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Determination of the Optimum Cement Content for Paste Backfill Samples

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ABSTRACT: In this study, the effect of cement content between, 3 and 7 wt %, on the mechanical strength of the paste backfill was examined at different size of slump between 6" and 7". The paste backfill samples were prepared using the tailings sample A and B. They were subjected to the unconfmed compressive strength test at predetermined *curing* periods. The results showed that the optimum cement content of the paste backfill sample A was found to be 7 wt% at a 7.0" slump value resulting in a compressive strength of 1.387 MPa at 28 days curing period. With 7 wt% binder, the highest compressive strength of 0.8J2 MPa at a 6.0" slump value was determined for the paste backfill mixture prepared for the tailings sample B for 28 days curing period. The differences observed in the compressive strengths and slump consistencies for paste backfill samples A and B could be attributed both tailings samples to have different characteristics such as particle size, chemical and mineralogical composition.

I INTRODUCTION

The process of mining involves the removal and recovery of economically valuable minerals from the earth's crust. The resulting voids are usually filled with waste materials by a process known as backfilling. Backfilling has long been an integral part of underground mining. The underground placement ol backfill falls into two categories-backfill required for ground support and underground disposal of tailings (Thomas et al. 1979,"Edwards 1992). Waste materials used as a backfill material include waste development rock, deslimed and whole mill tailings, quarried and crushed aggregate, and metallurgical process tailings (like slag) "(Grice 1998. Yılmaz et al. 2003).

The development and utilization of paste backfill technology has been evolving over the last two decades around the world and especially in Canada. Due to the low operating costs involved and high strength acquisition of paste backfill compared with the other backfilling methods (rock fill and hydraulic fill), the use of paste backfill has steadily increased in recent years (Landriault el al. 1993, Landriault 1995).

The disposal of mine tailings underground reduces the environmental impact and provides a material that can be used to improve both ground conditions and the economics of mining. A significant environmental benefit of the paste backfill, especially when tailings are acid generating, is the possibility of placing a large amount of tailings up to 100% to underground. This significantly reduces the oxidation risk and other environmental effects (Weaver et al. 1970, Brackebusch 1994, Strömberg 1997, Benzaazoua et al. 1999 and 2002).

Various binder materials are used to increase the support potential and stability of paste backfill. Portland cements are often used alone or with the addition of natural or artificial additives having specific hydraulic properties in cemented paste backfill. The additives are used to increase the durability and the strength of the mixture, and appreciably reduce the binder costs (Viles et al. 1989, Naylor et al. 1997, Hassani et al, 2001, Ouellet and Hassani 2002).

The characteristics of mechanical and rheological of paste backfill are connected to the physical, chemical, and mineralogical characterization of tailings, binder type and ratio used (Lamos and Clarck 1989, Ouellet and Hassani 2002, Chew 1999).

In this study, at 28-day curing period, the effect of cement content between 3 and 7 wt% on the mechanical strength of the paste backfill was examined at different size of slump between 6" and 7". The paste backfill samples were prepared using the tailings sample A and B.

Tailings sample A consists of pyrite and chalcopyrite, and less than 10% sphalerite. Tailings sample B consists of pyrite, chalcopyrite and sphalerite.

2 MATERIAL

In order to better understand the effect of the material composition of mill tailings on the mechanical strength of paste backfill, a series of unconfined compressive strength (UCS) tests was conducted in detail. For this reason, about 800 kg representative samples of tailings were obtained from a suitable disc filter. In addition, authors examined the main components of each tailings such as grain size distribution, specific gravity, chemical and mineralogical composition, and rheological properties.

2.1 *Tailings Material Determination*

The tailings were sized by using a Maslersizer S Ver. 2.15 (Malvern Instruments Ltd, UK) particle size analyser and the results are shown on Figure I.

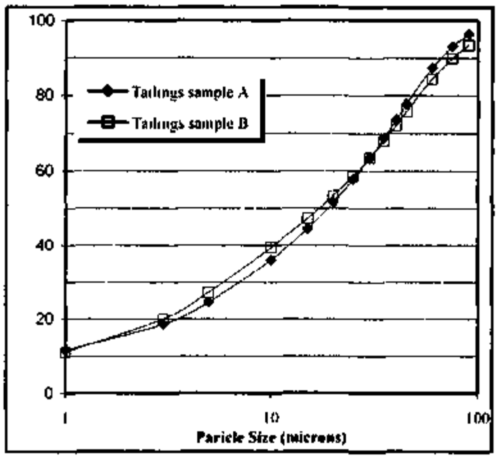


Figure I Particle size distribution of tailings samples A and B.

