



Optimisation of Fibrecrete through Trials and Advanced QAQC

Presented by Bridget Sladden

Presentation Overview

- Improvement of shotcrete process through trials
- This presentation will focus on optimisation in the batching, spraying and plant maintenance from completing trials in an owner operated batch plant.

- Mine location and layout
- Batch Plant
- Batch Design
- Issues
- Improvement in Fibrecrete (including Batching & QAQC) from Trials
- Improvement in batch maintenance
- Operator involvement
- Continued Improvements
- Conclusions

Mine Location

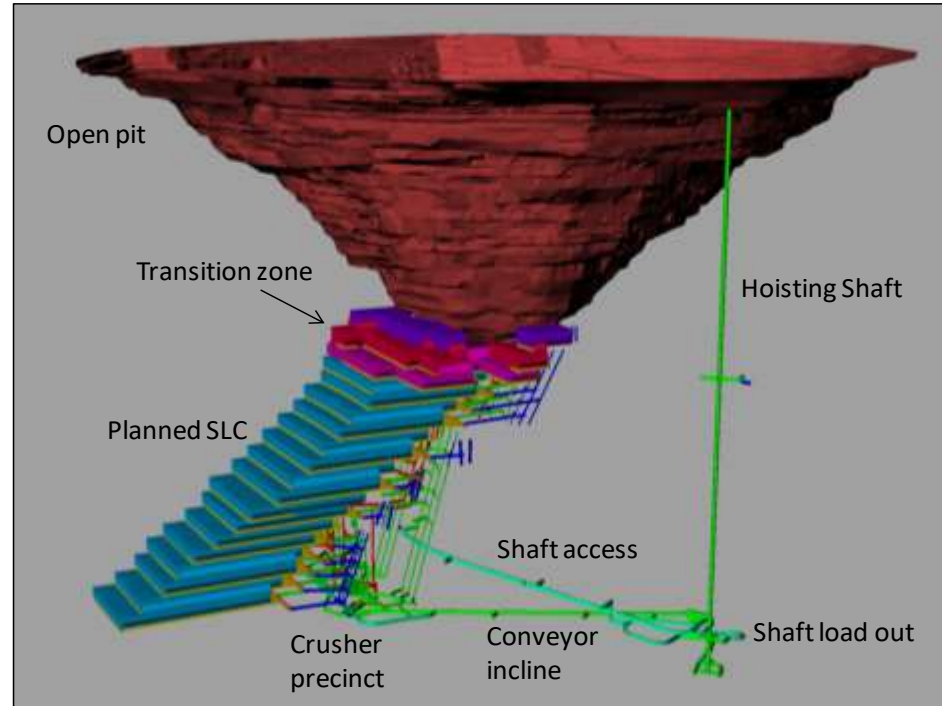
- Located 38km North East of Cloncurry
- Copper and gold deposit
- Open pit completed in 2011
- First underground production in December 2012
- Mine life to 2026



Mine Overview

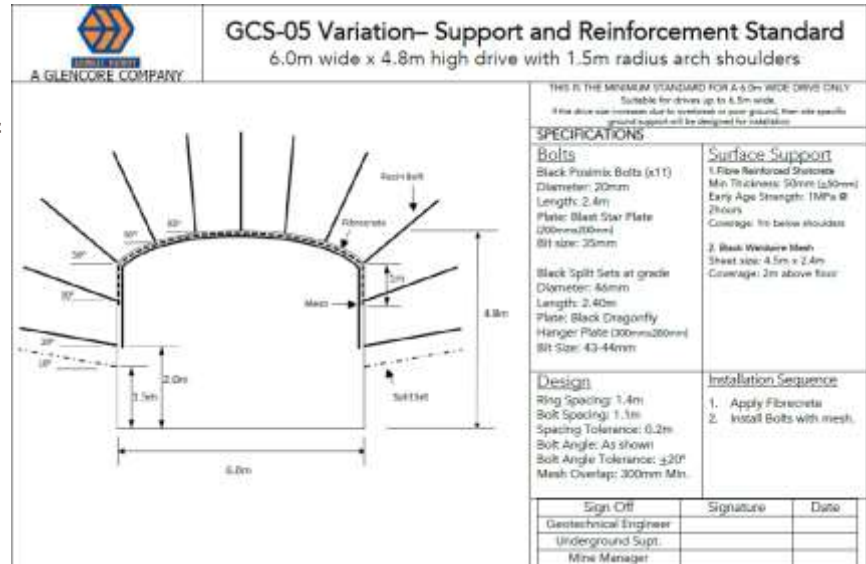
- Sublevel cave mining method
- Underground has a planned depth of 1km
- Transverse retreat from hanging wall to footwall
- 6.4 Mt / pa hoisting

