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Paste improvement at La Mancha's Frog's Leg underground mine

J Mgumbwa *La Mancha Resources Australia Pty Ltd, Australia*

T Nester *La Mancha Resources Australia Pty Ltd, Australia*

Abstract

La Mancha Resources Australia Pty Ltd's Frog's Leg Gold Mine is located approximately 20 km west of Kalgoorlie in Western Australia. The mine utilises long hole open stoping and cemented paste fill, to achieve full extraction of the orebody. The combined effects of high fines contents in the supplied reclaimed tailings, and very high water salinity, hampers the strength development and curing times of the paste fill, despite the high binder dosages. Given a decreasing gold price and a high operating cost environment, the need to identify areas where productivity and efficiency improvements can be made is paramount. Predominately due to the large volumes involved, paste backfill constitutes one of the largest costs to the underground operation, and therefore an area where even minor efficiency improvements can have a significant positive effect on mining costs. One of several improvement projects undertaken was to evaluate two paste additives, namely MM701 (supplied by BASF) and Acti-Gel® (supplied by Active Minerals) and their impact on paste flowability, compressive strengths, curing time and binder dosage rates.

1 Introduction

La Mancha Resources Australia's Frog's Leg Gold Mine is located within the Kundana mining district approximately 20 km west of Kalgoorlie in Western Australia. The mine has two main mineralisation zones; the Mist lode to the north and the Rocket lode to the south, which are joined by the link drive at the 8093 level (Figure 1). The mining sequence utilises long hole open stoping in a top-down (underhand), pillarless, continuous central access retreat, which is in transition to continuous end-on retreat sequence below the 7950 level. Cemented paste backfill was introduced at 8075 level in the Mist side and at 8025 in the Rocket side of the orebody to eliminate the need for leaving permanent ore pillars that provided the local and regional stability of the mined voids. Consequently backfill has become a critical component of mining cycle which allows high orebody recovery, and provides flexibility in terms of the stope extraction strategies.

Generally the mining cycle for stopes at Frog's Leg underground mine starts with a paste dig-out, paste rise, production blasting, bogging, backfilling and curing before commencing the next cycle. Curing time is the critical path which is determined by the developed uniaxial compressive strength (UCS) of the cemented paste backfill. The required UCS of the backfill depends on the size and geometry of the stope. Since self–weight stresses govern backfill design, the traditional design has been a free-standing wall requiring a UCS equal the overburden stress at the bottom of the filled stope (Belem & Benzaazoua 2008). Consequently the backfill poured at Frog's Leg mine must have adequate strength when free-standing stope faces and undercut backfilled stopes are exposed. This function has considerable impact on the required compressive strength and the desired curing time (Hassan & Archibald 1998) as the next stope in the sequence cannot be extracted until the paste backfill has achieved adequate strength to allow its exposure. Revell Resources Pty Ltd (2009) conducted numerical modelling to determine the strength that would be required for the paste fill exposure for various stope geometries at Frog's Leg underground mine. From this modelling and learnings from neighbouring mines using the same reclaimed tailings, an average of 750 kPa was found to be sufficient to allow horizontal exposure for most of the stope geometries. The current paste mix at Frog's Leg mine contains between 68-74% solid content of which 7% is low heat BGC (Australia) Pty Ltd (BGC) cement and the rest is underground hyper-saline water, which takes on average

21 curing days to develop 750 kPa. This has considerable impacts on stope turnover, production targets and economic efficiency.

Studies conducted by Kesimal et al. (2004), Fall et al. (2004), and Fall et al. (2005) have all shown that the mechanical properties of cemented paste backfill depends on the mix design and the characteristics of the tailings, binder and the type of water. The combined effects of high fines content in the supplied reclaimed tailings and very high water salinity hampers the strength development and curing times of paste backfill, despite the high binder dosage. Given a decreasing gold price and a high operating cost environment, the need to identify areas where productivity and efficiency improvements can be made is paramount. Predominantely due to the large volumes involved, paste backfill constitutes one of the largest costs to the underground operation, and therefore an area where even minor efficiency improvements can have a significant positive effect on mining costs.

This paper reports some of the initiatives to improve paste fill quality by introducing additives into the paste fill materials. The two additive products that were intoduced and investigated are the Mayco Minefill (MM701 supplied by BASF) and Acti-Gel® 208 (supplied by Active minerals). MM701 is a non-chloride liquid additive and Acti-Gel® 208 is a highly purified hydrous magnesium aluminum-silicate which is made from a process that creates pure, uniformly sized, rod-shaped mineral particles. The impacts of these products on paste flowability, curing time, uniaxial compressive strength and binder dosage was investigated. Several paste fill mix designs at varying binder dosage, solid contents and additives dosage were studied and evaluated to determine economical paste fill recipe. The objective was to optimise a mix design that will develop early strength to allow paste fill horizontal exposure within 14 curing days.

