore, better workability levels for CPB of AAS in this study can be ascribed to the interaction between the AAS binders and the tailings on the basis of the difference in the surface chemistry of the solid materials of CPB. Earlier studies [75, 76] also reported a beneficial effect of LSS for reducing the viscosity of clay slurries by the adsorption of silicate anions on the positive edges of clays, which generates repulsion between particles. Slightly greater workability levels of FT mixtures compared to those of DT can be attributed to the higher amount of fine particles (i.e., clay minerals: kaolinite and illite) in addition to having lower solids content at a given slump.

It is evident from these findings that AASs (i.e., LSS-S and SH-S) not only enhance the geotechnical properties of fresh CPB mixtures but also improve the workability characteristics of the materials especially in the case of LSS. Therefore, the transportation and placement of CPB mixtures of AASs are likely to be easier than those of OPC considering the transportation time which varies between 6 and 15 minutes from paste backfill plant to underground voids to be filled for most of the CPB applications [77]. Besides, DT-AAS combination was seen to produce no adverse effect on the workability of fresh CPB materials taking into account the initial values. However, it should be noted here that CPB materials can have different yield stress in terms of flowability characteristics for a given slump value. Besides, a small change in pulp density/solids concentration can cause a significant change in yield stress for a

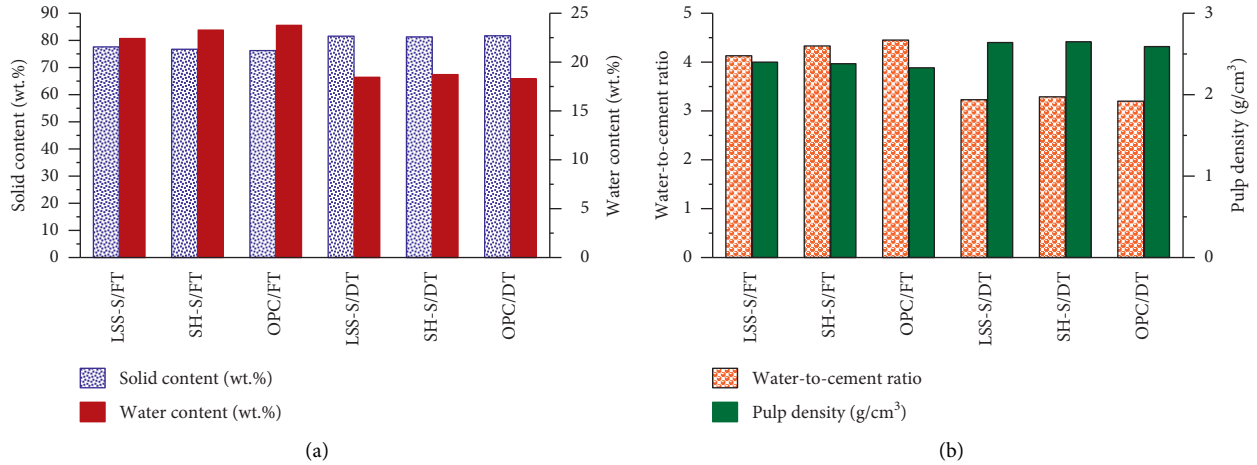


Figure 3: Effect of desliming of the tailings on the properties of fresh CPB mixtures.

