Consolidation characteristics of early age cemented paste backfill

Erol Yilmaz [a], Tikou Belem [a,b], Bruno Bussière [a], Mostafa Benzaazoua [a,b]
Université du Québec en Abitibi-Témiscamingue, Rouyn-Noranda, Québec, Canada
[a] *Industrial NSERC – Polytechnique – UQAT Chair on environment and mine waste management*
[b] *Canadian Research Chair on integrated management of sulphidic mine wastes by means of backfilling*

ABSTRACT

This paper presents a laboratory study undertaken to understand the effect of binder contents (0-control sample, 1, 3, 4.5 and 7 wt%) on one-dimensional (1-D) consolidation properties (e.g., coefficient of consolidation c_v, compression index C_c and recompression index C_r) of cemented paste backfill (CPB) at curing ages of 0, 1, 3, and 7 days. Test results show that the behaviour of 1-D consolidation under time-dependent loading is greatly affected by the amount of binder used within CPB. C_c varies from 0.06 to 0.54 while C_r is between 0.0019 and 0.0081. c_v decreases from 2.73×10^{-3} to 3.46×10^{-3} cm^2/s over time due to the gradual formation of cement bonds during hydration.

RÉSUMÉ

Cet article présente une étude expérimentale entreprise pour comprendre l'effet de la proportion de liant (0-échantillon témoin, 1, 3, 4.5 et 7%) sur les propriétés de consolidation unidimensionnelle (coefficient de consolidation c_v, indice de compression C_c et indice de ré-compression C_r) de remblai en pâte cimenté aux temps de curage de 0, 1, 3, et 7 jours. Les résultats montrent que le C_c varie entre 0.06 et 0.54 tandis que le C_r se situe entre 0.0019 et 0.081. Globalement, c_v diminue de 2.73×10^{-3} cm^2/s à 3.46×10^{-3} cm^2/s avec le temps dû à la formation progressive des liens de cimentation.

1 INTRODUCTION

Every day, a vast amount of sulphide-rich mill tailings are generated in mineral processing plants worldwide. These tailings can cause harmful impacts on the environment if they are not properly managed. Thus, how to treat such tailings effectively and economically has always been a major issue facing all mining operations (Aubertin et al. 2002; Yilmaz, 2007). Due to its rapid rate of delivery and placement (as compared to other forms of backfill such as hydraulic fill and rock fill) and the fact that mill tailings are recycled as backfill, cemented paste backfill (CPB) is a promising tailings management technique for mines.

From an ever higher density dewatered tailings (65–90 wt% solids content), CPB are produced by mixing them with a hydraulic binding agent which can be a blend of two or more cements and mineral additives (0–10 wt%) to provide mechanical strength and stability, and water (typically lake water, recycled process water or tap water) to obtain the desired slump consistency (152–254 mm or 6–10") allowing the safe transport and placement of the final CPB material to the underground stopes (Landriault, 2001; Benzaazoua et al. 2004, Belem and Benzaazoua, 2008a). CPB offers numerous operational, environmental, and economic benefits: lower operating and rehabilitation costs, higher regional and local ground support, the option of placing a part (up to 60 wt%) of mine tailings to the stopes (thus reducing the volume of tailings to be stored on the surface), and the control of environmental pollution associated with the safe storage of sulphide-rich tailings under atmospheric conditions allowing the formation and release of acidic waters and heavy metals (Hassani and Archibald, 1998; Aubertin et al. 2002; Bussiere, 2007). As a result of these facts, CPB is now in quite wide use by most mines as an efficient and beneficial backfill method.

A number of studies regarding the physical, chemical and mineralogical characteristics of CPB ingredients (i.e. tailings, binder and water) on the strength gain and micro-structural properties have been conducted by focussing on the inter-relationship between particle size distribution, solids concentration, binder type and content, curing time and temperature, and pore structure (Benzaazoua et al. 1999; 2004; Belem et al. 2000, 2002; Kesimal et al. 2005; Klein and Simon, 2006; Ouellet et al. 2007; Fall et al. 2008, Belem and Benzaazoua 2008b). However, aspects linked with *in situ* properties and conditions that affect the CPB performance are not well known. In fact, the effects of during- and after-placement conditions (i.e. enhanced consolidation) on the quality and behaviour of fresh and hardened CPB cured under time-dependent loads are not sufficiently investigated (e.g., Belem et al. 2002, 2006).

It is common practice at most underground mines to place CPB sequentially (plug fill and residual fill), except for small-scale mines where fill placement is continuous and governed by a constant filling rate based on the plant capacity. In general, it is necessary for pouring an initial "plug-fill" of CPB material and then let it cure under self-weight consolidation during a couple of days (typically 2-7 days) for achieving a good cement bonding and to prevent a barricade failure during subsequent residual filling. Due to the gradual reduction of void ratio after consolidation, the stiffness of the backfill increases over time (Bussiere, 1993; Belem et al. 2002, 2006; Cayouette, 2003; Le Roux, 2004; Grabinsky and Bawden, 2007). In some cases, a "continuous" filling application may damage cement bonds and/or give rise to barricade failures due to excess strain and stress developed within the CPB during placement (Yumlu and Guresci, 2007). Consequently, it is of a great importance to understand self-weight and surcharge load consolidation characteristics of fresh CPB materials.