The grain size distribution of tailings is closely similar. Tailings sample A was found to have approximately 52 wt% finer than 20 (im and tailings sample B was found to have approximately 54 wt% finer than 20 (im, which indicates that both tailings can be classified as a medium size tailings material (Kesimaletal.2002).

These tailings generally produce a good paste fill, but typically have lower strength than the coarse tailings because of a higher waterxement ratio (Landriault2001).

The specific gravity of the tailings was also measured using picnometer. The results indicated that tailings sample A had a specific gravity of 4.82 and tailings sample B had a specific gravity of 4.10.

In addition, the main chemical element of the two tailings was determined by atomic absorption spectrometry, spectro photometer, and wet chemical analysis and are listed in Table 1.

Table I. Chemical composition of tailings samples A and B.

Element (symbol)	Tailings sample A	Tailings sample B (%)
MgO	0.45	1.00
Al_2O_3	1.44	3.90
SiO_2	3.26	10.88
CaO	0.74	1.43
Fe_2O_3	57.00	43 67
$S^=$	2.24	3.68
K_2O	0.14	0.24
Na_2O	0.26	0.22
NiO	0.13	0.17
TiO_2	1 04	0.68
Cr_2O_3	0.04	0.0.3
Mn_2O_3	0.02	0.10
P_2O_5	0.08	0.13
Loss on ignition	31.55	27.72
Total	98.49	93.85

The presence of sulphur species within cementitious material can causes a deterioration in quality for construction works (e.g., mortars and concrete in the building trade) (Ducic and Miletic 1987, Bernier et al. 1999, Santhanam et al. 2001). It has been observed in many sulphide-rich backfills.

The high sulphide and low cement contents enhance the reaction. Calcium-rich cements like ordinary portland cement have many disadvantages, especially at a long term due to their weak resistance to sulphate attack on the cement bonds (Ouellet et al. 1998, Benzaazoua et al. 1999).

The mineralogical composition of the tailings materials of A and B was determined by X-ray diffraction analysis (XRD), which provides determination of the crystalline mineral assemblage of a sample (Fig. 2 and 3). The relative proportions of the minerals are based on peak height.

The major mineral identified in tailings samples A and B is pyrite. The results are summarised in Table 2 identified as major, minor and trace quantities. (Table 2).

Table 2. Mineralogical composition for tailings.

Ciystalline Mineral Assemblage (*)			
Sample Type	Major	Minor	Trace
Tailings sample A	pyrite	dolomite	sphalerite. barite
Tailings sample B	pyrite	kaolinite. dolomite	barite. sphalerite

: lelative proportions based on peak height.

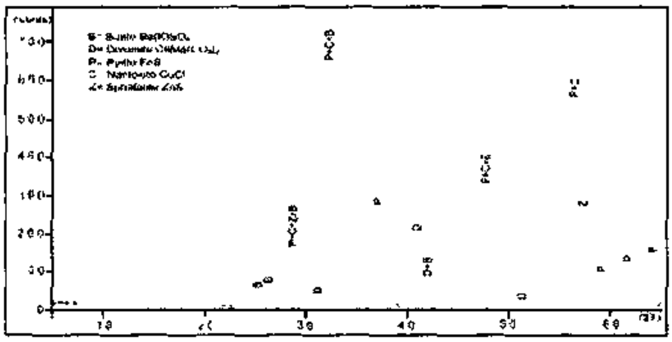


Figure 2. XRD analysis foi tailings sample A.

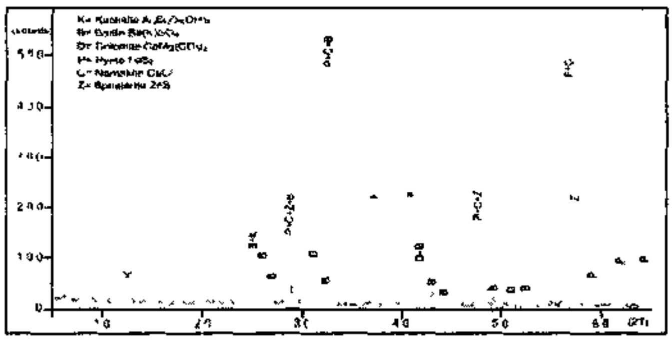


Figure 1 XRD analysis foi tailings sample B.