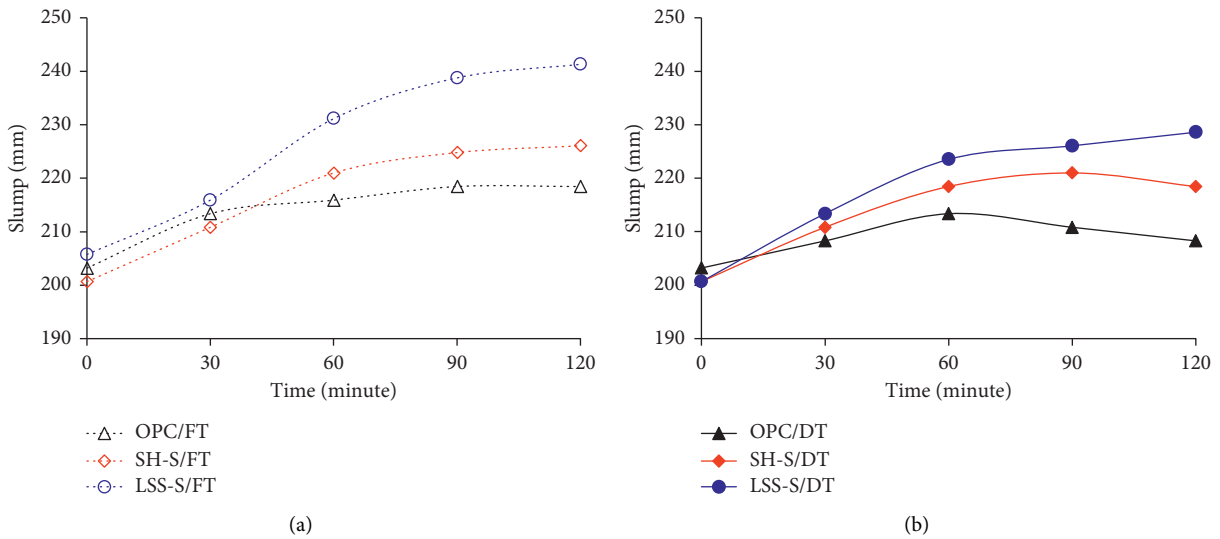


Figure 4: Workability characteristics of CPB mixtures for FT and DT.



Figure 5: Slump levels of LSS-S/DT mixtures: (a) initial (7.9 inches) and (b) after 2 hours (9 inches).

given mine tailing. Therefore, flow response of CPB mixtures should be tested in terms of flow rate, flow resistance, pipeline blockage, unwanted settling of coarse tailings particles, pressure loss, power consumption, etc. using a suitable surface loop test set.

In this study, contradictory results in terms of workability properties were obtained from CPB mixtures of AASs compared to those of fresh concrete/mortar mixtures [39, 40]. In these studies, significant workability losses were observed within the first hour. This behavior can be explained by (i) higher water-to-cement ratio of CPB (≈3.0–6.5-fold) compared to those of concrete/mortar mixtures (≈0.4–0.6-fold in general), (ii) greater water-retention capacity of the tailings particles (as aggregate) during and after the hydration process, and (iii) AASs which display different hardening characteristics in such mixture medium (i.e., CPB mixture) [46, 77]. Therefore, the workability characteristics of CPB materials were seen to be different from those of concrete/mortar systems as in hardening process which was discussed in detail by Benzaazoua et al. [8].

3.4. Effect of Desliming on the Hardened Properties of CPB. Figure 6 presents the water content (wt.%) for hardened CPBs over the curing period. Water content decreases for all CPBs with curing time due to the hydration products and the formation of secondary expansive minerals (i.e., gypsum ($CaSO_4{\cdot}2H_2O$) and ettringite ($3CaO{\cdot}Al_2O_3{\cdot}3CaSO_4{\cdot}32H_2O$ in OPC samples)) [22]. Since FT had more amounts of finer tailings, thereby higher specific surface area, the water content of FT resulted in higher values over the curing period. However, DT displayed lower water contents since tailings composed of coarser particles have lower specific surface area requiring less water to wet the entire surface of tailings particles. This can also be ascribed to the decrease in the amount of fine silicate minerals ($SiO_2 + Al_2O_3$) due to desliming. As a consequence, DT samples had resultant lower water contents by 22.71–27.63%, %18.74–24.25%, and 19.57–25.98% for OPC, LSS-S, and SH-S, respectively, as the curing time elapsed. OPC samples were seen to keep more water during the curing which can be attributed to the inherent properties of tailings and the interaction between the tailings and the binders as was seen in fresh CPB mixtures.

Figure 7 shows the porosity levels of FT and DT samples. Higher water-retention capacity of fine tailings led to higher total porosities. Therefore, lower porosities in DT were assumed to stem from the lower water-retention capacity of the coarse tailings as well as higher solid contents [4] compared to FT. The decrease in porosities after 14 days can be attributed to the continuous hydration products of the binders and the formation of secondary mineral phases. Details of the technical parameters of 56 day porosities in Figure 7 can be found elsewhere [22].

DT was observed to reduce the porosity by 19.4, 16.9%, and 15.3% in average for OPC, LSS-S, and SH-S samples, respectively, depending on the curing time. This can be ascribed to the higher self-consolidation characteristics of

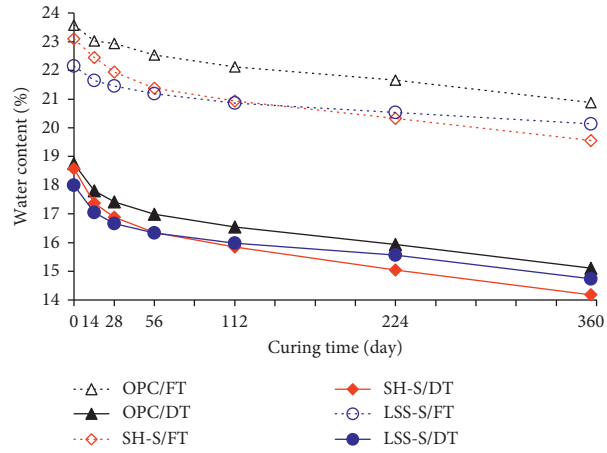


Figure 6: Effect of AAS and DT on the water content levels of CPBs over curing time.