In this study, a new laboratory consolidation apparatus named CUAPS (curing under applied pressure system) that allows one-dimensional (1-D) consolidation testing on the CPB materials was developed (Benzaazoua et al. 2006). The originality of this work is that it focuses on relations between the effects of curing, void ratio, and binder content on the CPB quality and behaviour. More specifically, the influence of binder proportion and curing time on 1-D consolidation characteristics (e.g. coefficient of consolidation c_v, coefficients of compression index C_c and recompression index C_r) as well as resulting physical and geotechnical properties (e.g. void ratio e_f, degree of saturation S_f, water content w_f, settlement S_p, vertical strain ε_v and specific surface S_s). Five binder proportions (0-control sample, 1, 3, 4.5, and 7 wt%) and four curing times (0, 1, 3 and 7 days) were considered.

2 MATERIAL AND METHOD

2.1 Tailings sample characterization

Sulphide-rich mill tailings sample was collected from LRD mine in Quebec, Canada. The sample was received in sealed plastic containers to avoid any oxidation.

The laboratory analysis results show that the tailings sample has an average water content w of 23.4 wt%, a specific gravity G_s of 3.7, a specific surface S_s of 2170 m^2/kg, an optimum water content w_{opt} of 9.1 wt%, a maximum dry unit weight γ_{dmax} of 24.9 kN/m^3, a relative compaction R_c of 91 wt%, a liquid limit w_L of 23 wt%, a plastic limit w_P of 18 wt%, a liquidity index LI of 1 wt%, a plastic index PI of 5 wt%, and a clay activity A (simply defined as the PI divided by the percent of clay-sized particles present, < 2 µm) of 1. The Atterberg limit results showed that the tailings sample would be designated as CL-ML, silty clay.

A laser diffraction-type particle size analyzer (Malvern Mastersizer) was used to determine the tailings' particle size distribution (PSD) curves, as shown in Figure 1.

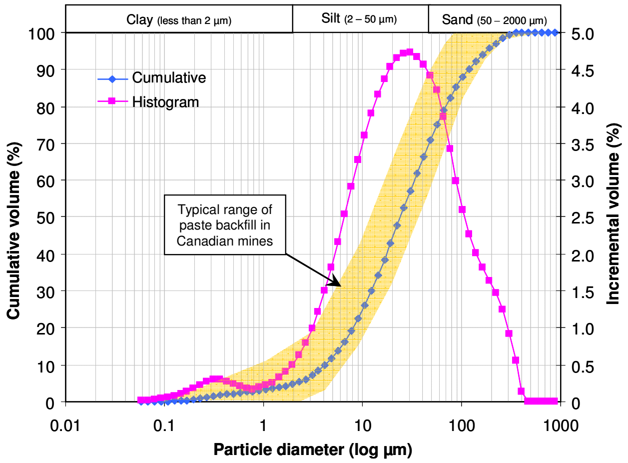

Figure 1. Particle size distribution (PSD) curves of the tailings sample, comparing with a typical range of PSD curves of 11 mine tailings sampled from Canadian mines

PSD results show that the sample contained only 4.7% of clay-sized particles. The most PSD fell in medium to fine sand and silt-sized particles. With the fines (< 20 µm) content of 44%, the sample is classified as a medium size tailings material (Landriault, 2001). Uniformity coefficient ($C_u = D_{60}/D_{10}$) and curvature coefficient ($C_c = D_{30}^2/D_{60}$xD_{10}) of the tailings sample are 7.9 and 1.1, respectively. Based on the USCS classification (Das, 2002), the tested tailings material is a low plasticity silt (ML),

Table 1 tabulates X-ray diffraction (XRD) analysis and ICP-AES analysis results of the studied tailings sample. It can be concluded from XRD analysis that the sample contains a high proportion of pyrite (47.05 wt%), mainly responsible for the high G_s of the tailings (3.7). The other major minerals are quartz (31.6 wt%), chlorite (8.9 wt%), paragonite (7.31 wt%) and muscovite (4.60 wt%). The ICP-AES analysis also indicates iron Fe (27.4 wt%) and sulphur S (24.9 wt%) are the most abundant elements identified within the tailings sample.

Table 1. Chemical and mineralogical analyses results

Element (ICP)	Grade (%)	Mineral (XRD)	Grade (%)
Aluminum, Al	2.8	Pyrite	47.05
Calcium, Ca	0.57	Quartz	31.6
Iron, Fe	27.4	Chlorite	8.9
Sodium, Na	0.3	Paragonite	7.31
Lead, Pb	0.1	Muscovite	2.92
Sulphur, S	20.6	Talc	1.34
Potassium, K	0.2	Gypsum	0.84
Zinc, Zn	0.35	Albite	0.04

2.2 Binding agent

The binder used for CPB preparation was a blend of 20 wt% of ordinary Portland cement (type I or PCI) and 80 wt% of ground granulated blast furnace slag (Slag). Five different binder contents were considered for each test series: 0 (control sample), 1, 3, 4.5 and 7 wt%. Table 2 tabulates the chemical and physical properties of the binder used in the mixtures.

Table 2. Chemical composition and physical properties

Properties	CPI	Slag	PCI-Slag (20-80 wt%)
G_s	3.08	2.89	2.92
S_s (m^2/kg)	1580	3540	2840
Al_2O_3 (%)	4.86	10.24	8.39
CaO (%)	65.76	31.41	42.82
Fe_2O_3 (%)	2.44	0.55	0.64
MgO (%)	2.21	11.29	6.19
Na_2O (%)	2.11	2.01	2.03
SO_3 (%)	3.67	3.27	3.35
SiO_2 (%)	19.51	36.22	30.91
Hydraulic index	0.36	1.09	0.80

The hydraulic index ($[SiO_2+Al_2O_3]/[CaO+MgO]$) values of the binders are 0.36 and 1.09 for PCI and Slag binders, respectively. Metallurgists classify slag as either basic or acidic: the more basic the slag, the greater its hydraulic activity in the presence of alkaline activators (Lea and Hewlett, 2000). Physical characterization indicates that the specific surface area S_s and the specific gravity G_s for Slag binder and PCI are 3540 m^2/kg and 1.58, and 2890 m^2/kg and 3.08, respectively.