- RQD generally >80%
- Ore body RMR is 'Good' (60-65)



Ground Support

- Average drive dimensions range from 5m-7m(W) x 4.8m-6.5m(H)
- Ground support consists of a combination of primarily shotcrete, mesh and bolts (split sets & resin bolts). Cable bolts utilized for intersections and where deeper embedment required.



Batch Plant

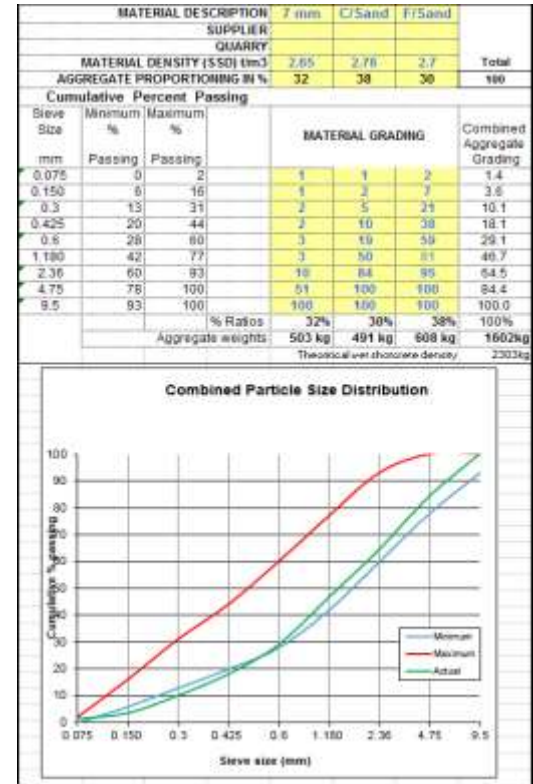
- EHM has an onsite batching facility:
 - 2008 – late 2013: batch plant owned and operated by Barminco.
 - Late 2013 onwards: batch plant owned and operated by EHM.
- 100 tonne cement silo
- Water sourced from Lake Julius (NW Cloncurry)
- Sand and Aggregates sourced from local supplier.
- 2 Agi's and 1 spray rig
- Spray approx. 5,000m³ of shotcrete per year; increasing linearly with depth in relation to stress and seismicity.



Batch Design

- Batch designed to equal 1,000L of materials
- 1MPa at 2 hours for re-entry
- 32MPa at 28 days curing for Sprayed Cores
- 400J absorption energy from Round Determinant Panel (RDP)
- Particle Size Distribution (PSD) designed for even distribution in line with industry standards
- W/C 0.43

Material	Admix dose	Weight (kg)	Density (kg/l)	Volume (L)
Cement		460	3.15	146
Fibres		5	0.9	6
Superplasticiser	1.45%	6.67	1.09	6.12
Hydration Control	0.80%	3.68	1.49	2.47
Accelerator	6%	27.6	1.45	19
Target W:C	0.43	197.8	1	198
Air	3%	0	0	30
Volume excluding Aggs (L)				407
Aggregate volume remaining (L)				593



Shotcrete Issues pre Trial

- Inconsistent moisture in aggregates
- Reduction in short & long term strength (poor results from sprayed panels)
- Insufficient early age strength for re-entry
- Deterioration of equipment (build up on fins)
- Aggregate lumps in batch
- Incorrect accelerator dosage



