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Feasibility of Acti-Gel® as a cost-effective additive for underground mine hydraulic backfill applications

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Abstract

Backfill is an integral part of an underground mining operation. Its two main purposes are safety of the underground openings, and environmental remediation by use of mill tailings as a construction material underground. Backfill will play a vital role in the process of ore extraction in deep mining, as a solution to rock stability issues. Depending on the mining method used, backfill provides a working surface, stabilises stope and pillar walls, as well as the surrounding rock mass, and controls caving of stope backs. The economic feasibility of many mining techniques depends on the ability to place competent backfill in the underground voids to ensure safe working conditions. Portland cement is primarily used to solidify backfill, which represents a major cost in mining operations. In addition, the manufacturing of cement raises environmental considerations because it produces a considerable amount of CO_2 *emissions. Therefore the search for additives which allow for a reduction in the required cement content in backfill has been ongoing for decades.*

Acti-Gel® is a highly purified magnesium aluminosilicate that acts as a high performance anti-settling agent and rheology modifier used in a wide variety of water-based industrial applications. Previous studies have shown that as an additive in paste backfill, it results in improved strength and flow properties, such as friction loss and segregation. Since additives may perform differently in a hydraulic system with various backfill materials, it is recommended to conduct controlled laboratory testing on the additive with the materials and binder used at each specific mine site. This is done to determine the additive's suitability for use in a given underground mine's backfill operation, in order to ensure the integrity of the flow properties as well as the resulting backfill matrix.

This paper presents the results of a study conducted at the CanmetMINING Sudbury Laboratory to investigate the feasibility of Acti-Gel®, as a cost-effective additive for underground hydraulic backfill applications. The materials and binder used in the study were from two of Vale's Operations in the Sudbury Basin; Coleman Mine and Creighton Mine. The materials were first physically characterised, followed by the preparation of samples to determine optimal dosages of the additive for strength development required for Vale's hydraulic fill compliance. In addition, specialised laboratory pilot studies to determine Acti-Gel®'s effect on flow properties were conducted. It was found that at a low dosage of 0.03 wt%, Acti-Gel® delivered enhanced performance in unconfined compressive strength tests as well as in the pilot-scale flow tests. A significant reduction in binder content could be realised with addition of Acti-Gel® at the Coleman and Creighton Mine operations. The economic benefits of such a binder reduction are also discussed in this paper.

1 Introduction

Backfill is an integral part of an underground mining operation. Its two main purposes are safety of the underground openings, and environmental remediation by use of waste material as a construction material underground. There are various sources used for backfill material, however mines typically choose materials which are locally available and economical, such as mill tailings. Hydraulic fill has historically been preferred over paste fill, due to its ease of pouring, however paste fill is seeing increased usage lately (Hartman 1992). As of the late nineties, hydraulic and paste fills were equally used in the Ontario mining industry (Grice 1998). An advantage of paste fill is that if there is ever a pipeline blockage, it is much less likely to settle in the pipe. In contrast, hydraulic fill typically settles rapidly in the pipe, compounding the issue of the pipe blockage. The majority of pipeline distribution failures underground are only partially due to backfill quality control issues, and are principally due to inadequate knowledge of design methodologies for the distribution system, such as inadequate understanding of behaviour than can cause flow blockages, and inadequate flow delivery rates (Archibald et al. 2009).

Backfill velocity is linked to the effect of solids concentration. At low solids concentrations, high velocities must be maintained to achieve optimal flow regimes. Ackim (2011) also stated that hydraulic slurry backfill must be transported in pipelines at high velocities in order to maintain turbulent flow to keep its solid phase in suspension. When finer particle fractions of hydraulic backfill slurry settle at considerable slower rates than the coarse fractions, the phenomenon is called, segregation or stratification. Backfill material in the stope will show grading if fine fractions are carried away in the decant water. Segregation causes the fill mass to be non-homogeneous and may result in an overall reduction in fill strength due to the creation of planes of weakness and areas of low binder content (Ackim 2011).

Backfill plays a vital role in the process of ore extraction in deep mining, with respect to rock stability issues. Depending on the mining method used, backfill provides a working surface, stabilises stope and pillar walls, as well as the surrounding rock mass, and controls caving of stope backs. The economic feasibility of many mining techniques depends on the ability to place competent backfill in the underground voids to ensure safe working conditions. Portland cement is primarily used to solidify backfill, which represents a major cost in mining operations. In addition, the manufacturing of cement raises environmental considerations because it produces a considerable amount of CO_2 emissions. Therefore the search for additives which allow for a reduction in the required cement content in backfill has been ongoing for decades.

Additives have been studied for the purpose of allowing dense fill-like materials to restart flowing after a shutdown in long distance pipeline transportation, such as would be needed in deep mining situations (Wang et al. 2011). The aim of the investigation by Wang et al. (2011) was to find suitable stabilising additives to prevent sedimentation during an interrupted period of pipelining. Additives which have the potential to improve rheological properties of slurry backfills, such as reducing the risk of segregation, will be even more of an asset in deep mining because of the increased distances required to transport the slurry.

Acti-Gel® is a highly purified magnesium aluminosilicate that acts as a high performance anti-settling agent and rheology modifier used in a wide variety of water-based industrial applications. Previous studies have shown that as an additive in paste backfill, it results in improved strength and flow properties, such as friction loss and segregation. Since additives may perform differently in a hydraulic system with various backfill materials, it is recommended to conduct controlled laboratory testing on the additive with the materials and binder used at each specific mine site. This is done to determine the additive's suitability for use in a given underground mine's backfill operation, in order to ensure the integrity of the flow properties as well as the resulting backfill matrix.

This paper presents the results of a study conducted at the CanmetMINING Sudbury Laboratory to investigate the feasibility of Acti-Gel®, as a cost-effective additive for underground hydraulic backfill applications. Acti-Gel® 208 was introduced to Mines Technical Support at Vale Canada Ltd. by Active Minerals International LLC in May 2013. Its two key benefits were explained as early strength and flowability improvement in backfill, and it was further explained that these benefits would bring potential binder reduction and effective sand fill transportation by improving flow and preventing pipe plugging for operational and maintenance benefits. Early strength, improvement in flow and prevention of pipe plugging could be of particular interest to Vale's deep mining operations.