A series of tests was conducted to determine the solids content of specific slump values for both tailings. For this reason, uncemented mill tailings were mixed at slump consistencies of between 5.4" and 7.4". Thus, solids content of each tailings samples was determined. Figure 4 indicates a relationship between solids content and slump consistencies.

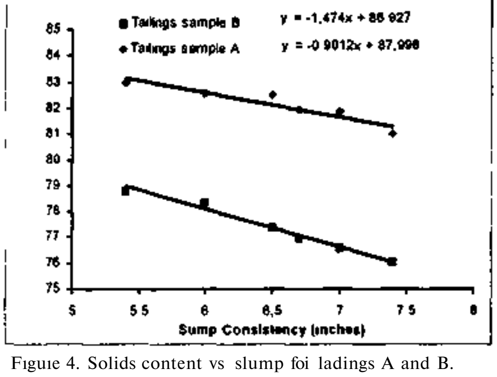


Figure 4. Solids content vs slump foi ladings A and B.

A series of Theological index tests was performed to gain an appreciation of the tailings potential for pipeline transport and to determine tailings properties. The index testing consists of a series of water retention, settling and modified slump cone tests designed to assess the colloidal properties of an uncemented material. In general, a granular material must have at least 15wt% finer than 20 microns to produce sufficient colloidal water retention to create paste-flow properties and can be transported through a borehole/pipeline by a fluid material with paste How properties (Landriault 2001).

The rheological index test results for tailings samples A and B are presented at Figure 5.

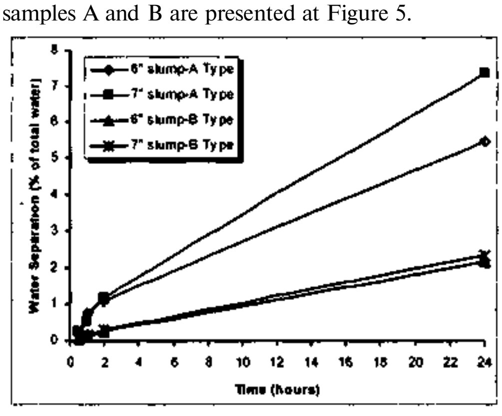


Figure 5. Water separation vs time foi tailings A and B.

2.2 *Binder characteristics*

Various binder types are used to increase the durability and the strength of the mixture. Backfill strength and curing period are directly dependent on the binder quality and their content. The increase in cement content generally results in a higher strength of paste backfilf In this study, PKÇ/B 32.5-R type Unye portland compose cement was used as binder. The mam chemical elements of PKÇ/B type binder are listed in Table 3.

Table 3. Chemical compositum of Unye portland cement.

Chemical Composition	PKÇ/B 32.5-R (%)
SiO;	32.X7
Insoluble residue	26.3 X
Soluble SiO	6.49
Al;0,	8 91
Fe^O,	3.83
CaO	44 02
MgO	1.41
SO,	1.99
Loss on ignition	4.06
Undetermined	2 91
Free CaO	0.26
Total	97.09

Binder costs can be a significant contribution to the operating costs of the mine (Grice 1998). Pozzolanic products such as fly ash and blast furnace slags can be used to increase the strength of backfill and reduce the binder consumption (Hassanı et al. 2001, Ouellet and Hassani 2002). Portland compose cement is a hydraulic binder which consists of 21-35 wt9f additives (blast furnace slag, silica, natural and industrial pozzolan, fly ash), 65-79 wt% clinker, 5 wt% minor additives, and calcium sulphate as the setting regulator (UÇS 2002).

3 METHODS

3.1 *Paste backfill mixture preparation*

Two different paste backfill mixture were prepared for tailings samples A and B. Proportions of between 3 and 7 wt% binder types and slump values between 6" and 7" were chosen for the tailings samples to make the various mixture of paste backfill. Water was added to bring the mix to the desired slump prior to casting the cylinders. Lake water was used as mixing-water.