2.3 Mixing water

Two types of water, the mine recycled process water and tap water were used for preparing CPB mixtures and their chemical and geochemical compositions are listed in Table 3. The mine recycled process water is very highly aggressive with respect to sulphate content (4882.8 ppm) but also contains calcium Ca of 559 ppm because of the addition of lime during the milling. Tap water used within the CPB mixture contains a Ca concentration of 40.9 ppm and a magnesium Mg concentration of 2.27 ppm.

A Benchtop pH/ISE meter Orion Model 920A coupled with a Thermo Orion Triode combination electrode (Pt-Ag-AgCl; Orion Inc.) was utilised for the pH, redox potential (Eh) and electrical conductivity (EC) measurements. In addition, Table 3 gives the pH, Eh and EC parameters for recycled process and tap waters.

Table 3. Chemical and geochemical analyses results

Parameter	Recycled process water	Tap water
Al (ppm)	0.212	0.01
Ca (ppm)	559	40.9
Fe (ppm)	0.011	0.066
Mg (ppm)	1.83	2.27
Si (ppm)	0.891	0.901
SO_4^{2-} (ppm)	4882.8	137.8
pH	9.41	7.82
EhN (mV)	146.6	430.7
EC (mS/cm)	7.42	0.274

2.4 Mixing, pouring, and curing of paste backfills

The required amounts of CPB ingredients such as mine tailings, cement and water) were prepared in a Hobart mixer (Model No D 300-1). The mixing procedure was as follows: to ensure the homogeneity of the final paste material, tailings, accompanied by little water were first mixed by a rigid "B" stainless beater for 4 minutes at a low speed of 54 rpm (speed 1), then added the cement and mixed by a floppy "D" wire whip for 4 minutes at a medium speed of 100 rpm (speed 2) and later added the remaining water to the premixed materials, and mixed with the same beater for 4 minutes at a high speed of 183 rpm (speed 3). Consequently, the total mixing time for CPB materials was 12 minutes. Each CPB mix has a typical water content of 28.2 wt% (corresponding to a solids concentration of 78 wt%) and diverse binder contents (0, 1, 3, 4.5 and 7%). CPB containing 1, 3, 4.5 and 7 wt% binders have a water-to-cement ratio of 27.8, 9.7, 6.5 and 4.3, respectively.

Each CUAPS cell or apparatus is then poured with the CPB material into a Perspex transparent cylinder in three equal thickness layers of ~68 mm. Each layer is rammed in 25 blows using a ¼" diameter steel rod in order to eliminate any large trapped air bubbles within the sample. After the paste was poured into cylinders, the top porous stone, the loading piston and platen connected with a pneumatic pressure line are then placed (Figure 2).

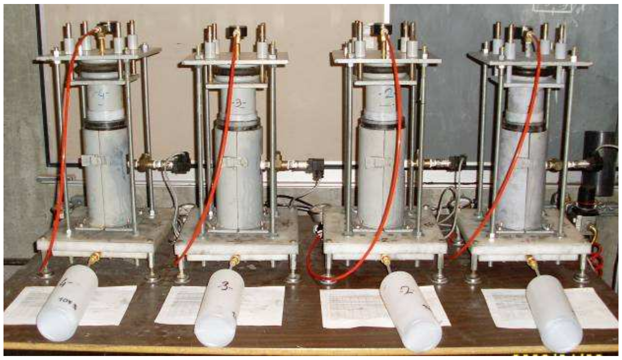

Figure 2. A series of 1-D consolidation tests conducted on CPB samples being cured for 0, 1, 3 and 7 days

A total of 20 test samples (16 cemented tailings and 4 uncemented tailings as control sample), having 4" (101.6 mm) in diameter and 8" (203.2 mm) height was prepared and cured for 0, 1, 3 and 7 days at a room temperature of 20-25ºC and at a relative humidity greater than 70%. It has been observed that, for a given binder content, the slump (paste consistency) values measured by means of Abrams cone slump test (ASTM C143 standard) ranged between 165 mm and 254 mm. Slump in this range was suitable for the safe placement without segregation, as testified by a number of underground mines worldwide (Hassani and Archibald, 1998).

2.5 One-dimensional consolidation tests

The one-dimensional (1-D) consolidation tests, based on the ASTM D2435 and D4186 standards were performed by using CUAPS (curing under applied pressure system) cells in order to investigate the effects of binder content and curing time on the evolution of CPB microstructure and to simulate *in situ* placement of lab-prepared CPB.

Basically, the CUAPS cell is a consolidometer having a polycarbonate cylinder as the CPB sample holder and a pneumatic pressure system, including porous stone discs to cover the top and bottom ends of the backfill sample to enable pore water to escape from CPB as compression is taking place. A complete description of the CUAPS cell employed in the experiments is beyond the scope of this paper. Further information on this multiple-aim laboratory tool and some related works can be found in Benzaazoua et al. (2006) and Yilmaz et al. (2006, 2008).