Proven data using Vale specific backfill materials was required to review the benefits of Acti-Gel® 208 for Vale Mines to initiate projects at mines. Therefore in cooperation with Vale Canada Ltd., raw backfill materials, plant water, binder, as well as the flocculant commonly used at two mines, the Coleman Mine operation and the Creighton Mine operation, were used in this laboratory study. Raw materials were first characterised for particle size distribution and moisture content, and then several batches of backfill were prepared, at varying binder contents, flocculant dosages, and Acti-Gel® contents for determination of uniaxial compressive strength at various curing periods. In addition, a unique pilot-scale flowability apparatus was constructed in the CanmetMINING Sudbury Laboratory in early 2014. A total of 12 batches of backfill were prepared, at varying binder contents, flocculant dosages, and Acti-Gel® contents. The flow properties of each batch were investigated by allowing the backfill to free-fall from the hopper through the piping, while measuring flow rate.

2 Approach

2.1 Bulk handling procedures and characterisation of raw materials

In preparation for physical characterisation and batch mixing, the bulk raw materials used at each mine were thoroughly mixed and sampled through a coning and quartering method, according to ‘ASTM C702: Standard Practice for Reducing Field Samples of Aggregate to Testing Size’ (ASTM International 2011). The materials were then physically characterised according to CanmetMINING standard operating procedures for particle size analysis and moisture content determination.

3 Laboratory strength determination

A total of 12 batches of backfill were prepared representing the backfill employed at the Coleman Mine Operation, at varying binder contents, flocculant dosages and Acti-Gel® contents, from which 144 cylindrical samples were prepared for determination of uniaxial compressive strength (UCS) at various curing periods. The batches were prepared by adding the materials into a propeller mixer, using a standard mixing sequence, as follows: water, tailings, sand, flocculant, binder, and Acti-Gel®. The batches were then mixed for 15 minutes prior to casting. In order to achieve the desired solids content, the initial moisture content of the raw materials were taken into account when determining the amount of water to add to the mix.

Testing protocols have been developed by CanmetMINING and its partners to reflect underground conditions and reduce the amount of variability in the tests. It is necessary to determine whether samples should be prepared in drained or undrained conditions. For this study, since Coleman and Creighton mines both employ a hydraulic fill system, drained samples of 100 mm (4 in) in diameter and 200 mm (8 in) in height were selected. Therefore, the moulds had perforated bases with filter paper of medium fast speed and medium crystalline retention placed in the base of the perforated cylinders to prevent loss of fines. Collars of 100 mm (4 in) in height were affixed to the moulds prior to casting in an attempt to ensure proper sample height after drainage. The UCS samples were cured on sand beds for the first 24 hours to allow the water to drain. The samples were cured in a controlled environment of 100% relative humidity and 20 +/- 3°C.

The 12 batches of backfill were prepared at two binder contents, two flocculant dosages, and three Acti-Gel®. Batches were repeated without flocculant addition to determine the effect of Acti-Gel® with and without the flocculant in the mix. For each batch, at least three repetition samples were prepared for each curing period. Curing periods included three, five, seven, 14 and 28 days.

3.1 Strength results and discussion

3.1.1 Effect of Acti-Gel® in the 10:1 higher binder content case

The UCS as a function of curing time for the first six batches, which were prepared at the higher binder content is shown in Figure 1. It can be seen from the figure that overall for the higher binder content case, in general, the highest strengths were achieved with 0.03 wt% Acti-Gel®, followed by 0.05 wt% Acti-Gel®, and that the batches containing no Acti-Gel® returned the lowest strengths. Even as early as three days, the Acti-Gel® batches generally returned higher UCS values.

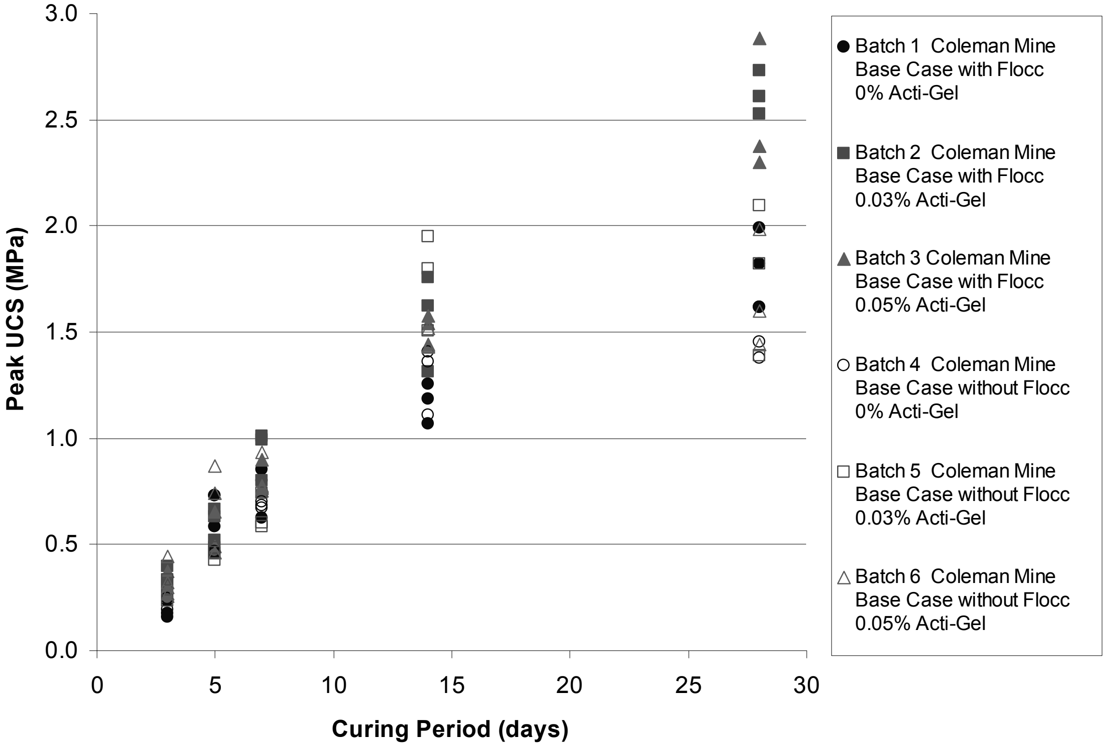

Figure 1 UCS as a function of curing period for higher binder content with/without flocculant