Shotcrete Trial

	Current Batch 1m3	Provider 1	Trial 1	Trial 2	Trial 3	Trial 4	Trail 5	Trial 6	Avg 1m3
Super-Plasticizer	5L		6	6	7	7.2	6	5	6.20L
Stabilizer	3L		3	3	3	3.6	3	3	3.10L
Accelerant	30L/m3		19.7	26.9	22.4	21.5	21.9	22.4	22.47L/m3
	Current Batch 1m3	Provider 2	Trial 1	Trial 2	Trial 3	Trial 4	Trail 5	Trial 6	Avg 1m3
Super-Plasticizer	5 L		5	5	5	5	5	5	5.00L
Stabilizer	3 L		1.3	2.6	1.3	1.3	1.3	1.3	1.52L
Accelerant	30 L/min		23.2	21.4	17.0	20.5	17.0	15.6	19.12L/m3
	Current Batch 1m3	Provider 3	Trial 1	Trial 2	Trial 3	Trial 4	Trail 5	Trial 6	Avg 1m3
Super-Plasticizer	5 L		4	4	4	4	4	5	3.9L
Stabilizer	3 L		3	3	3	3	2	2	2.5L
Accelerant	30 L/min		23.6	27	25.7	25.7	22.3	20.6	24.2L/m3

2015/16 Admixture Trial:

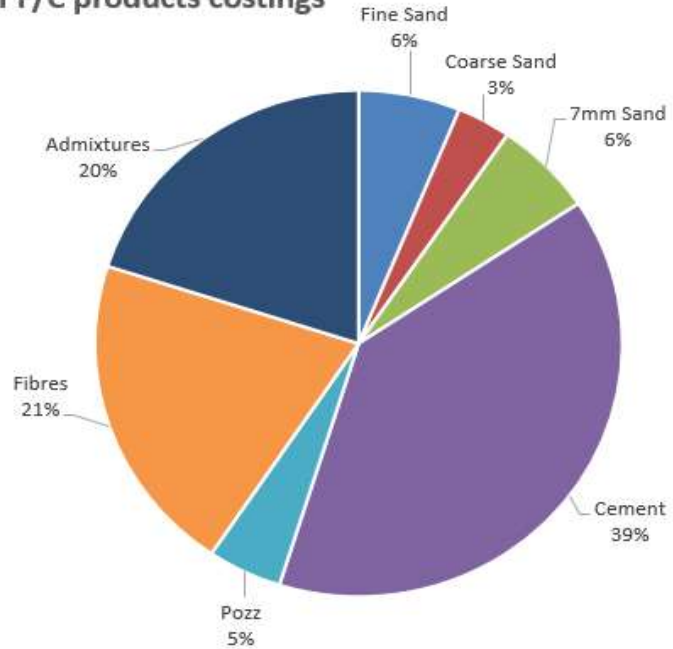
- Cost
- Strength
- Support
- Future/ Downstream Improvements

Shotcrete Trial

Key learning's and improvements from trials:

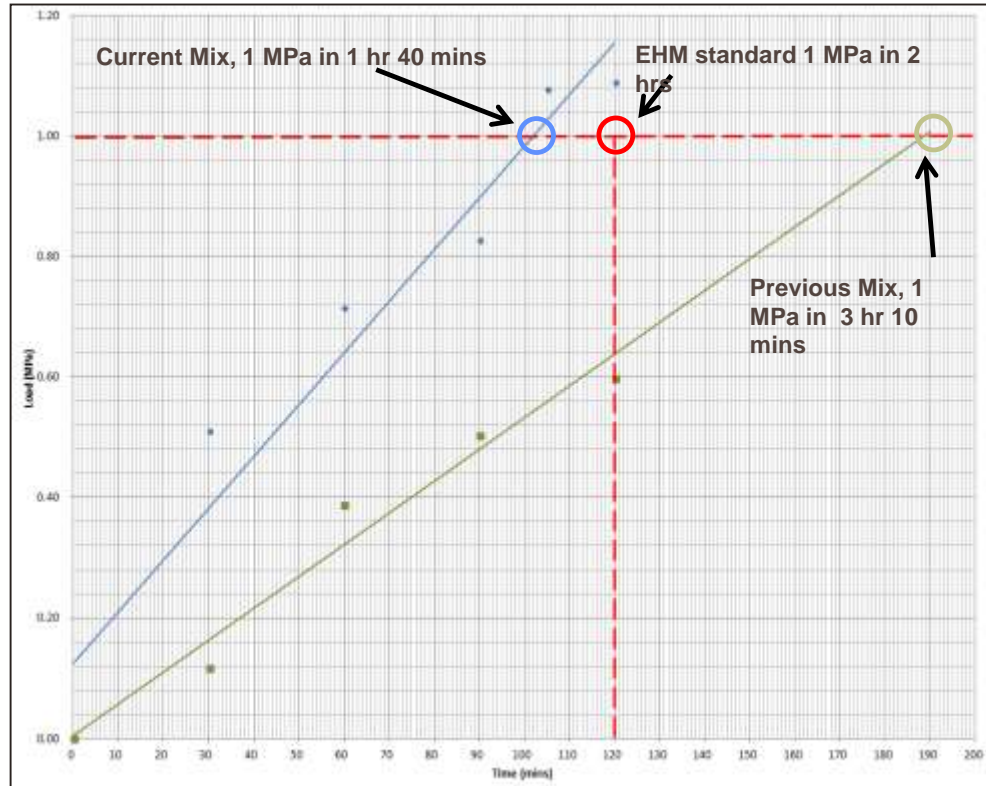
- Mix design
 - Aggregate quality
- Batching process
 - Moisture content
 - Effects of modern super plasticiser's
 - Slump Testing
- Fibrecrete application
 - Correct dosage and application of accelerator
 - Early age strength
 - Long term strength

Breakdown of F/C products costings



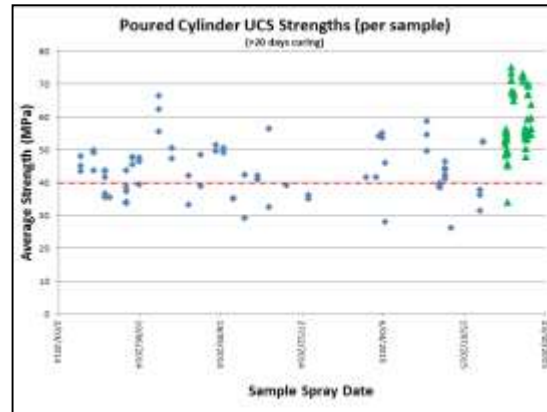
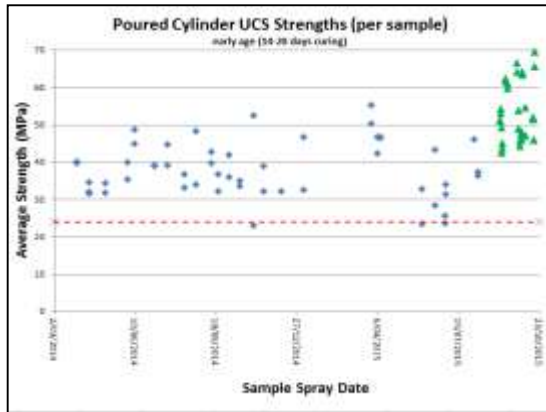
Improvements – Early Age Strength

- Issue around not achieving required re-entry time frame at EHM.
- Previous Mix – 0.6MPa at 2 hours;
- Investigated the use of alternative admixture providers.
- Identified:
 - Stricter adherence to W/C ratio, understanding water Vs chemical slump.
 - Accountability for MCs in batch design.
 - Ensuring correct dosing correlation (dose rate calculator)
- Current mix (after trials) – 1MPa at 1 hour and 40 minutes.