1-D consolidation tests are carried out on CPB samples under time-dependent loading. Immediately after samples are placed into the consolidometer, a pre-contact pressure of 15 kPa is applied in order to put the piston and the top porous stone in contact. Then, the pressure sequence of 0.5, 25, 50, 100, 200 and 400 kPa is applied to the CPB material and vertical displacement is recorded following a time interval of 0, 2, 4, 6, 8, and 10 hours. The load increment ratio (LIR) is 1 ($\Delta\sigma/\sigma$, where $\Delta\sigma$ = increase in pressure and σ = pressure before the increase). Pressure is applied following this LIR until the maximum pressure of 400 kPa is reached. During consolidation tests, test data such as pressure, deformation and time are concurrently and continuously recorded and stored in a data logging system. These data can be recovered and downloaded on a laptop for total test duration of 7 days. In the tests, at first, the samples are allowed to cure under self-weight consolidation until the predetermined curing time, and, later incrementally applied the pressure varying from 0,5 to 400 kPa to simulate time-dependent consolidation.

3 CONSOLIDATION TEST RESULTS

3.1 Effect of binder content on consolidation properties

Variations in the initial void ratio e_0 of uncemented and cemented backfills during 1-D consolidation tests versus applied pressure (*log p*) are presented in Figure 3.

Once can say from Figure 3 that, in spite of the major difference in the magnitude, the overall trend of the variation in the void ratio (Δe) versus pressure are similar and decreases with curing time. Table 4 summarizes the variation of the difference between the initial (e_0) and the final (e_f) void ratios for four binder contents and curing times. It can be observed that for a given curing time, Δe decreases with increasing binder. For a given binder content, Δe decreases with increasing curing time.

Table 4. Magnitude of variation of void ratio

Curing time	$\Delta e = e_0 - e_f$			
	1 wt%	3 wt%	4.5 wt%	7 wt%
0-day	0.25	0.24	0.23	0.18
1-day	0.24	0.23	0.21	0.17
3-day	0.21	0.19	0.18	0.08
7-day	0.20	0.08	0.06	0.05

Let us consider Δe as «resistance to consolidation» of CPB material. Consequently, a low Δe value means high resistance to consolidation, while a high Δe value means low resistance to consolidation. It can be noticed that this resistance to consolidation is highest for the 7-day curing time which can be explained by the strength development because of the gradual formation of cement bonds during hydration.

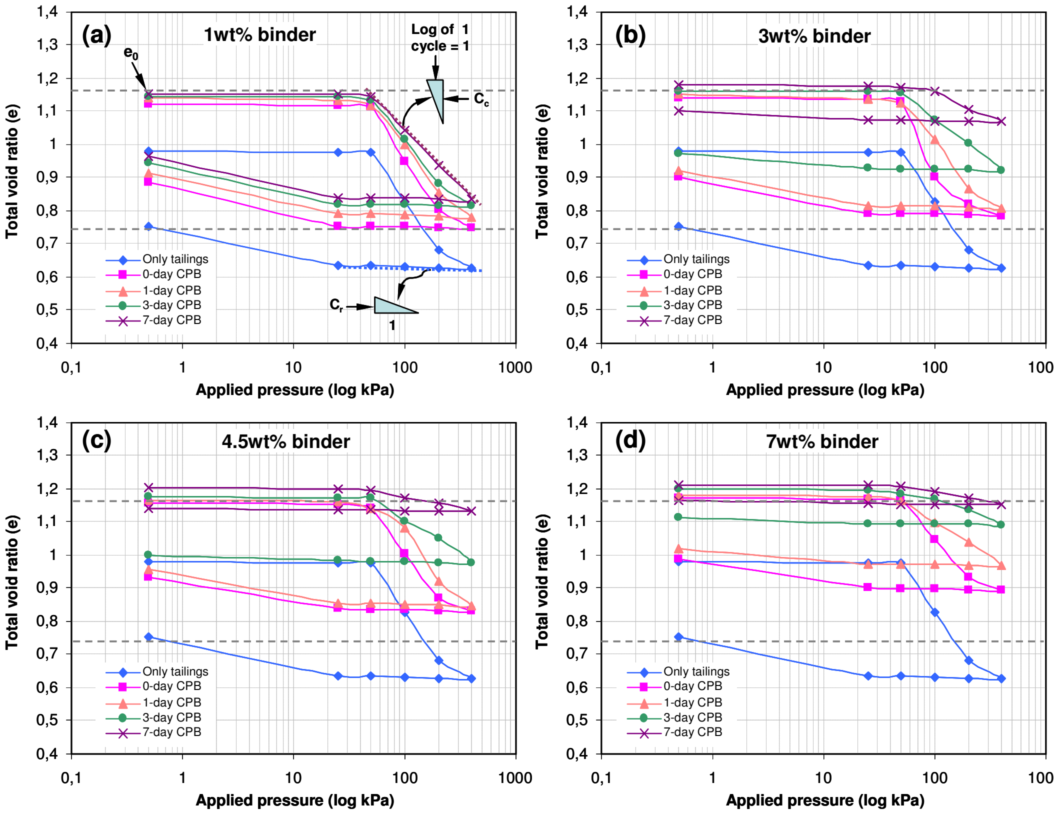

Figure 3. Consolidation curves of CPB samples: a) 1 wt%, b) 3 wt%, c) 4.5 wt% and d) 7 wt% binder

3.2 Evolution of compressibility parameters

Compressibility parameters (i.e. compression index C_c, recompression index C_r, and coefficient of consolidation c_v) are obtained from the linear portions of consolidation curves in Figure 3.