3.1.2 Effect of Acti-Gel® in the lower binder content case

The UCS as a function of curing period for batches 7 through 12, which were prepared at the lower binder content, is shown in Figure 2. It can be seen from the figure that overall for the lower binder content case, in general, the highest strengths were achieved with Acti-Gel® addition, whether it be at a dose of 0.03 or 0.05 wt%. On average, the batches containing no Acti-Gel® returned the lowest strengths, however this was more apparent in the early curing periods. Even as early as seven days, the Acti-Gel® batches generally returned higher UCS values.

3.1.3 Overall analysis of the effect of Acti-Gel®

It was found that in general, at dosages of 0.03 and 0.05 wt%, Acti-Gel® delivered enhanced uniaxial compressive strength. It should be noted that there was a fair amount of variability in the UCS values, especially in the lower binder content batches, and in batches containing no flocculant. The standard deviations are shown in Table 1. It can be seen that in batches prepared at the higher binder content, the standard deviation values were generally greater at later curing periods, and that for batches prepared at both binder contents, on average, the standard deviation values were greater in batches prepared without flocculant addition. Perhaps this indicates that, as would be expected, flocculant addition resulted in less segregation within the mix and/or samples, and therefore returned a lower variability in strength between samples.

Using the average UCS values of each batch, increase in strength was calculated as a percentage of improvement over the base case without the additive (Table 2). The percentage improvement of average UCS for samples with Acti-Gel® versus those without ranged from no improvement to 45% improvement. In two cases, which were at seven days, the improvement was less than 10%, and in one of these cases it was -6%. This was from a batch prepared with no flocculant and is believed to be due to variability in UCS results. At 14 days, the improvement ranged from 11-45%, and at 28 days, it ranged from 10-45% improvement. Improvements of 30% or greater are highlighted in Table 2.

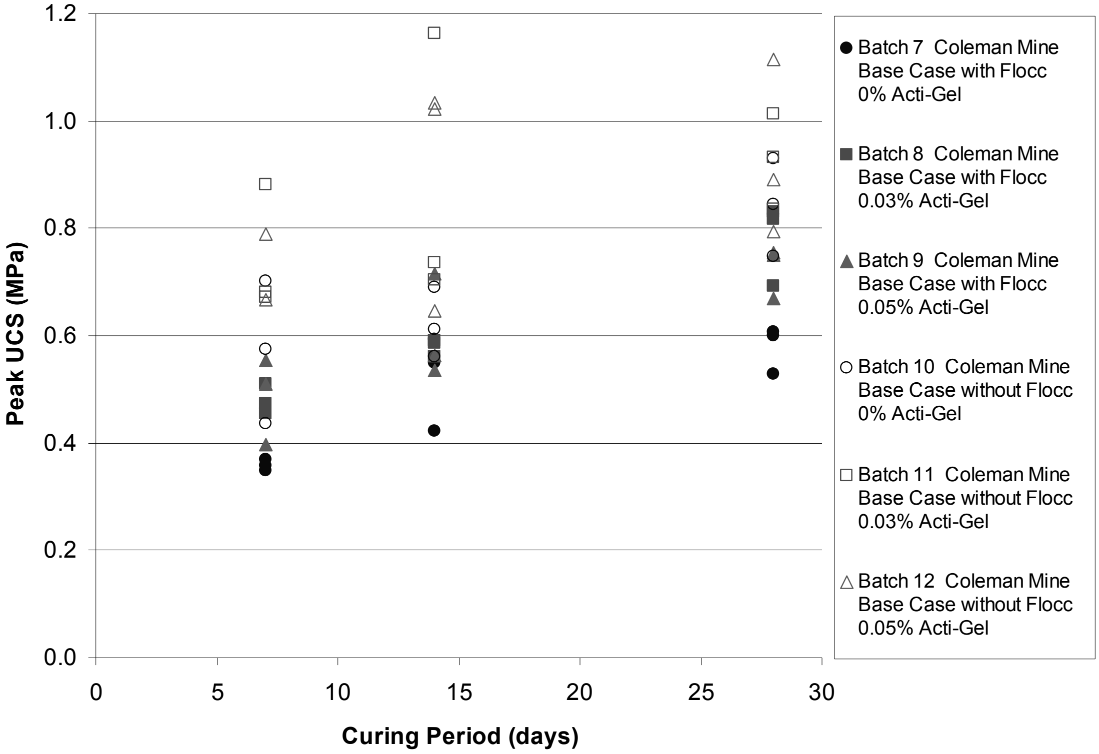

Figure 2 UCS as a function of curing period for the lower binder content with/without flocculant

Table 1 Average UCS test results

Batch #	Binder ratio	Flocculant	Average UCS (MPa) Acti-Gel® (%)	7 day	7 day st. dev.	14 day	14 day st. dev.	28 day	28 day st. dev.
Batch 1	Higher	With	0	0.76	0.12	1.17	0.09	1.81	0.19
Batch 2	Higher	With	0.03	0.93	0.12	1.56	0.23	2.63	0.10
Batch 3	Higher	With	0.05	0.81	0.08	1.52	0.07	2.52	0.32
Batch 4	Higher	Without	0	0.69	0.01	1.29	0.16	1.48	0.12
Batch 5	Higher	Without	0.03	0.64	0.08	1.75	0.22	1.77	0.36
Batch 6	Higher	Without	0.05	0.82	0.10	1.46	0.05	1.67	0.28
Batch 7	Lower	With	0	0.36	0.01	0.52	0.09	0.58	0.04
Batch 8	Lower	With	0.03	0.48	0.03	0.58	0.02	0.78	0.08
Batch 9	Lower	With	0.05	0.49	0.08	0.60	0.10	0.72	0.05
Batch 10	Lower	Without	0	0.57	0.13	0.62	0.06	0.84	0.09
Batch 11	Lower	Without	0.03	0.74	0.12	0.87	0.26	0.93	0.09
Batch 12	Lower	Without	0.05	0.73	0.09	0.90	0.22	0.93	0.16