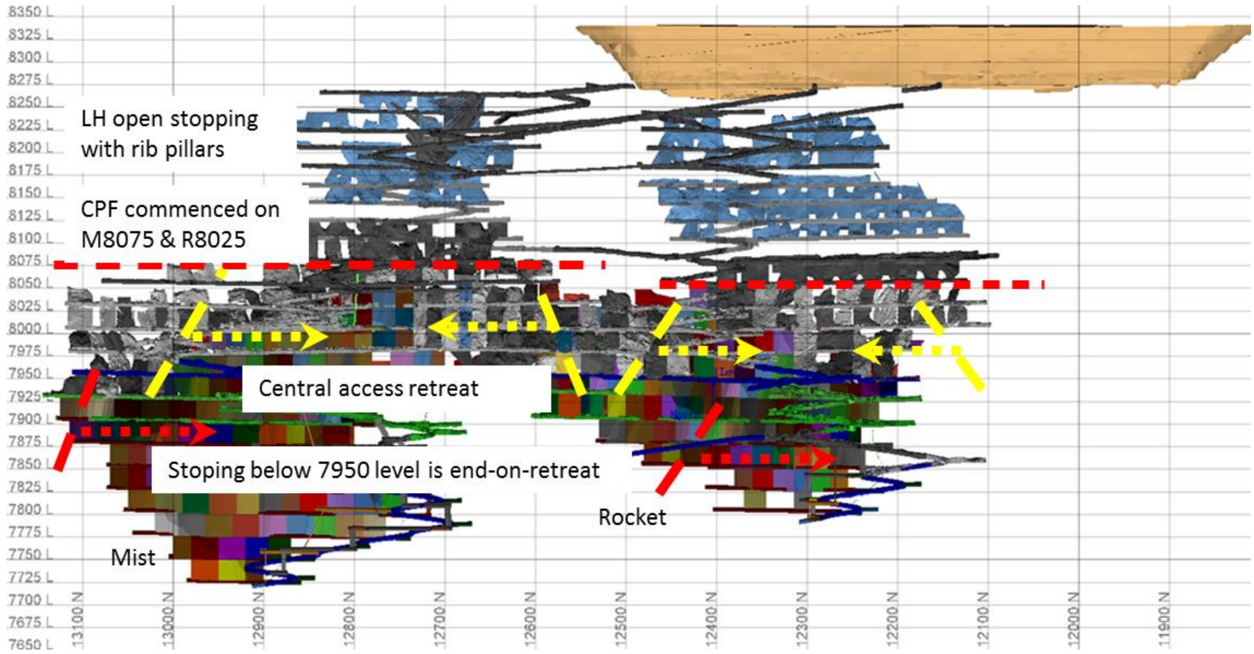

Figure 1 Frog's Leg underground mine stoping sequence

2 Paste fill materials and methods

2.1 Paste fill materials

The paste backfill materials at Frog's Leg underground mine consists of reclaimed tailings purchased from Barrick Gold's Kundana tailings storage facility (TSF), low heat cement supplied by BGC and Frog's Leg reclaimed underground hyper-saline water. Figure 2 illustrates a schematic diagram of paste fill materials that was used to prepare a new mix design. Each of these components contributes to the resulting paste backfill quality as discussed in the following sections.

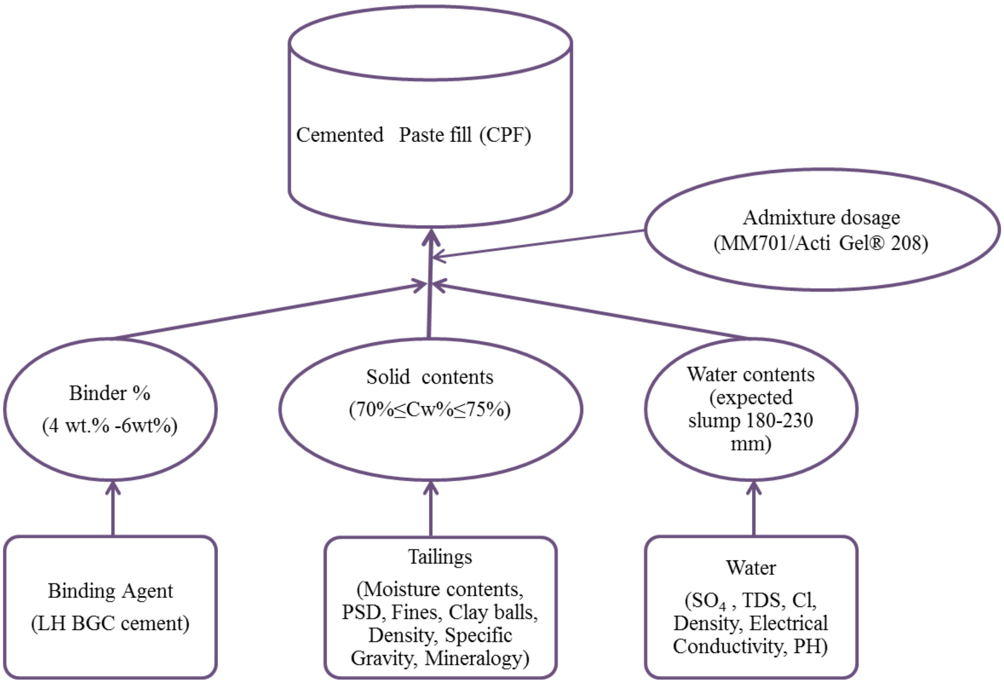

Figure 2 Schematic diagram of various paste fill components (modified from Benzaazoua et al. 2002)

2.1.1 Material characterisation

2.1.1.1 Tailings characterisation

The mechanical properties of cemented paste backfill (CPF) is directly attributable to the physico-chemical properties of tailings (Hassan & Archibald 1998). The important physico-chemical properties of tailings are the moisture content, specific gravity, mineralogy and the particle size distribution. The moisture content helps to calculate the correct amount of water to be added for a given tailings composition. One of the major issues in regards to the reclaimed tailings is the lack of control over the moisture content variation, as generally this variation introduces a major hurdle in achieving consistency of the paste fill, resulting in flowability problems. The moisture contents of the Kundana tailings ranges from 10% up to 17% with 12% being common.

The specific gravity of the solid material is the ratio between the unit weight of the solid and the unit weight of water and it determines the void ratio, porosity and the density of the resulting paste fill product. The specific gravity of Kundana tailings was determined to be in the range from 2.7-2.8 which is heavily influenced by the dominant minerals of the tailings which is quartz.