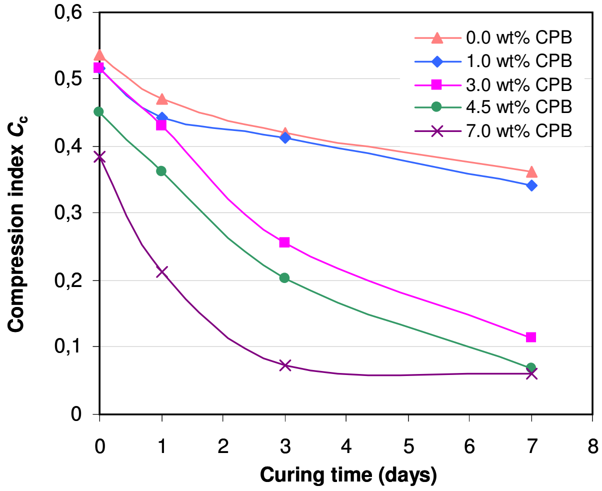

Figure 4. Compression index vs. curing time

Figure 4 shows that the compression index C_c of CPB material decreases non-linearly with the increase of curing time, regardless of the binder content. In the other hand, the rate of decrease in C_c with curing time is higher with the increase of the binder content because the CPB matrix becomes increasingly rigid. By increasing the binder content from 0 wt% to 7 wt%, the C_c value is reduced by about 30% and 83% for 0-day and 7-day curing time, respectively. For the CPB with binder content of 7 wt%, the C_c value is reduced by 82% while for the binder content of 1 wt% this reduction is about 34%.

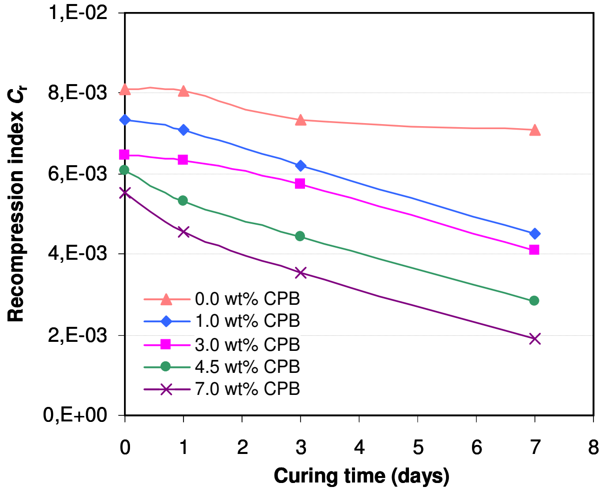

Figure 5. Recompression index vs. curing time

Figure 5 shows the variation of C_r with curing time. It can be observed that the C_r value decreases linearly with the increase of curing time, regardless of the binder proportion. This linearity seems to relate the evolution of C_r to the elastic properties of CPB material. Calculated C_r values are very low compared to C_c values. This can be explained by the fact that once the CPB is compressed (packed) the recompression phase affects very little its skeleton.

4 DISCUSSION

4.1 Calculated coefficient of consolidation c_v

Figure 6 shows the variation of coefficient of consolidation c_v with curing time. c_v was estimated from the square root of time or Taylor's method ($c_v = 0.848 \ast H_{dr}^2/t_{90}$). It can be observed that value c_v decreases with the increase in curing time, regardless of the binder content. Also, for a given curing time, the c_v value slightly increases with the increase of binder content.

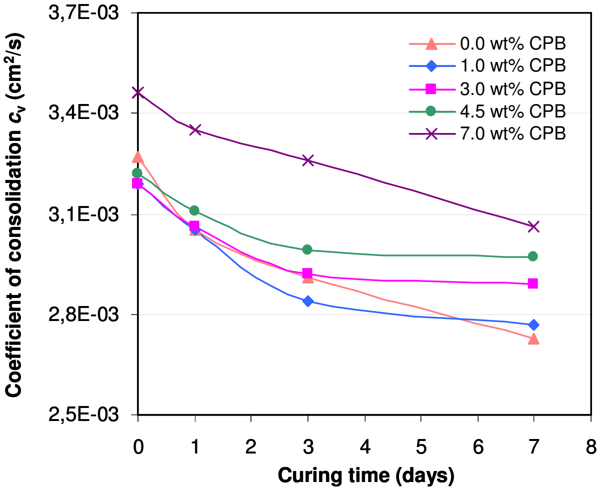

Figure 6. Variation of CPB c_v with curing time

4.2 Calculated hydraulic conductivity k_{sat}

Figure 7 shows the calculated CPB theoretical saturated hydraulic conductivity k_{sat} ($= c_v \ast m_v \ast \gamma_w$) from values c_v and coefficient of volume compressibility m_v (Taylor's method) values. The overall trend is similar to that of the variation in compression index (C_c) with curing time (see Figure 4). It can be noted that for the binder content varying from 0% to 4.5% by dry mass, the calculated k_{sat} decrease quasi-linearly with the increase of curing time. This k_{sat} decrease becomes non-linear when the binder content used in the CPB mixture is of 7 wt%. Previous work done by Godbout (2005) demonstrated that the measured k_{sat} decreases non-linearly with the increase of curing time in the contrary of what was calculated in this study.