Table 2 Improvement over the base case

	Improvement in average UCS value		
	7 day	14 day	28 day
Higher binder content – 0.03% Acti-Gel® addition with flocculant.	23%	34%	45%
Higher binder content – 0.05% Acti-Gel® addition with flocculant.	6%	30%	39%
Higher binder content – 0.03% Acti-Gel® addition without flocculant.	-6%	35%	20%
Higher binder content – 0.05% Acti-Gel® addition without flocculant.	20%	13%	13%
Lower binder content – 0.03% Acti-Gel® addition with flocculant.	34%	11%	35%
Lower binder content – 0.05% Acti-Gel® addition with flocculant.	36%	16%	25%
Lower binder content – 0.03% Acti-Gel® addition without flocculant.	30%	40%	10%
Lower binder content – 0.05% Acti-Gel® addition without flocculant.	28%	45%	11%

3.1.4 Effect of flocculant on strength results

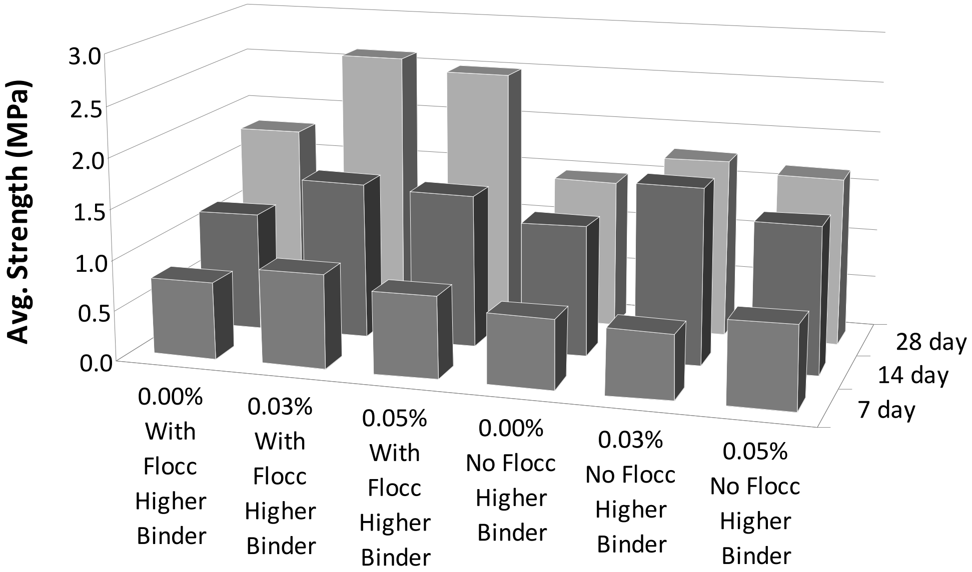

Figure 3 Average UCS for higher binder content as a function of mix details and curing period

For batches prepared at the higher binder content, in general, and especially at 28 days, the absence of flocculant resulted in lower average UCS values (Figure 3). For batches prepared at the lower binder content, in general the opposite was found, it appears that batches prepared without flocculant achieved higher average UCS values (Figure 4).

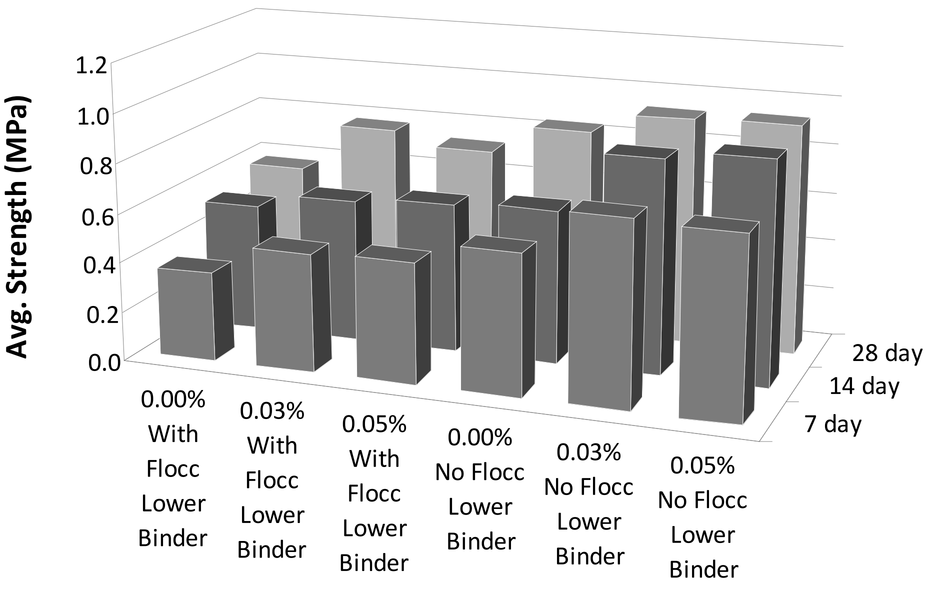

Figure 4 **Average UCS for lower binder content as a function of mix details and curing period**

4 Flowability properties determination

As mentioned earlier, Acti-Gel® is a highly purified magnesium aluminosilicate that acts as an anti-settling agent and rheology modifier used in a wide variety of water-based industrial applications. In early 2014, a unique pilot-scale flowability apparatus was constructed in the CanmetMINING Sudbury Laboratory. A total of 12 new batches of backfill were prepared, at varying binder contents, flocculant dosages, and Acti-Gel® contents. The flow properties of each batch were investigated by allowing the backfill to free-fall from the hopper through the piping, while measuring flow rate.