The mineral properties of the tailings influence a number of other characteristics, such as water retention, strength, settling characteristics and abrasiveness. Table 1 below illustrates the mineralogical analysis by x–ray diffraction (XRD) of the supplied tailings from Kundana, and as stated above the dominant mineral from the Kundana tailings is quartz and plagioclase minerals. Its high percentage in the tailings is likely to assist with the strength development of CPF however this will be affected by the micas minerals, i.e. muscovite and biotite, which have smooth and plate geometry and therefore make it difficult for the cement to form high strength aggregates.

Table 1 Mineral composition of tailings

Mineral	Chemical composition	Percentage
Quartz	SiO_2	44
Plagioclase (oligoclase)	$(Na, Ca)(Si,Al)_4O_8$	17
Muscovite	$KAl2(Si_3Al)O_10(OH,F)_2$	11
Chlorite	$(Fe, Mg, Al)_6(Si, Al)_4O_{10}(OH)_8$	14
Biotite	$K(Mg, Fe{+}{+})_3[AlSi_3O_{10}(OH, F)_2$	5
Dolomite	$CaMg(CO3)_2$	3
Calcite	$CaCO_3$	5
Pyrite	FeS_2	1

Particle size distribution analysis was conducted with the results indicating the fines content in the Kundana tailings are in the range from 45-55%, refer to Figure 3 overleaf. Landriault (1995) explains there are three size distribution categories for paste-backfill-mix design for most hard rock mine tailings throughout the world. These are; coarse (15-35% by weight (wt%) minus 20 microns), medium (35-60 wt% minus 20 microns) and fine (>60 wt% minus 20 microns), which categorises the Kundana tailings as medium in particle size distribution. Benzaazoua et al. (2004) note that all of the physical parameters (water proportion, humid and dry volumetric mass, weight solid percentage, volume of the solid, volume of voids, void index, degree of saturation, theoretical porosity and volumetric water content) are directly influenced by the particle size distribution of the tailings. Fall et al. (2005) conducted a study to investigate the effects of tailings fineness on the quality of cemented paste fill and found that:

- Coarse and medium tailings are more favourable for CPF strength gain.
- The UCS increases as the grain fineness decreases until approximately 35-55% of the fines content.
- At fines >55 wt% minus 20 microns the UCS slowly decrease with decreasing grain fineness.

Thus although Kundana tailings is in the medium size distribution which is favourable for CPF, its UCS is likely to be affected by high fines contents. As a rule of thumb, the minimum amount of particles finer than 20 microns in tailings to make paste fill is normally around 15-20% (Kesimal et al. 2005; Landriault 2001; Henderson et al. 2005). This range of fine particles is important to maintain the lamina flow in the reticulation system and helps to float the coarse grains in the slurry and achieve a non-settling state of slurry in pipe reticulation (Grice 1998).

Overall the impacts of high fines content in tailings are:

- Increased water demand to achieve the target rheology. However, higher water content in CPF reduces its strength development because of high water: cement ratio.
- Increase in the specific surface area per unit volume that must be cemented, leading to more cement consumption and high cost per volume of paste fill.

One methodology to overcome this issue is by blending tailings with fine aggregates or sand (Hasan, Suazo Fuentealba & Fourie 2013; Laudriault et al. 2000). In this case the size distribution is improved by producing coarse tailings resulting in better flowability and strength gain with lower binder dosage. However, the effectiveness of this approach is mainly governed by the availability of sand/aggregate and the potential benefits in terms of the costs.

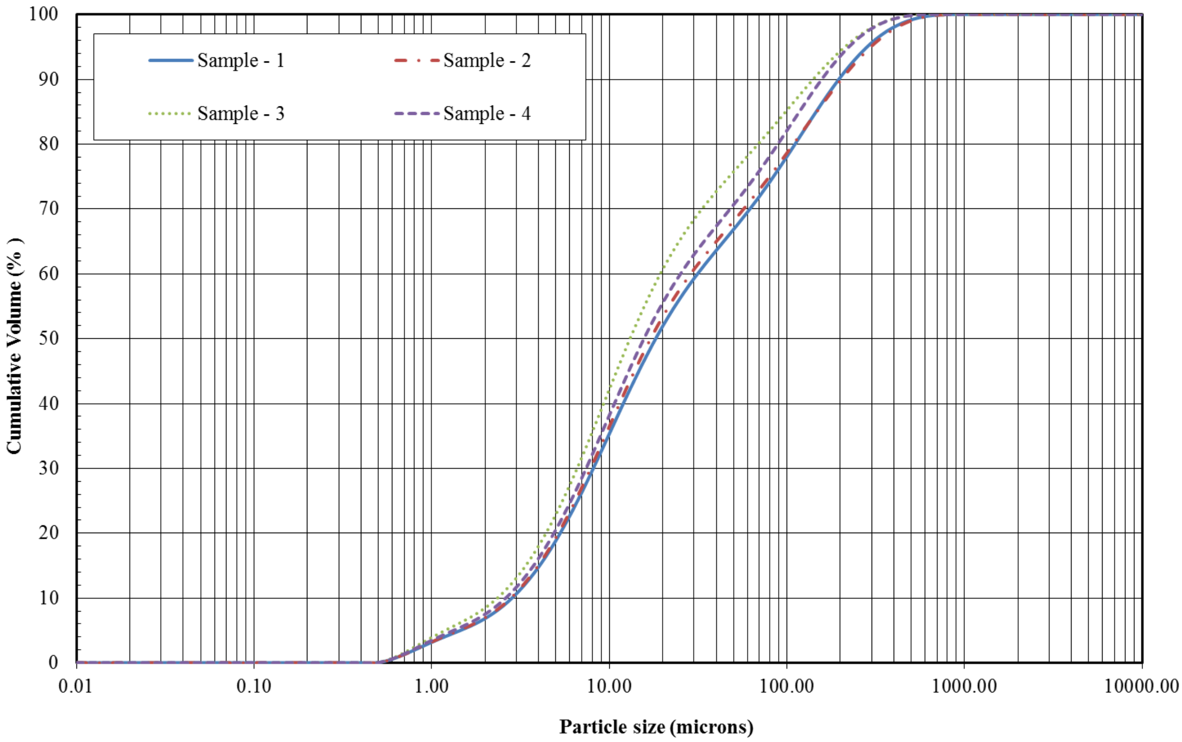

Figure 3 Particle size distribution of Kundana tailings

2.1.1.2 *Water*

Water is required to ensure proper hydration of the binding agents (Belem & Benzaazoua 2004), as without adequate binder hydration the fill cannot meet the required strength and stiffness. Water is also an important media for the paste fill slurry transportation into the reticulation system. The sampling analysis, as displayed in Table 2, indicates a high amount of chloride, sodium, sulphate ions and total dissolved solids (TDS).