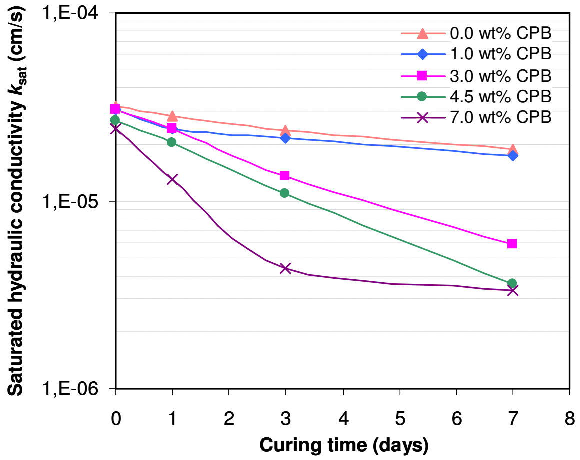

Figure 7. Calculated CPB k_{sat} vs curing time

However, data presented in Figure 7 are overall in the same orders of magnitude as those obtained by Godbout (2005) for identical binder type, binder content and curing times, even if they are slightly lower. But in the literature it is stated that calculated k_{sat} is lower than measured k_{sat}. It should however be noted that the samples tested in the study done by Godbout (2005) were not consolidated in the contrary of the samples tested in this present study.

4.3 Evolution of the physical parameters

Figures 8 and 9 show the evolution of the final values of different physical index parameters calculated after 1-D consolidation tests performed on both tailings and CPB.

Figure 8a shows that binder content strongly affects the final void ratio e_f of consolidated CPB samples. Also, the increase in curing involves the increase of the final void ratio e_f. This is probably due to the precipitation and the formation of the hydration products within the CPB matrix. As an example, for 7wt% binder, e_f increases from 0.99 to 1.17 as curing time increases from 0 to 7 days. Figure 8b also indicates a variation of water content w_f with curing time. As the curing time increases from 0 to 7 days, CPB containing 1wt% and 7wt% binders reduces the w_f value from 23.5 wt% to 20.6 wt% and from 19.2 wt% to 14.1 wt%, respectively. Knowing that the initial water content w_0 is 28.2 wt%, the first major drop of water content can be explained by water drainage due to stress application (0.25 to 400 kPa). In terms of final degree of saturation (S_{rf}) this corresponds to a reduction of the initial degree of saturation (S_{ri} = 100%) by 10% for 1wt% binder and by 21% for 7wt% binder. The rest of the reduction (~7% and 15% for binder contents of 1 wt% and 7wt%, respectively) can be attributed to binder hydration. It can also be noted that the binder type used (CP10-slag/20-80) and especially 7wt% binder seems to support the mixture water drainage of fresh CPB.

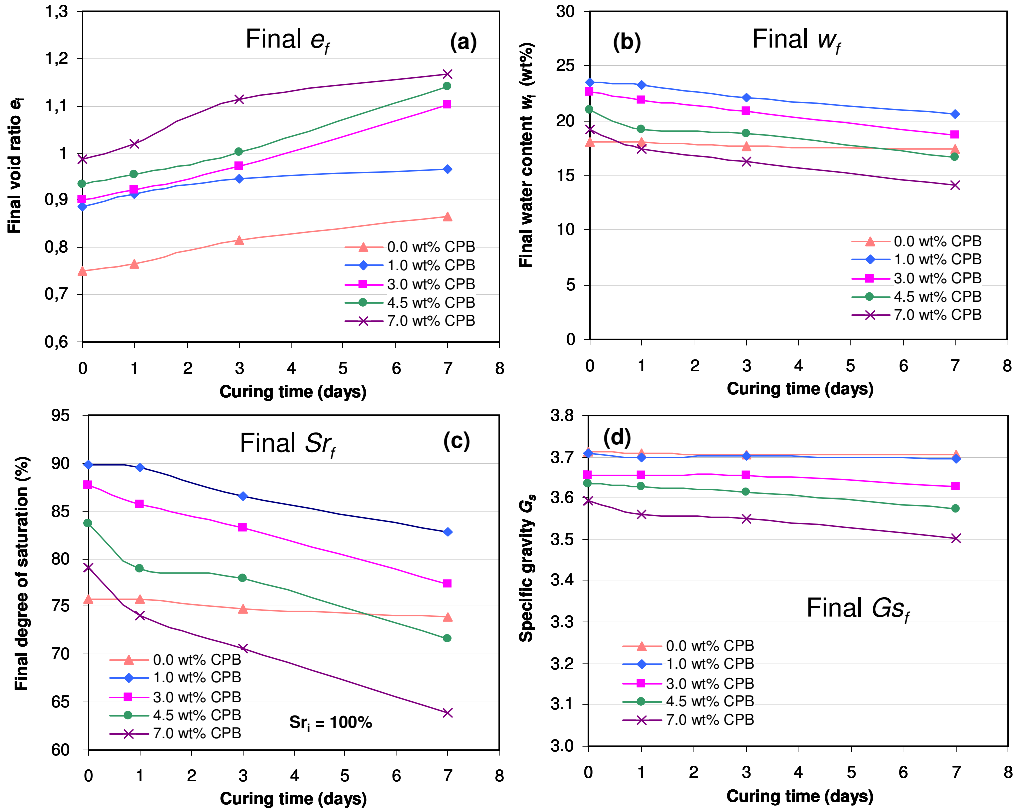

Figure 8. Evaluation of the CPB final index properties as a function of curing time; a) void ratio, b) water content, c) degree of saturation, and d) specific gravity

The reduction of the paste backfill water by drainage, in fact, gives rise to a more dense structure (higher solids concentration) having a lower final degree of saturation S_r, as shown in Figure 8c. It can be observed that as the binder content increases from 1 to 7 wt%, S_r decreases from 98% to 72% for 0-day curing time, and 79% to 64% for 7-day curing time. Figure 8d shows that the specific gravity varies very slightly and remain almost constant with the curing time and binder content. For example after 7 days curing time, G_s slightly decreases from 3.7 to 3.64 when the binder content is increased from 0 to 7 wt%.