4.1 Laboratory pilot-scale flow apparatus

The flow test apparatus consisted of the propeller mixer used in preparation of the UCS samples to batch all of the mix materials, followed by a transfer hopper which was located directly above a 2.8 m vertical section of 2 in ID piping. The vertical section of pipe transitioned to a 1.8 m horizontal section by way of a 90° elbow. At the end of the horizontal pipe section was a quarter turn valve to release the flow and begin the flow test. Directly following the quarter turn valve was a short section of downspout connected via a second 90° elbow which discharged the slurry material into 20 L pails. A schematic and photograph of the apparatus are shown in Figure 5.

4.2 Flowability test procedure

Each batch consisted of approximately 75 kg of hydraulic fill slurry. The batches were prepared by adding the materials into the propeller mixer, using the same standard mixing sequence as was used for the UCS tests. During the backfill mixing time, for each batch the pipe system was filled with water from the quarter turn valve at the end of the pipe run up to the bottom of the hopper. A foam ball was used to seal the top of the pipe system and separate the water from the fill material to be tested. Following this, the backfill mixture was poured into a hopper before being released by the opening of the quarter turn valve. The fill was captured into 20 L pails, which were weighed immediately after the test. Pour times were recorded by stopwatch from the moment the valve was opened until a pre-determined time had elapsed. The volume of the pipe section was calculated to determine the amount of water in the lines to be taken out of the captured fill calculations. A video record was also taken of all tests.

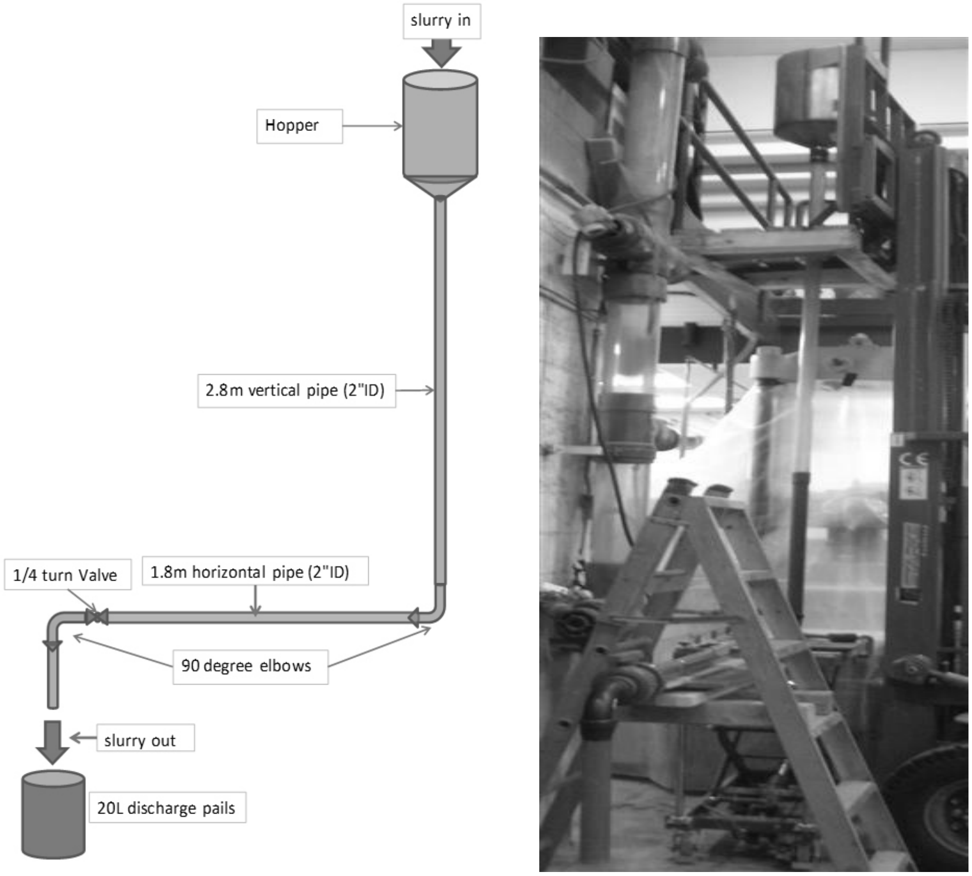

Figure 5 **Schematic and photograph of the pilot-scale flow apparatus**

4.3 Flowability test results and discussion

As testing progressed it was determined that the time span being recorded (10 seconds) was too long, as a full flow rate was not able to be recorded for all batches. Therefore it was decided that the time interval was to be reduced to six seconds. Four of the initial five batches were re-tested with the new time interval of six seconds to allow for consistent comparison between batches. Upon examination of the video records for each test, it was decided that the determination of flow rates would be most accurately performed by viewing the video records at slow speed, with (i) the time interval required to fill the second 20 L pail, and (ii) the recorded mass of the slurry in said pail, being the determining factors for calculating flow rate. Figures 6 and 7 show the results of the twelve flow trials performed. Some of the trials were repeated, as indicated on the horizontal axes of the figures.