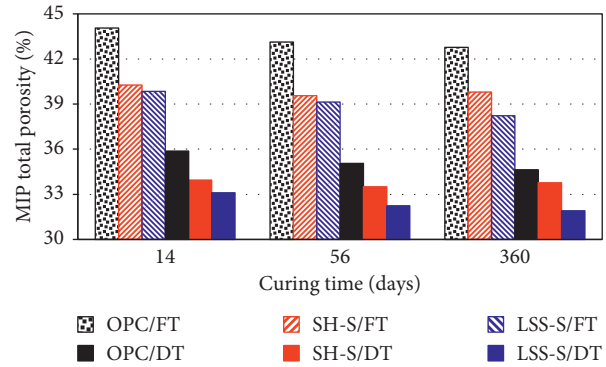


Figure 7: Effect of AAS and DT on the total porosity levels of CPBs.

DT leading to drainage of excess water [19, 78]. As observed in Figures 6 and 7, reduced water content and porosity suggest the refinement of microstructure [79, 80] in case of DT, which is in good agreement with Ercikdi et al. [19].

Additionally, Guo et al. [81] used sodium silicate as additive to Portland cement for CPB preparation and found that the cement containing sodium silicate significantly decreased the porosity and refined the pore structure of CPB. Similarly, as can be seen from Figure 7, LSS-S provided the lowest porosities for both tailings. Therefore, these results can be related to the better bonding and dense packing capacity of sodium silicate promoting more condensed binding gel structure leading to refinement of porosity [82].

The porosity of materials was reported to decrease while higher solid content was obtained in the case of lower water-to-cement ratios [78, 83]. In [84], the authors also reported that the lower the water-to-cement ratio, the higher the amount of cement bonds resulting in higher strength gain of CPB. These are well consistent with the findings of [22]. They observed that DT and AASs had profound effects on the mechanical, hydraulic, and microstructural properties, enabling a good durability and the refined geotechnical characteristics of hardened CPB for the corresponding

materials used in the current paper too. Use of DT and AAS combinations provided ~4–10-fold strengths compared to the CPBs made from FT-OPC. DT-AAS was also found to decrease the acid and sulphate effects owing to the high degree of cementation and dense microstructure with reduced permeability. More details can be found elsewhere [22].

One can infer from these results that since the porosity and the water retention of materials are responsible for the generation of acid and sulphate in the case of sulphide-rich tailings, desliming significantly contributes to the strength gain and the durability performance of CPBs [22]. These findings may be attributed to the faster rate of water drainage in case of deslimed tailings and the faster settling of the coarser particles. Both scenarios favor the cementation degree and a dense packing matrix alleviating the oxidation of pyrite grains in CPB materials [3, 8, 19, 21, 70, 85]. Given the considerations above, not only does DT provide significant practical advantages in some aspects such as reducing water content (Figure 3) but it may also decrease the pore water pressure on barricades during mining activities, therefore reducing the potential risks of liquefaction due to the blasting activities [67, 68, 86].

4. Conclusions

This study has demonstrated the influence of desliming and AAS as binder on the workability and geotechnical properties of CPBs. Owing to the removal of fine particles/clay minerals, desliming decreased the specific surface area and increased the specific gravity of the tailings. On the one hand, desliming led to a significant reduction in water-retention capacity of the tailings. On the other hand, it allowed improvement of the geotechnical properties of hardened CPB, which is a result of dense CPB mixture with higher solids content, lower water-to-cement ratio, and higher settling ability of fresh CPB. Therefore, DT displayed lower water contents and porosities with increase in the curing time by 18–26% and 15–20% in average, respectively. The refinement of such geotechnical properties is of great importance in respect of increasing the mechanical performance of CPB in practice.

Workability characteristics of CPB mixtures containing AAS binders appear to be different from those of concrete/mortar systems. The increase in solid content due to desliming was observed to result in little lower consistency. However, DT and AAS produced no adverse effect on the workability of fresh CPB materials. In fact, LSS-S appears to improve the workability properties of CPB presumably due to its dispersant effect on fine particles. However, flow response of CPB mixtures in case of any important change in solids concentration should be tested by a suitable surface loop test set.

Data Availability

The data supporting the findings of this study are included in the article. Additionally, raw data generated during the study are available from the corresponding author on request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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