The salinity of water negatively impacts the strength development of cemented paste fill due to the presence of high concentration of the TDS. Investigation conducted by Li et al. (2003) to study the impact of water salinity on the strength development of cemented paste backfill indicated a decrease in strength with increased water salinity. The difference in UCS for paste fill using potable water versus saline water, were in the order of 30-80% predominately due to the level of salinity. The impacts of water salinity on backfill strength development have also been reported on cemented hydraulic fill and cemented aggregate fill (Wang & Villaescusa 2001). Benzaazoua et al. (2002) conducted similar experiments to study the impacts of water salinity on strength of cemented paste backfill. Their experiment mainly concentrated on the presence of high quantities of sulphate ions in the paste fill mixing water with the cement used being normal Portland, fly ash and slag based cements. Again, this study demonstrated significant strength reduction for the samples that were prepared using water with high sulphate ions, i.e. high salinity.

Bellmann et al. (2006), attributes when the sulphate content in water is higher than 10,000 mg/L, a sulphate attack can be expected which is characterised by massive and harmful precipitation of secondary gypsum and ettringite (swelling phases). This excess volume is unable to fill capillary pores, as gypsum and ettringite crystals become much larger than the pores, which leads to expansion and microcracking of cured paste backfill. Benzaazoua et al. (2002) and Bellmann et al. (2006) suggest the most recognisable concept to increase resistance to sulphate attack in concrete is to decrease porosity (high cement content, low water-cement ratio) and the use of more resistant types of binders (sulphate-resisting Portland cement, with the addition of pozzolans and blast furnace slag). Both of these approaches have been adopted and applied at Frog's Leg for cemented paste backfill with the use of low heat cement which is a 35:65 blend ratio of Portland cement and ground, granulated blast furnace slag and the use of high cement contents of 7%. The main challenge has been to find an alternative approach that will enable a reduced cement content, which is the highest cost component in the CPF, without compromising the required mechanical properties. Reducing binder consumption to provide economical backfill system is the main theme of this work.

Table 2 Chemical and mineralogical analysis of underground water

Analyte	Quantity	Units
Ca	722	mg/L
Cl	110,000	mg/L
Electrical conductivity	19,300	mS/m
Fe	0.089	mg/L
K	341	mg/L
Mg	10.100	mg/L
Na	75,500	mg/L
SO_4	22,000	mg/L
Total solids in suspension (TSS)	12	mg/L
Total dissolved solids (TDS)	210,000	mg/L
Density	1.15	t/m^3
pH	7.1	

2.1.1.3 Additives

Additives are materials other than water, aggregates, hydraulic cement and fibre reinforcement used as an ingredient of concrete or mortar and added to the materials immediately before or during its mixing (ASTM C125 (2) from Henderson and Revell 2005). Additives are mostly applied in the concrete industry to enhance specific performance properties of the cement, and in recent years the mining industry has developed more of an interest in additive application in CPF. Increased interest into the use of additives in CPF is being driven by increased depth and complexity of underground mines and the need to reduce backfill costs. The increased adoption of CPF within the industry results in a wide range in the consistency and quality of the locally sourced fill components, and the resulting need to control a number of variables during the CPF's construction, transportation and placement. Ouellet (2001) recognised that additives add to the cost of concrete but the benefits gained through their use can represent savings on the overall operation. Additives can benefit the physical, chemical and mechanical properties of concrete but should never be used without first testing and establishing the implication on cost and performance (Henderson & Revell 2005; Millette et al. 2002). Millette et al. (2002) attributes that additives should be able to:

- Reduce water content,
- produce high early and ultimate strengths,
- increase compressive and flexural strength,
- increase cohesion,
- reduce segregation in a high density hydraulic fill and paste fill,
- improve pumpability and workability,
- increase slump and flowability,

- adjust cement setting time,
- reduce shrinkage and creep; and
- reduce the abrasiveness of fill flowing in pipelines.

There are various types of additives that can perform different functions in the backfill. However, their effectiveness will vary depending on dosage and the constituents of the backfill mix design. The dosage rate for the MM701 additive was initially investigated at the Western Australian School of Mines (WASM) in 2011 and its impact on a binder content of 6.5%. The effectiveness and dosage rate of Acti-Gel® 208 additives in CPF had never been evaluated at Frog's Leg therefore, a full investigation of this product was required.

2.2 Methodologies

2.2.1 Sample preparation

Various paste fill mix designs were prepared following the guidelines presented by Belem and Benzaazoua (2008) and Hassan and Archibald (1998). This consisted of screened tailings supplied from Kundana TFS sampled at the paste plant stockpile. The moisture content of the tailings samples were determined 24 h prior to the mixing as per Australian Standard (AS) 1289.2.1.1-2005 'Determination of the moisture content of a soil – oven drying method' (Standards Australia 2005). The weight of each component of the paste fill mix was measured and mixed using a Hobart machine for about 10-15 minutes. After mixing, the consistency of the paste fill was determined by measuring the slump height, and as a guideline the target slump was set to a range of 180-230 mm using a full size slump cone (100 mm top diameter, 200 mm bottom diameter and 300 mm height). These values are based on the range of slump heights at which the paste plant is currently running and the yield stress measurement results conducted at WASM. After measuring the slump, the samples were prepared by pouring the paste fill mix into the plastic cylinders 100 mm diameter and 230 mm height, sealed, labelled and cured into the humidifier chamber. The chamber was set to maintain a temperature range between 32-35°C and 90% humidity, which is equivalent to an underground environment.