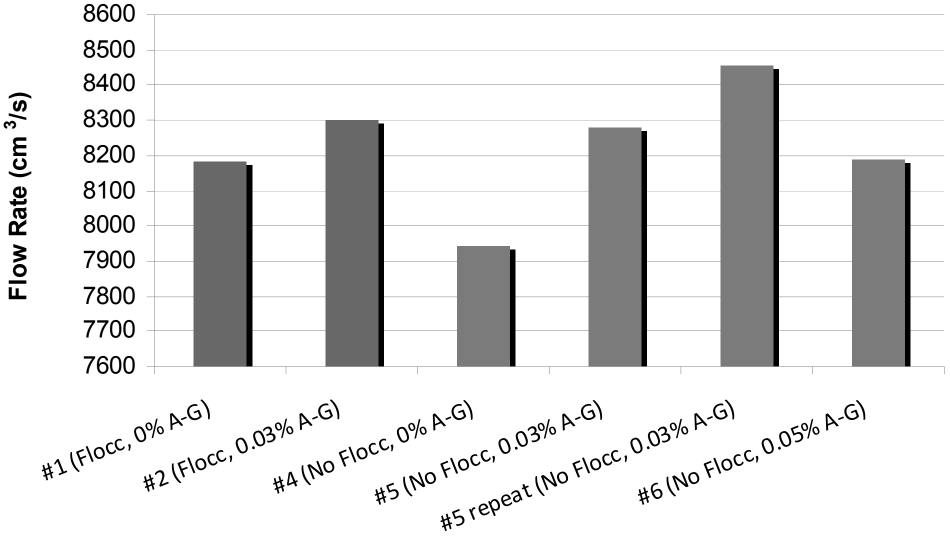

Figure 6 Flow rate results for batches prepared with the higher binder content

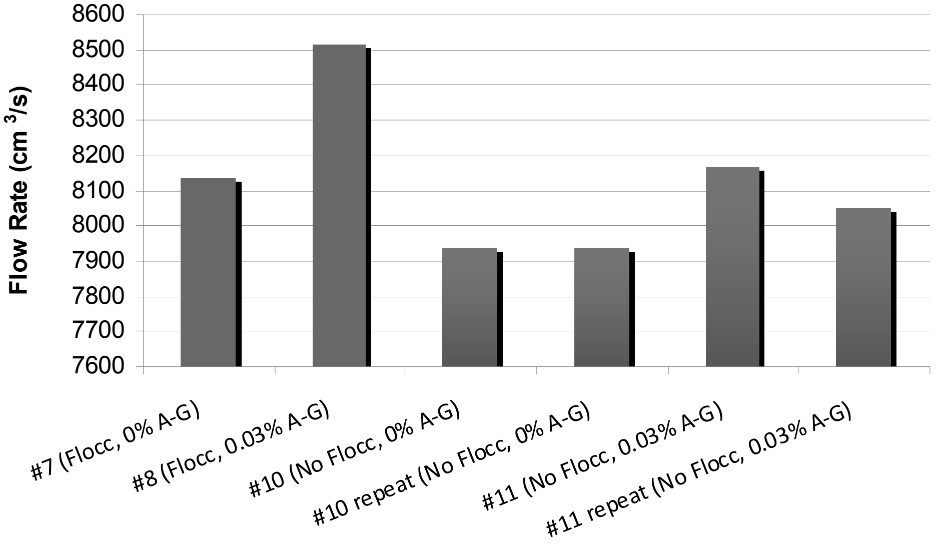

Figure 7 Flow rate results for batches prepared with the lower binder content

It can be seen from the flow rates, shown in Figures 6 and 7, that in all cases, 0.03 wt% Acti-Gel® addition resulted in a slight increase in flow rate. It can also be said that the results seem to show consistency when comparing the repeated batches (batches 5, 10, 11). The benefit of Acti-Gel® addition in the higher binder content trials was slight in those which also contained flocculant (1% faster flow rate), however, there was a 4-6% flow rate increase in the batches that did not contain flocculant. It seemed that with the lower binder content, the highest gain in flow rate was in the flocculant batches where a 5% increase in flow rate was realised. In both binder content cases, the results seem to show that, on average, the use of 0.03 wt% Acti-Gel® without flocculant addition gives similar flow rate values as in the base case trial (hydraulic backfill mix with flocculant used currently at Coleman Mine). This suggests that it is possible that substituting the flocculant for Acti-Gel® at 0.03 wt% in the current Coleman Mine mix could provide similar flow rates.

It is important to note that the variability of this novel test method for flow rate is unknown at this time. It is recommended that further trials be conducted in an attempt to determine the repeatability of the method. It should also be noted that the determination of collection time, performed by examining the videos at slow speed, was very sensitive; changing the collection time by as little as one frame (1/29 of a second) resulted in a notable difference in the calculated flow rate. For instance, in batch 6 (as seen in Figure 6), if the number of frames selected was one less, the difference in flow rate would be an increase of 108 cm^3/s. In future trials this could be addressed by increasing the quantity of material used per batch by at least double. This would increase the elapsed time of each test considerably and thereby reduce the sensitivity of the collection time determination. Lastly, in some trials, a considerable amount of spillage occurred when transitioning between 20 L pails. For future tests it is recommended that a larger vessel with a known volume be filled by a flexible hose. The initial flow material as well as any material discharged after the vessel has filled could then easily be discharged into a separate receptacle.

5 Cost-effectiveness of addition of Acti-Gel®

In order to complete a preliminary analysis of the cost-effectiveness of Acti-Gel®, it was decided to include another mine, Creighton Mine, in the analysis. The classified tailings used at Creighton Mine were collected, mixed and sampled in the same manner as with the Coleman Mine raw materials. Nine batches of backfill were prepared for UCS testing with the aim of determining the degree to which the overall binder content could be reduced with the addition of 0.03 wt% Acti-Gel®, while maintaining the same UCS. The samples were prepared in the same manner as with the Coleman Mine tests, and the same two binder contents were selected. A total of 132 cylindrical samples were prepared for UCS determination at curing periods ranging from 3-14 days. Since 0.05 wt% Acti-Gel® did not provide significantly higher strength than 0.03 wt% in the Coleman Mine trials, it was decided to focus on only zero or 0.03 wt% in the Creighton Mine trials.

5.1 Strength results and discussion for the Creighton Mine trials

5.1.1 Effect of Acti-Gel® in the higher binder content case – Creighton Mine trials

The UCS as a function of curing time for the first three Creighton Mine batches, which were prepared at the higher binder content is shown in Figure 8. In general, the highest strengths were achieved with 0.03 wt% Acti-Gel®, and at the later curing period of 14 days, the batch prepared with both Acti-Gel® and flocculant returned the highest strengths.