Improvements - UCS

- Noticeable downward trend in the short and long term strength results.
- Investigated the use of alternative admixture providers and review of sands and aggregates.
- Identified:
 - The impact of MC
 - A finer sand recommended
 - Potential moving panel sample too soon after spraying
 - Lab issues
- Controls:
 - Sprinkler systems to maintain MCs.
 - Checking MC prior to batching.
 - Review lab QAQC
- Avg UCS 2016/2017 in line with required standards



- ▲ Trial Data
- ◆ Historic Data

Improvement in Batching

- Moisture contents (MCs) calculated for fine sand, coarse sand and 7mm aggregate for each batch (different time of the days)
- Individual Batch Card calculated for each load based on MCs
- Corrected amount for sands & aggregate calculated considering water present in material and total water adjusted based on water in sands and aggregate



	A	B	C	D	E	F	G	H	I	J
1										
2										
3		Date:								
4		Time sample is taken:				e.g. 7:02 PM				
5		Operator:								
6		Location:								
7		Agg:								
8		Batch Size:								
9										
10		Moisture Content (in field test)								
11		Tray	Wet + Tray (g)	WET (g)	Dry + Tray (g)	DRY (g)	MC (%)	Absorption (%)	Corrected MC (%)	Water in aggregate (L)
12	F/S	18	324	306	293	275	11.3	1.28	10.1	64.51
13	C/S			0		0	#DIV/0!	1.00	#DIV/0!	#DIV/0!
14	7m			0		0	#DIV/0!	0.61	#DIV/0!	#DIV/0!
15										#DIV/0!
16										

Batching

Batch Card Example

Date	5/9/2017
Time completed	7:30 AM
Operator	B. Stadden
Location	MSO LID 11
Bag	201
Batch Size	8

Material	Wet	Wet + Free (kg)	WET (kg)	Dry + Free (kg)	DRY (kg)	MO (kg)	Absorption (%)	Corrected MO (kg)	Value in aggregate (kg)
FIS	10	365	351	335	313	10.1	1.00	9.5	8100
G/S	10	348	330	312	314	5.3	1.00	4.1	18.77
Tm	10	377	359	368	348	3.2	0.01	2.6	12.83
									93

Batch Mix	Cum	Actual	Batch Time
7mm aggregate	3094	3094	
Coarse sand	2862	2862	
Fine Sand	4209	10168	
Cement	2740	2709	
Fibres	80	79	
TanCem HCA Plus	15	15	
TanCem 44	36	36	
Adjusted Water	631	600.5	
Tail water		30.5	
Slump	730	830 mm	

Tem Shot 110 6% Acc
 AF Accelerator 19L/m³

Batching Sequence Fibres --> Water --> TanCem 44 --> Cement --> Agg --> Sands --> TanCem HCA Plus --> Tail water (required to achieve 220mm slump)

Comments: No assets Slump 220mm.

Save as PDF

Details of operator, sample time and required batch size.

Total water in 1m³ of sands and aggregates.

Actual quantities used during batching..

Batch Card for operator to follow.

Recommended batching sequence.

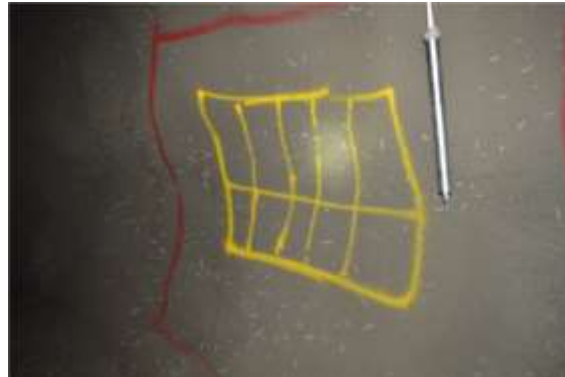
Improvement QAQC

- Slump on surface and UG. Surface slump 220mm.
- Poured cylinders on surface. 24MPa at 14 days and 40MPa at 28 days.
- Sprayed panel UG. 18MPa at 14 days and 32MPa at 28 days.
- Completed by Operators.