3 Results and discussion

The following sections discuss the results of test works that were conducted on site and at WASM to evaluate the effects of the two additive products on paste fill quality. The reported results include yield stress, slump, and the mechanical properties of cemented paste fill.

3.1 Impacts of MM701 on paste fill quality

3.1.1 Rheology measurement

Prior to the start of the project, the tailings, underground hyper-saline water and MM701 were sent to WASM for determination of the rheology properties, focusing predominately on the yield stress of the paste fill mix. The yield stress (and the rate at which yield stress increases with time) is primarily a function of the tailings properties and water content (Clayton et al. 2003), and its measurement will assist in the understanding of the flow properties of CPF at various pulp densities.

The measurement of yield stress was conducted by varying the solid contents from 67-78% in controlled samples with and without the MM701 additive. Figure 4 shows the results of this measurement for the samples with solid content ranging from 68-73%. The yield stress for the samples with a solid content ranging from 74-78% both with and without MM701 could not be determined as the paste fill was thick beyond the limit of the viscometer. Consequently, this allowed for concentrating on sampling the paste fill with solid contents that ranged between 71-73%. As expected the yield stress for the samples without additives was higher than the yield stress for the samples with additives, and the additives dosage rate had a direct impact on the resulting yield stress of the paste fill mix. For the controlled samples at a dosage rate of 450 mL/ wet tonne the yield stress decrease ranged from 12-24%, while at a dosage rate of 600 mL/wet tonne the decrease ranged from 32-37%. Since the higher additive dosage rate gave better results in terms of the yield stress, a 600 mL/wet tonne dosage rate was found to be optimal for a further onsite testing program. This experiment also indicated that the binder dosage did not have significant influence on the rheological properties of the paste fill.

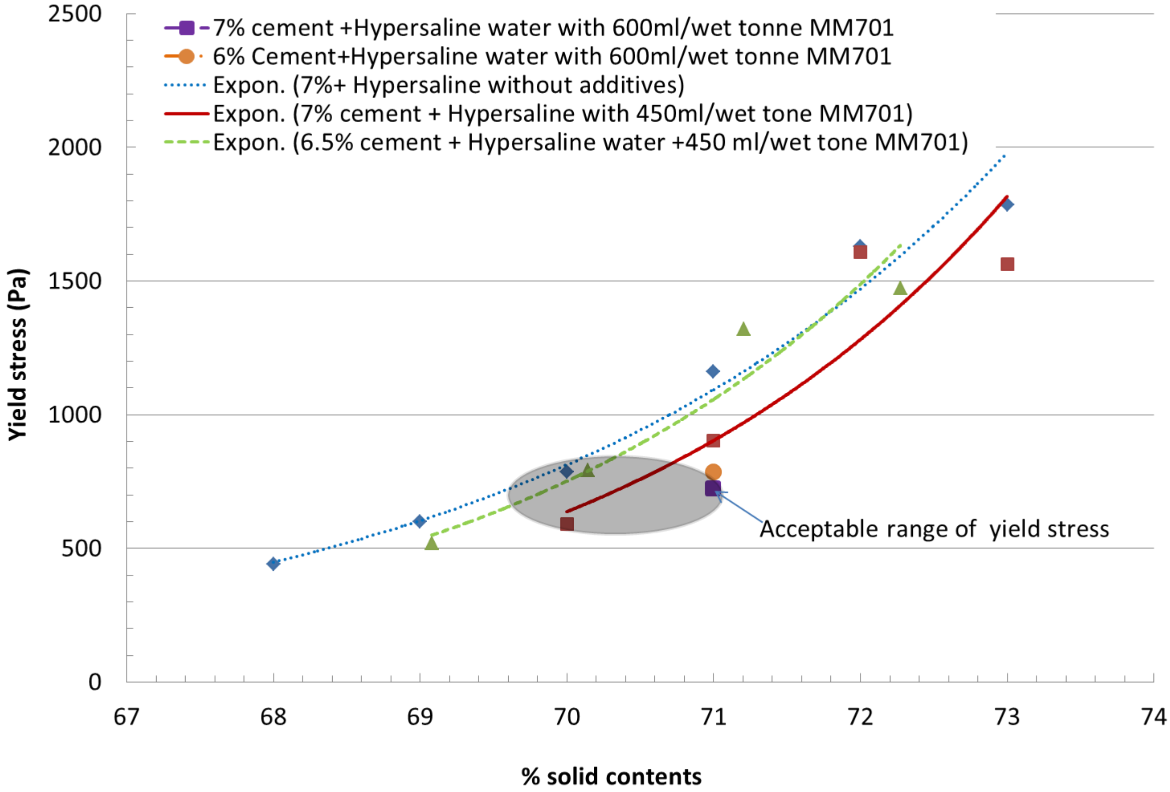

Figure 4 Yield stress measurement results

3.1.2 Effects of MM701 on paste fill strength development

The purpose of the UCS tests was to generate an understanding of the influence of the MM701 additive on various components of paste fill mix with time. The main variables were the binder addition, solid contents and the curing time at a fixed dosage of 600 mL/wet tonne of the MM701 additives. The UCS test was conducted on large number of samples at different curing time and binder dosage. The range of solid contents was based on the yield stress measurement results and the slump height guidelines. The curing time was set at five, seven, 14 and 28 days with cement contents ranging from 5-7% and the main target to achieve a UCS of 750 kPa within the first 14 days of curing.