Figure 9a shows that vertical strain ε_v decreases with increasing curing time, depending a lot on the amount of binder used in the CPB mixture. This is because there is a progressive formation of cement bonds with curing time and which develop the material stiffness and prevent the deformation. The exactly same observations were made for the primary settlement (Figure 9b).

Figure 9c shows the evolution of cumulative drainage water W_d as a function of curing time. It can be observed that as for the vertical strain ε_v, the cumulative drainage water significantly decreases with the increase of curing time and depends much on the binder proportion. This is most probably due to the increase of CPB matrix stiffness with curing time, which allows less drainage water volume to be collected once the pressure was applied (p = 400 kPa) and, at early ages (< 5 days), hydration reactions took place. For the CPB sample containing 7wt% binder, W_d decreases drastically from 18.6% to about 3% when the curing time increases from 0 to 7 days.

Finally, the variation of the specific surface area S_s of CPB samples as a function of curing time is illustrated in Figure 9d. The overall trend is that S_s value increases proportionally with increasing binder content because of the gradual formation of the cement hydration products which eventually filled the void space.

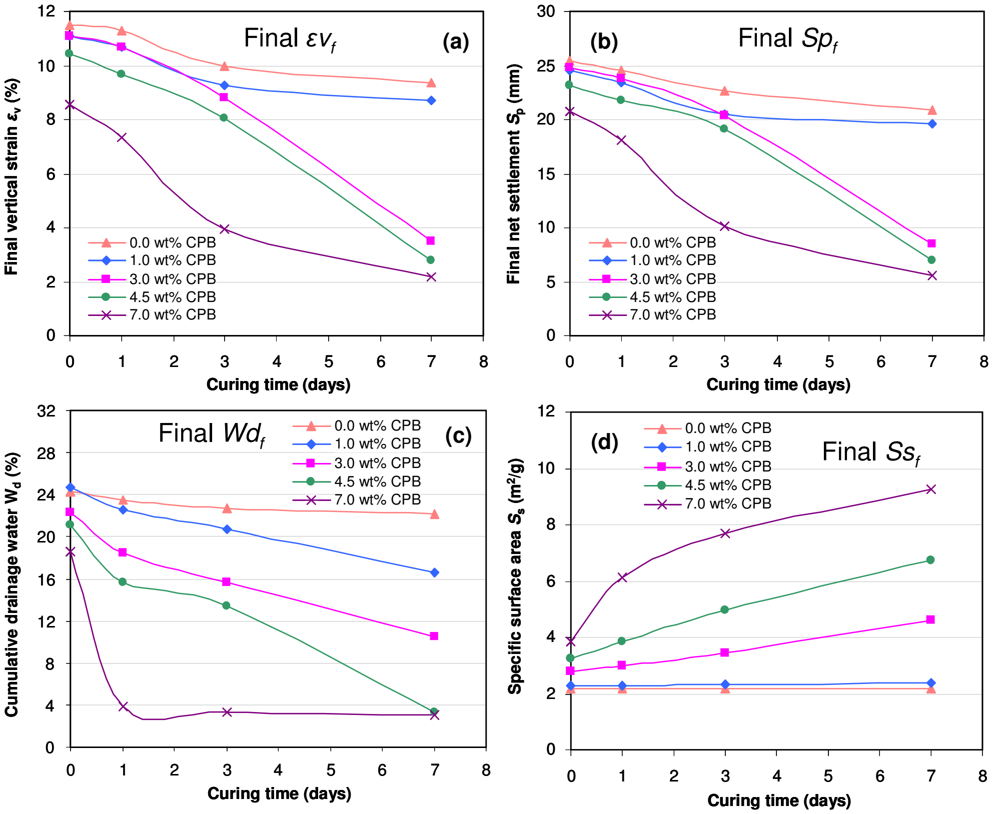

Figure 9. Evaluation of the CPB final index properties as a function of curing time; a) strain, b) settlement, c) cumulative drainage water, and d) specific surface

5 CONCLUSION

This study presents the effects of curing time and binder content on 1-D consolidation characteristics and resulting hydraulic properties (e.g. saturated hydraulic conductivity k_{sat} and degree of saturation S_r) of early age CPB. The main conclusions from this work are as follows:

1. Coefficient of consolidation c_v is greatly affected by the CPB binder content as a function of curing time. Overall trend is that c_v increases with the increase of binder content and decreases with curing time.
2. Compressibility parameters such as compression index C_c and recompression index C_r decreases as the curing time increases.

3. The calculated saturated hydraulic conductivity k_{sat} (based on Taylor's method) and degree of saturation S_r decrease with increased curing time and are in good agreement with the measured values from the literature.

Finally, this study has shown that the knowledge of 1-D consolidation of the CPB materials can effectively help on the understanding of their placement and curing process during backfilling. More importantly, it brings a light on the effect of consolidation on CPB properties that can help operators to make a very efficient CPB design for underground hard rock mines.

ACKNOWLEDGEMENTS

This research was partly financed by the Canada research chair on *Integrated management of sulphidic mine wastes by means of backfilling* and the NSERC-Polytechnique-UQAT industrial chair on *Environment and mine wastes management*. The authors would like to thank the financial support provided for the manufacture of lab test setups by Canadian Foundation for Innovation (CFI). Special thanks are due to Pierre Trudel of G+*Plus* Industrial Plastics Inc. for his collaboration and help during setups' modification. Special thanks are extended to URSTM chemists and technicians, principally David Bouchard and Nil Gaudet for their technical support.