5.1.2 Effect of Acti-Gel® in the lower binder content case – Creighton Mine trials

The UCS as a function of curing period for Batches 4 to 6, which were prepared at the lower binder content, is shown in Figure 9. It can be seen from the figure that overall for the lower binder content case, the highest strengths were achieved with Acti-Gel® addition, whether it be with or without flocculant. On average, the batches containing no Acti-Gel® returned the lowest strengths, however this was more apparent in the early curing period of seven days.

5.1.3 Effect of Acti-Gel® addition on reduced binder content samples – Creighton Mine trials

A further three batches were prepared at a reduced binder content in order to determine the degree to which the binder content of Creighton Mine's bulk pour recipe could be reduced with the addition of 0.03 wt% Acti-Gel®, while maintaining the same UCS. Figure 10 shows the 14 day results directly comparing the base case for bulk pouring with no Acti-Gel® to the proposed case for bulk pouring of reduced binder content with 0.03 wt% Acti-Gel® (these two cases are circled on the graph). It was found that by adding Acti-Gel®, UCS was maintained even with the reduction in binder content. It can also be seen that, in general, samples containing Acti-Gel® prepared without flocculant returned slightly higher strengths than those prepared with flocculant.

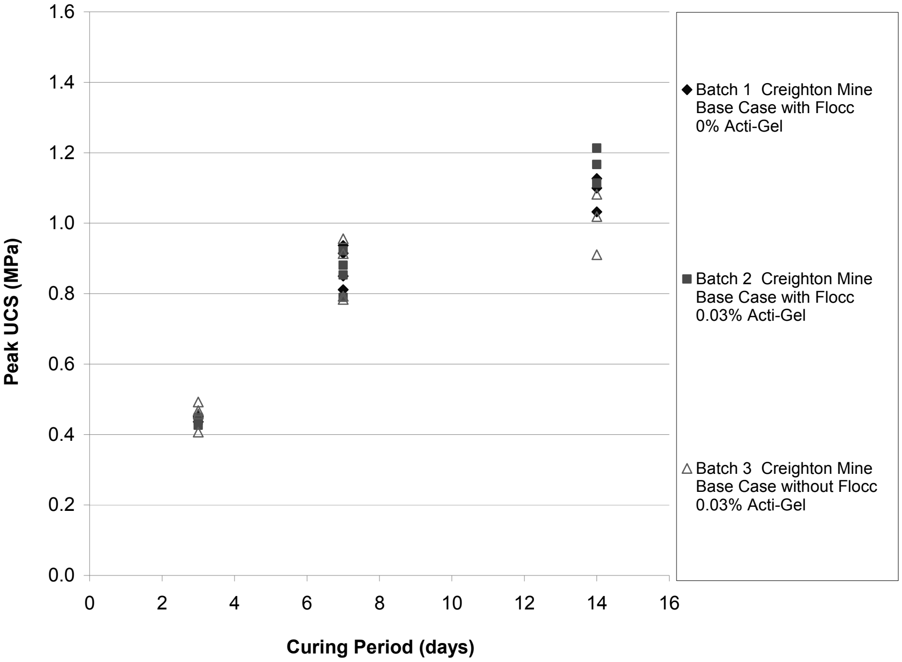

Figure 8 UCS as a function of curing period for the higher binder content with/without flocculant – Creighton Mine trials

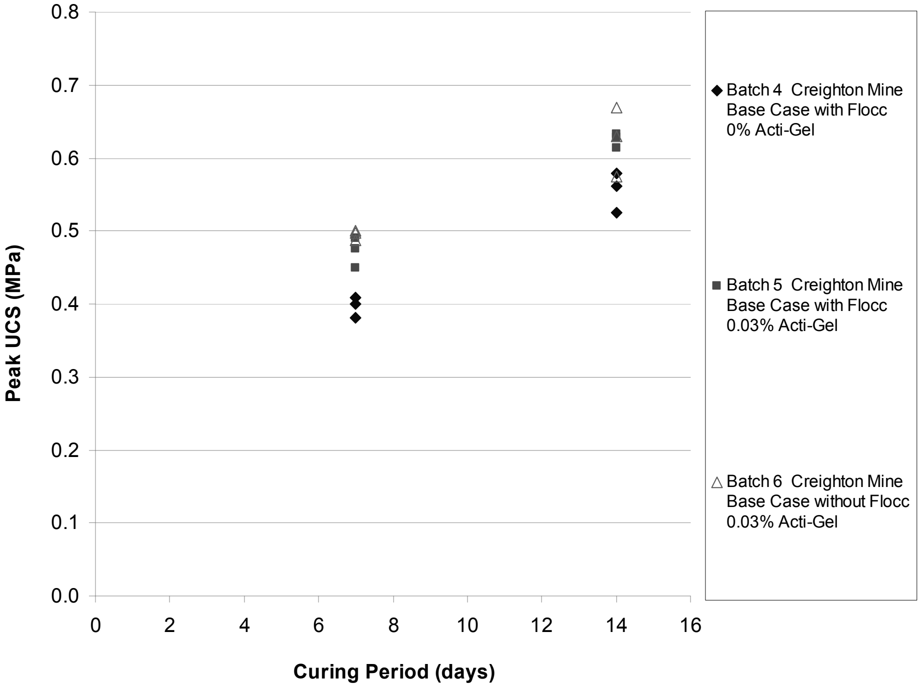

Figure 9 UCS as a function of curing period for the lower binder content with/without flocculant – Creighton Mine trials

The possible annual cost savings of such a binder reduction at Creighton Mine were explored, assuming a yearly fill tonnage of 500,000. Noting that the reduced binder samples containing Acti-Gel®, and also containing no flocculant returned strengths as high as those that did contain flocculant, perhaps a savings could be realised by a reduction, if not an elimination, of flocculant. The resulting potential savings for a 500,000 t operation were determined to be approximately CAD 165,000 per year.