Figure 5 illustrates the strength development of paste fill samples at various curing dates, it can be determined that the paste fill strength developed rapidly within the first 14 days and then levelled off with less increase over time. As expected the higher solid and cement contents, lead to higher paste fill strength and an increased rate at which high early strengths were achieved. After 14 curing days, all samples over 6% cement content developed a minimum UCS of 750 kPa. Samples with 5% binder dosage could not develop a minimum UCS of 750 kPa even after 28 days.

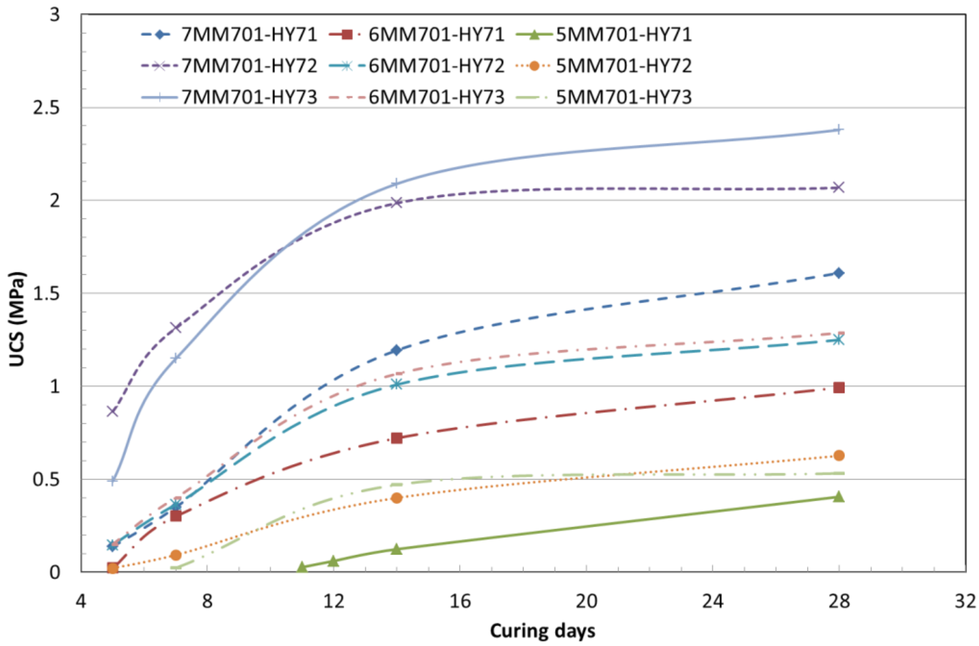

Figure 5 Paste fill strength development at different solid contents and binder dosage rate

3.1.3 Effects of binder addition on strength development

The current stoping sequence at Frog's Leg requires the minimum paste fill strength for horizontal exposure be developed within the first 21 days. With the change of mining sequence to end on access retreat below 7925 level, this strength will need to be achieved within 14 days of curing. Gaining early strength is particularly important for the removal of barricades and scheduling the extraction of adjacent stopes and, thus for the reduction of the mining cycle time, which increases mining efficiency and production (Yin et al. 2012). For the paste fill to develop early strength in a short time frame as per future stope extraction sequence, the strategy has been to use higher binder dosage in CPF (Section 2.1.1.2). However, an increased binder dosage in the backfill resulted in an escalated paste fill operating costs. At present the binding agent comprises between 65-75% of the total paste fill operating costs hence reducing the cement content in CPF without compromising the required mechanical properties will ensure an economical backfill system.

The limit of binder reduction when the MM701 additive was introduced into the CPF was evaluated by the relationship between the cement dosage (horizontal axis) and the developed strength after 14 curing days (vertical axis) as shown in Figure 6. It is evident that the solid contents had a significant impact on developed strength of CPF. With the MM701 additive, sufficient strength can be maintained by increasing the solid contents while reducing the binder dosage, for example at 73% solid contents the binder dosage can be reduced to a minimum of 5.4% and still maintain the required strength.