HOBART A 200 model mixer (ASTM C-305) was used to homogenize paste backfill mixture consisted of tailings samples, cement and water (Fig. 6).

Figure 6 Hobart Mixer

The final slump, which corresponds to the height between the top of an initial state of the paste (moulded into a 6.0" height conic cylinders) and its final state (after removing the cone) was measured using the standardized ASTM CI43-90 (Fig. 7).

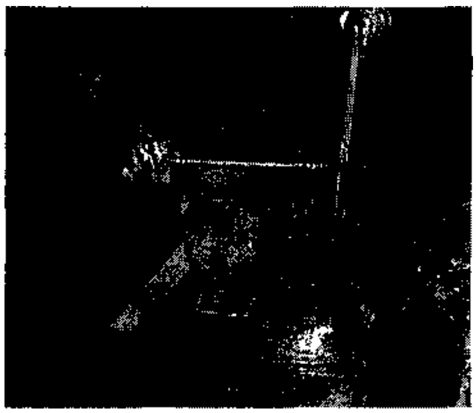
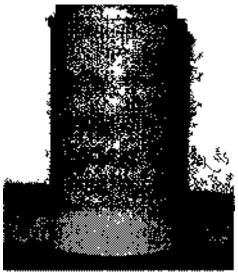


Figure 7. Détermination of slump value.

3.2 *Casting paste backfill cylinders*

The paste backfill mixtures were poured into plastic-cylinders with a diameter of 4" and a height of 8". Between seven and nine small diameter holes were drilled in the bottom of each cylinder mould so that excess water could drain and to simulate the free diainage that may occut when paste backfill was plated in a stope (Fig 8)

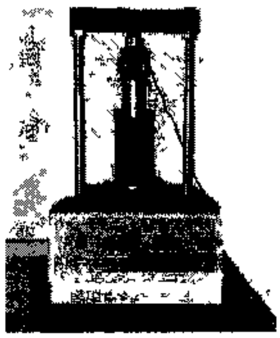


hguie 8 Plastic cylindei used in [he tests

After pouung the ditteient mixtuies into the cylindeis they weie sealed and cuied in a humidity chambei maintained at appioximately 95% humidity and 25"C temperatuie (this is similar to underground mine conditions) tor 28 days cuıng penod Aftei the curing penod paste backfill specimens weie tested by UCS tests

? ? *Uniaxial compiessive stienglh tests*

A total ot 135 backfill samples (78 and 57 samples tor tailings sample A and B. lespectively) were conducted to uniaxial compression stiength (UCS) tests using a digital mechanical pıess (ELE Multiplex 5 0) having a normal loading capacity of 50 kN and a displacement rate ot I mm per minute (Fig 9)



Fıgııe 9 ELE Mulıpłex 5 0

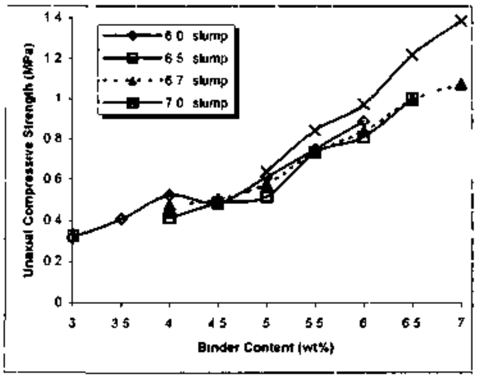
The two ends ot the samples weie fust ıectıfied to get plane suitace before tunning the tests The specimen's heıght-to-dıameter ıatıo was 2 Thiee cylindeis weie tested tor each cement and cunng period tor the paste pouied at between 6' and 7" slump consistencies and the ıesults averaged to provide tepiesentative results

4 RESULTS

The aim ot these strength tests mainly was to obtain optimum cement content and slump value between paste backfill samples A and B poured the different mixtuies

4 I Results of pa Me backfill ladings sample A

The UCS tests results obtained horn tailings sample A is shown in Fisuie 10



hguie l() UCS test ıesults toi paste backfill sample A at 28 cuııng penod

Fiom the Figure I0, the maximum value ot UCS obtained with the paste backfill sample A is always pıoportıonal to the binder proportion at a given slump value (6 0', 6 5", 6 7", 7 0")