REFERENCES

Aubertin, M. Bussière, B. and Bernier, L. 2002. *Environnement et gestion des résidus miniers,* Presses Internationales Polytechnique, Montréal, QC, Canada.

Belem, T. Benzaazoua, M. Bussière, B. 2000. Mechanical behavior of cemented paste backfill. *53rd Canadian Geotechnical Conf.,* Montreal, Canada, 1:373-380.

Belem, T. Benzaazoua, M. Bussière, B. and Dagenais, A.M. 2002. Effects of settlement and drainage on strength development within mine paste backfill, *Tailings and Mine Waste'01,* Vail, CO, 139-148.

Belem, T. El Aatar, O. Bussière, B. Benzaazoua, M. Fall, M. Yilmaz, E. 2006. Characterization of self-weight consolidated paste backfill. *Paste and Thickened Tailings'06,* ACG, Limerick, Ireland, 333-345.

Belem, T. and Benzaazoua, M. 2008a. Design and application of underground mine paste backfill technology, *J. Geotech. Geol. Eng.* 26(2):147-174.

Belem, T. and Benzaazoua, M. 2008b. Predictive models for prefeasibility cemented paste backfill mix design. Post-Mining 2008. February 6-8, Nancy, France, 1-13.

Benzaazoua, M. Ouellet, J. Servant, S. Newman, P. and Verburg, R. 1999. Cementitious backfill with high sulfur content: physical, chemical and mineralogical characterization, *Cem. Concr. Res.,* 29(5):719-725.

Benzaazoua, M. Fall, M. Belem, T. 2004. A contribution to understanding the hardening process of cemented pastefill, *Miner. Eng. J.* 17(2):141-152.

Benzaazoua, M. Belem, T. and Yilmaz, E. 2006. Novel lab tool for paste backfill, *Can. Min. J.* 127(3):31-31.

Bussière, B. 1993. Evaluation des propriétés hydrogéologiques de résidus miniers utilisés comme barrières de recouvrement, *M.Sc. Thesis,* Université de Montréal, École Polytechnique, Canada, 1-171.

Bussière, B. 2007. Colloquium 2004: Hydro-geotechnical properties of hard rock tailings from metal mines and emerging geo-environmental disposal approaches, *Canadian Geotechnical Journal,* 44(9):1019-1052.

Cayouette, J. 2003. Optimization of the paste backfill plant at Louvicourt mine, *CIM Bull.,* 96(1075):51-57.

Das, B.M. 2002. *Soil mechanics laboratory manual,* 6th ed., Oxford University Press, New York, USA.

Fall, M. Benzaazoua, M. Saa, E. 2008. Mix proportioning of underground cemented tailings backfill. *Tunnelling and Underground Space Technology*, 23(1):80-90.

Helinski, M. Fahey, F. and Fourie, A.B. 2007. Numerical modeling of cemented paste backfill deposition, *J. Geotech. Geoenvir. Engrg.,* 13(10):1308-1319.

Godbout, J. 2005. Évolution des propriétés hydriques des remblais miniers cimentés en pâte durant le curage. *MSc Thesis,* Ecole Polytechnique de Montréal, 213 p.

Grabinsky, M.W.F. and Bawden, W.F. 2007. In situ measurements for geo-mechanical design of cemented paste backfill systems, *CIM Bulletin,* 100(1103):1-8.

Hassani, F.P. and Archibald, J.F. 1998. *Mine backfill hand book,* CIM, Montreal, Quebec, Canada.

Hsu, T.W. and Lu, S. 2006. Behavior of one-dimensional consolidation under time-dependent loading, *Journal of Engineering Mechanics,* 132(4):457-462.

Kesimal, A. Yilmaz, E. Ercikdi, B. Alp, I. and Deveci, H. 2005. Effect of properties of tailings and binder on the short and long terms strength and stability of cemented paste backfill, *J. Mat. Let.,* 59(28):3703-3709.

Klein, K. and Simon, D. 2006. Effect of specimen composition on the strength development in cemented paste backfill, *Can. Geotech. J.,* 43(3):310-324.

Landriault, D. 2001. Backfill in underground mining: Underground mining methods engineering basics and case studies, Littleton, CO, Chapter 69:601-614.

Lea, F.M. Hewlett, P.C. 2000. *Lea's chemistry of cement and concrete,* 4th ed., B-H College, London, 1-1092.

Le Roux, K.-A. 2004. In situ properties and liquefaction potential of cemented paste backfill. PhD thesis, University of Toronto, 1-271.

Ouellet, S. Bussière, B. Aubertin, M. and Benzaazoua, M. 2007. Microstructural evolution of cemented paste backfill: MIP results, *Cem. Conc. Res.,* 37:1654-1665.

Yilmaz, E. El Aatar, O. Belem, T. Benzaazoua, M. and Bussiere, B. 2006. Effect of consolidation on the performance of cemented paste backfill, *Underground Support'06,* AMQ, Val d'Or, Quebec, Canada, 1-14.

Yilmaz, E. 2007. How efficiently the volume of wastes produced from mining operations can be reduced without causing any significant environmental impact? *Environ. Synthesis Report,* UQAT, Canada, 1-45.

Yilmaz, E. Benzaazoua, M. Belem, T. Bussiere, B. 2008. Influence of applied pressure on the hydro-mechanical properties of cemented paste backfill, *Geotech. Geol. Eng.*, (submitted on 14 January).

Yumlu, M. and Guresci, M. 2007. Paste backfill bulkhead monitoring: A case study from Inmet's Cayeli Mine, Turkey, *CIM Bulletin,* 100(1103):1-10.