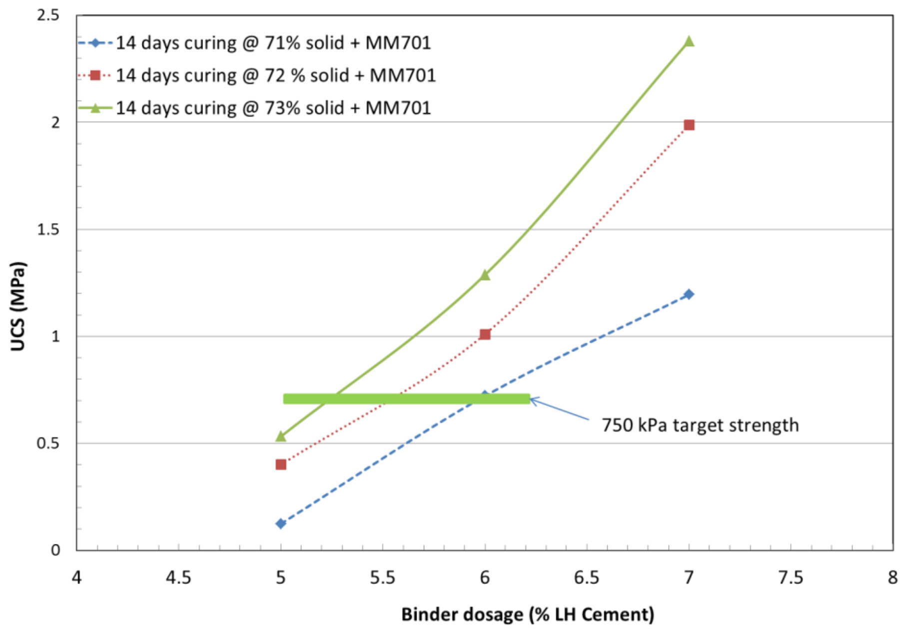

Figure 6 Effects of binder contents on strength of paste fill at 14 curing days

4.2 Impacts of Acti-Gel® 208 on paste fill quality

4.2.1 Effects of Acti-Gel® 208 on paste fill slump

Acti-Gel® 208 is an anti-slump product that aids in improving pumping and flow behaviour of paste fill. The product is not soluble and as such for sample preparation purposes requires a high speed shear mixing machine to inter-mingle its particles with the paste fill ingredients, hence a high speed hand held drill was used to mix paste fill. In the absence of any previous testing the dosage rates were set at 0.03 and 0.05% based upon the recommendations of the additive supplier, and the solid contents in the paste fill mix set at 71 and 72%. The amount of Acti-Gel® 208 to be added was calculated by multiplying the dosage rate and the dry weight of the mix components, in this case it is the solid contents only.

In similar methodology to the MM701 additive trial, the influence of Acti-Gel® 208 on paste fill consistency was investigated by measuring the slump height of the paste fill mix. The first sample batch was prepared by varying the binder dosage from 4, 5 to 6% while maintaining a constant 0.03% Acti-Gel® 208 dosage and 71% solid contents. The second sample batch, the additive and solid contents were increased to 0.05% and 72% while maintaining the binding agent at 4, 5 and 6%. The influence of Acti-Gel® 208 on paste fill consistency is illustrated in Figure 7; it can be observed that the Acti-Gel® 208 additive reduced the slump of the paste fill mix from the current operating range of 180-230 mm, to a range between 125-150 mm. This decrease in paste fill slump height can be explained by the thixotropic effects of Acti-Gel® 208 on cemented paste fill. By definition thixotropy is a reversible behaviour of certain gels that liquefy when they are shaken, stirred, or otherwise disturbed and reset after being allowed to stand (Quanji 2010). The product suppliers advised that this effect can reduce the paste fill slump between 25-30% but still provides better flowability. Studies conducted by Wang et al. (2011) to investigate the effects of Acti-Gel® 208 on concrete paste indicated that Acti-Gel® 208 increases the thixotropic properties of concrete. In paste fill the thixotropic behaviour is normally experienced when there are sufficient ultra-fine particles in tailings–water mixture (Kuganathan 2005). The benefit of the thixotropic properties in cemented paste fill is the ability for the paste fill to flow easily when it is at rest in the reticulation system with the application of a small amount of shear force.

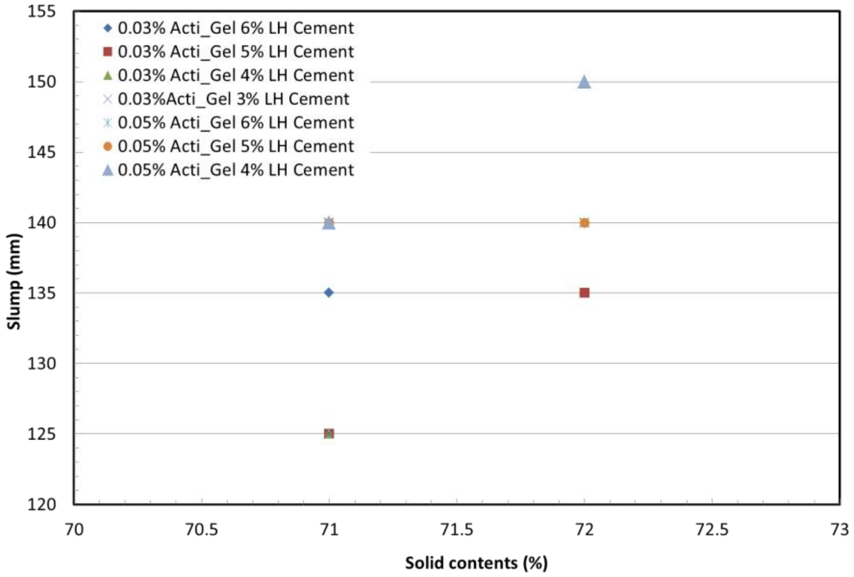

Figure 7 Effects of Acti-Gel® 208 on paste fill slump height

4.2.2 Effects of Acti-Gel® 208 on paste fill strength development

Following slump measurements, several samples were cast in a 100 mm diameter and 230 mm height plastic cylinder, sealed and stored in a humidifier chamber at 90% humidity and temperature ranging from 32 to 35°C, and allowed to cure for a period of five, seven, 14 and 28 days. All samples consistency acquired rapid strength development in the first seven days of curing after which an increase in strength over time decreased significantly. Figure 8 illustrates the strength development of paste fill with Acti-Gel® 208 additive at different curing durations. The addition of Acti-Gel® 208 improved the short-term strength gain by seven curing days against the target 14 curing days. The improved short-term strength gain of CPF with Acti–Gel® 208 additive may be attributed to the small particles of the Acti-Gel® 208 which held together the tailings and cement at rest due to thixotropic behaviour causing a denser CPF. As with the MM701, the binder and Acti-Gel® 208 dosage rate had a significant impact on the resulting mechanical properties of cemented paste fill, with the higher the concentration of Acti-Gel® 208 added to the paste fill mix the better the resulting strength. Paste fill containing 6% binder dosage achieved the 750 kPa after seven days of curing while those with 5% binder dosage achieved the 750 kPa after 14 days of curing. At 4% cement addition the CPF could not achieve the required strength even after 28 curing days.