The paste backfill sample at 7' slump value and 7 wtVr of cement content produced higher strength acquisition than that ot the other slump values alter 28 days cuıng penod It ıeached a value of about 1 387 MPa

4 2 Results of paste backfill tailings sample B

The UCS tests results obtained from tailings sample B is presented at Fıguıe I I

With 6 0 ' slump value, the paste backfill sample B having 7 wt% binder pioduced the highest strength ot 0 812 MPa altei 28 days ot curing penpd Howevei, with 7 0 ' slump value, the strength acquisition ot the paste backfill sample B is lower than that ot the paste backfill sample A with the same slump value

The îequired watei addition lor hydrated phases of the cement was 21 625 wt% tor the paste backfill sample B having 6 0' slump value and 7 wi<ff binder This was"17 450 wf/< tor the paste backfill sample A having the same slump value and bindet content. In other words, the paste backfill sample B seemed to have more water retention compared with the paste backfill sample A and therefore resulted in low strength acquisition.

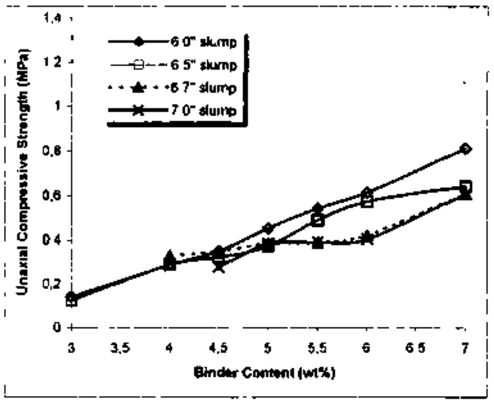


Figure 11. UCS test results for paste backfill sample B at 28 etiiing peiiocl.

The UCS test results showed that the paste backfill sample A produced strengths approximately between 1.5 and 2.5 times that of the paste backfill sample B at (he same binder content and slump value.

4.3 *Mineralogical and chemical characteristics*

The tailings sample A is dominated by iron oxide, Fe.0, (57%). Minor quantities of silicon dioxide. Si_2O (3.26%) and aluminium oxide, A1.0, (1.44%) were detected as well as trace amounts of magnesium, calcium, potassium, sodium, nicelium, titanium, chromium, manganese and phosphorous oxides (all less than 2%).

The tailings sample B arc also dominated by iron oxide, Fe_2O.i (43.67%)) and minor quantities of silicon dioxide, SbO (10.88%) and aluminium oxide, AI.Oi (3.90%), together with trace amounts of magnesium, calcium, potassium, sodium, nicelium. titanium, chromium, manganese and phosphorous oxides (all less than 2%).

The tailings samples A and B have more enough pyrite minerals according to the chemical analysis results. This means that the presence of sulphide minerals within cemented composites as well as the soluble sulphates have a deleterious effect on the strength of paste backfill due to sulphate attack at a long time. In addition, the tailings ample B seems to have higher silicate content than that of the tailings sample A. This makes the tailings sample B retain more water and affects negatively by reducing the strength of the paste backfill al a long term.

5 CONCLUSIONS

The purpose of this study was to investigate the effect of binder and tailings chemistry on the UCS of paste backfill after curing period of 28 days using tailings sample A and B.

According to the UCS test results, the paste backfill sample A with 7" slump value resulted in a higher strength acquisition than other slump consistencies. With a mixture containing 7 wt% cement content, cylinders poured with 7" slump indicated the highest strength development compared with other slump consistencies after 28 days curing period. This can be attributed to the need of potential water content (18.125 wt%) of 7 wt% cement content for binder hydration. In this point, it reached the highest *UCS* value of 1.387 MPa.

The paste backfill sample B with 6" slump value produced higher strengths. At 28 days curing period the UCS of 6" slump reached a value of 0.8 f2 MPa. However, the UCS results of the backfill sample B with 7" slump were much lower than those achieved for the backfill sample A with 7" slump. This could be interpreted the water retention of the backfill sample B.

Both tailings samples are sulphide-rich in terms of mineralogical characteristic. Therefore, they had a deleterious effect on the strength of paste backfill generating acid in the presence of water and oxygen.

Additionally, this study highlighted that the mechanical and rheological properties of cemented paste backfill depended on physical, chemical and mineralogical properties of the mill tailings, binder types and their proportions.

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