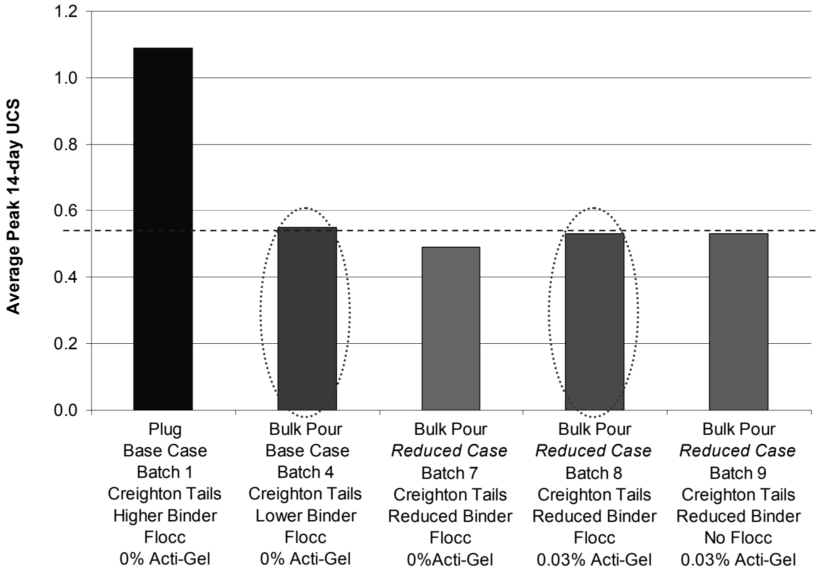

Figure 10 14 day average UCS directly comparing bulk pour base case and reduced binder content case – Creighton Mine trials

5.2 Further discussion on cost-effectiveness for the Coleman Mine Operation

The results of this laboratory study suggest that the potential benefits of Acti-Gel® could be greater with the Coleman Mine raw materials because the strength increase with Acti-Gel® and Coleman Mine materials was notably greater than that with Creighton Mine raw materials. Therefore, using the UCS data from the Coleman Mine trials, it was determined by linear interpolation (Table 3), that it appears the higher plug pour binder content could potentially be reduced by approximately 2 wt% and still maintain strength with the addition of 0.03 wt% Acti-Gel®. The possible annual cost savings of such a binder reduction at Coleman Mine, again assuming a yearly fill tonnage of 500,000, were determined to be close to CAD 500,000 per year.

Table 3 Determination of equivalent binder ratio by linear interpolation

			Average UCS (MPa)			
Batch #	**Percent binder reduction**	**Acti-Gel (%)**	**7 day**	**14 day**	**28 day**	
Batch 1	0.0%	0.00%	0.76	1.17	1.81	Baseline values (target)
Batch 2	0.0%	0.03%	0.93	1.56	2.63	
Batch 3	1.4%	0.03%	0.79	1.25	2.03	
Batch 4	1.9%	0.03%	0.73	1.12	1.79	
Batch 5	2.8%	0.03%	0.64	0.92	1.41	
Batch 6	3.8%	0.03%	0.53	0.69	0.99	
Batch 7	4.8%	0.03%	0.48	0.58	0.78	

6 Conclusions

It was found that in general, at dosages of 0.03 and 0.05 wt%, Acti-Gel® delivered enhanced uniaxial compressive strength. It should be noted that there was a fair amount of variability in the UCS values, especially in the lower binder content, bulk pour batches, and in batches containing no flocculant. Using the average UCS values of each batch, increase in strength was calculated as a percentage of improvement over the base case without the additive. The percentage improvement of average UCS for samples with Acti-Gel® versus those without ranged from no improvement to 45% improvement. In two cases, which were at seven days, the improvement was less than 10%, and in one of these cases it was -6%. This was from a batch prepared with no flocculant and is believed to be due to variability in UCS results. At 14 days, the improvement ranged from 11-45%, and at 28 days, it ranged from 10% to 45% improvement.

It is important to note that the variability of the novel test method for flow rate is unknown at this time. It is recommended that further trials be conducted in an attempt to determine the repeatability of the method. It was found from the flow rates tests that in all cases, 0.03 wt% Acti-Gel® addition resulted in a slight increase in flow rate. The results seem to show consistency when comparing repeated batches. The benefit of Acti-Gel® addition in the plug pour, higher binder content trials was slight in those which also contained flocculant (1% faster flow rate), however there was a 4 to 6% flow rate increase in the batches that did not contain flocculant. It seemed that with the lower binder content, the highest gain in flow rate was in the flocculant batches where a 5% increase in flow rate was realised. In both the binder content cases, the results seem to show that, on average, the use of 0.03 wt% Acti-Gel® without flocculant addition gives similar flow rate values as in the base case trial (hydraulic backfill mix with flocculant used currently at Coleman Mine). This suggests that it is possible that substituting the flocculant for Acti-Gel® at 0.03 wt% in the current Coleman Mine mix could provide similar flow rates.

It was determined that, for a 500,000 t per year operation, a potential annual savings of approximately CAD 165,000 could result if Acti-Gel® were implemented at the Creighton Mine Operation. It was also determined, based on interpolation from UCS data, that with reduced binder content and 0.03 wt% Acti-Gel® at the Coleman Mine Operation, assuming again a 500,000 t per year operation, there could be a potential annual savings of close to CAD 500,000. A stope-by-stope analysis is recommended in order to refine these cost savings estimations.

The cost-benefit analysis for the Creighton Mine Operation was based on 14 day UCS data, and it is therefore planned that the 28 day UCS results from the Creighton Mine trials be reviewed to ensure similar trends as the curing period increases beyond 14 days. It is planned for the near future that a further 12 batches for UCS determination be prepared using Coleman Mine materials, including batches prepared at various lower binder contents, in an effort to determine if the interpolated reduced binder content could, in fact provide sufficient strength with the addition of 0.03 wt% Acti-Gel®. It is also recommended that longer term UCS tests for both operations be conducted to ensure that sample integrity remains beyond 28 days. It should be noted that a possible reduction and/or elimination in flocculant use at Vale's Creighton Mine Operation was suggested in this paper as a potential option, however sufficient laboratory and field trials have not been undertaken to confirm this as a viable option at this time.

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