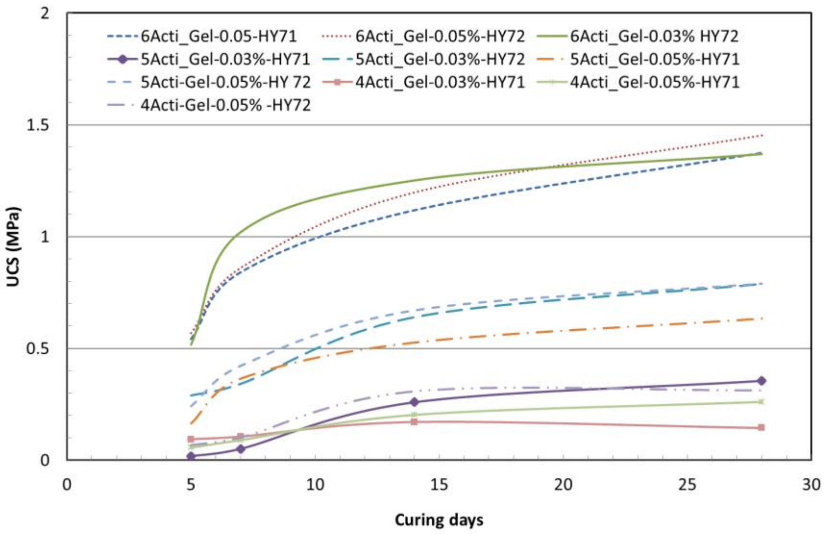

Figure 8 Effects of Acti-Gel® 208 of paste fill strength development

4.2.3 The effects of binder dosage on paste fill strength development

As stated previously in this investigation, the Acti-Gel® 208 addition into the paste fill mix was kept constant at 0.05% while the solid contents was varied from 71-72%, with Figure 9 illustrating the effects of binder addition on paste fill strength after 14 curing days. It can be observed with the use of Acti-Gel® 208 additive it is possible to reduce the cement content to as lower as 5% whilst achieving the required 750 kPa within 14 curing days. As with MM701 the range of binder reduction is however controlled by the solid contents in the paste fill mix.

Although Acti-Gel® 208 additives produced very promising results in terms of strength gain, true thixotropic behavior was not observed and therefore further investigations needs to be conducted on the impact of Acti-Gel® 208 additive on paste fill flowability and strength when sufficient ultra-fine particles are present in the tailings. The high fines content in the tailings is one of the contributing factors to flowability and strength development issues of CPF at Frog's Leg underground mine and the results from further studies will provide better understanding on the thixotropic effects of this product on CPF at high fines content.

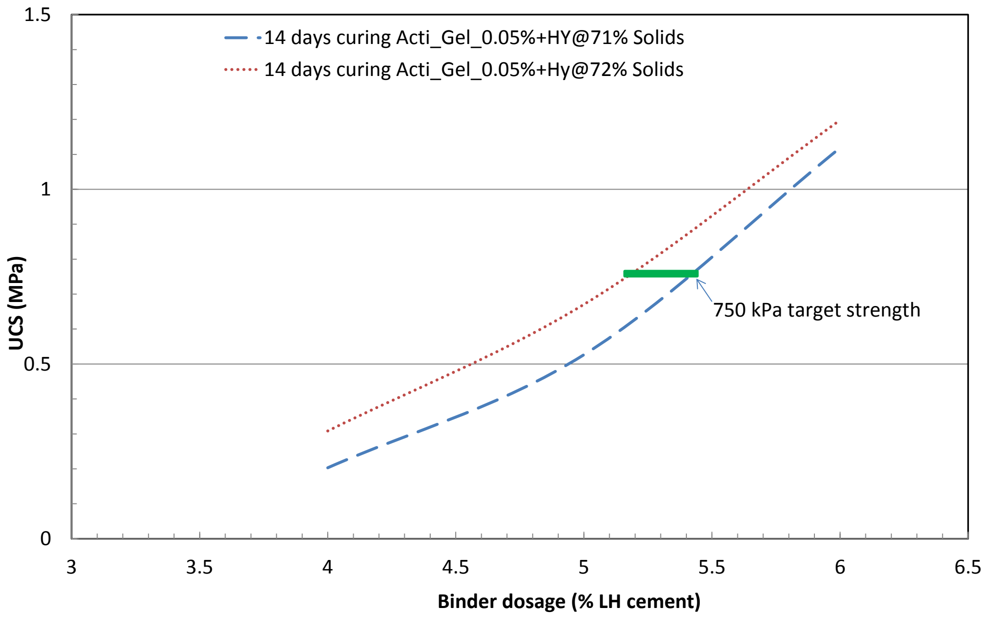

Figure 9 Effects of binder dosage on paste fill strength deveopment

5 Conclusions

Many factors are involved in the selection and application of cemented paste fill additives. These factors cannot be properly determined with certainty without testing. This paper presented the test work that was conducted to investigate the effects of two additives on paste fill flowability, curing times, slump, and strength development and binder dosage. The two products that were investigated were MM701 supplied by BASF and Acti-Gel® 208 which was supplied by Active Minerals.

For both products it can be concluded that the potential binder reduction in CPF is heavily influenced by the solid contents.

The MM701 additive reduced the targeted curing time of CPF from 21 to 14 days, whilst reducing the binder content. It is also possible to achieve sufficient paste fill strength by marginally increasing the solid contents whilst further reducing the cement contents using MM701. This study has also shown that the MM701 additive can reduce the yield stress of CPF up to 37%.

The Acti-Gel® 208 additive has shown significant benefits in terms of the early strength development and reduction in cement consumption, with the curing time to achieve the target strength reduced to seven days. However, the observed low slump of CPF with Acti-Gel® 208 additive and thixotropic behaviour suggests this product needs further investigation to ascertain the effectiveness of its thixotropic behaviour when there is a high fines content in the supplied tailings. A plan is under way to conduct further test work by categorising tailings into fines >60 wt% passing 20 microns, medium 35-60 wt% passing 20 microns and course 15-35 wt% passing 20 microns, in order to better understand the effectiveness of this product based on the size distribution of the tailings.

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