QAQC – Underground

- Early age strength requirement 1MPa at 2 hours. Needle Penetrometer and beam testing.
- Fill Rate can be adjusted accordingly dependent on slump feedback.
- Average stroke rate 10 strokes per min.
- Confirm accelerator dosage settings. L/min and pump speed.



$$\text{Dose Rate (\%)} = \frac{\text{SG} \times \text{L/min} \times 6000}{\text{Pump Speed} \times \text{Cement Content}}$$

QAQC – Spray Rig

EHEM SPRAY RIG OPERATOR'S FORM	
Date	
Location	
Sprayer	
Site Operator	
Surface Dosing	yes
MSM Usage (if required)	yes

ACCELERATOR

Control Manual automatic

If spraying in manual, why? _____

Map filter available, (C/NO), if not, why? _____

Zoom rate manual (check) = _____ L/min

Spray Rig Parameters

Acc Density		%
Acc Density		kg/m ³
Flow Rate		%
Current Control		%

MSM USAGE

Batch operation (check)

UNIT	MIN	NO-RELEASE	WALLE

Comments: _____

Pumping Issues: _____

BATCH SUMMARY

Start location	
End location	
Accelerator Setting	%
Accelerator Used	L
Concrete Flow	kg/m ³ /hr
Adhesive	L

REPORTS Displacement Issues, anything operator needs to be ML, actual issues

EHEM Spray Rig Operator Feedback Spraying + MS Feedback

Auto or Manual dosage

Rig dosage parameters check.

Batch mix feedback.

Equipment issues.

Improvement in Batch Maintenance

- Built a new storage facility inside admixture bund
- Installed a shield from sands & aggregates loading point to protect pumps
- Placed a cover over fibres loading bay
- Installed computer in batch plant office
- Created a QAQC shed for testing equipment storage



Operator Education

- Batching and Spraying training from industry professional
- Benefits of an informed and aware work workforce
- Spray rig operators to gain EFNARC Nozzleman Accreditation
- Open communication to allow issues to be resolved quicker and easier



Test	Test Frequency	Test Completed By
UCS – Poured Sample (cylinder)	Two sets of samples per swing (one by N/5 and one by D/5). Geotech department to send samples away.	Agi Driver
UCS – Sprayed Sample (cores from square panel)	Two panels per swing (one by N/5 and one by D/5). Geotech department to collect samples from UG and send away.	Agi Driver
Flexural Toughness (RDP)	1 round of test panels per month	Geotechnical Dept
PSD – Coarse Sand	1 per month	Geotechnical Dept
PSD – Medium Sand	1 per month	Geotechnical Dept
PSD – Fine Sand	1 per month	Geotechnical Dept
Fibrecrete Thickness	4 tests per cut or as requested	Face Prep Crew
Slump Test (slump cone method or Agi reading)	Every Batch	Agi Driver
Certificate of Compliance (batch docket)	Every Batch	Agi Driver
Maturity for Re-entry (beam test or needle penetrometers)	Every month (Short-term Strength)	Geotechnical Dept
Batch Review	Two times per year. Batch design and products reviewed and optimised accordingly.	Admixure Provider

Table 2 EHM UG Fibrecrete Testing Program

Continued Improvements

- Commissioning of chilled water at the batch plant
- Stricter air pressure controls to ensure correct spraying standards
- Continued operator education and involvement
- Complete a check on strength and toughness specifications for EHM



Final Summary

- Consistent shotcrete supply for increased demand with mine depth met with a proactive approach
- Owner operator operation in line with industry standards
- Key focus on education of operators
- Batch card created per load based on moisture contents of sands and aggregates
- Strict adherence to QAQC to allow monitoring of overall shotcrete process
- Working within the reality of shotcreting in an underground operation





Thank you