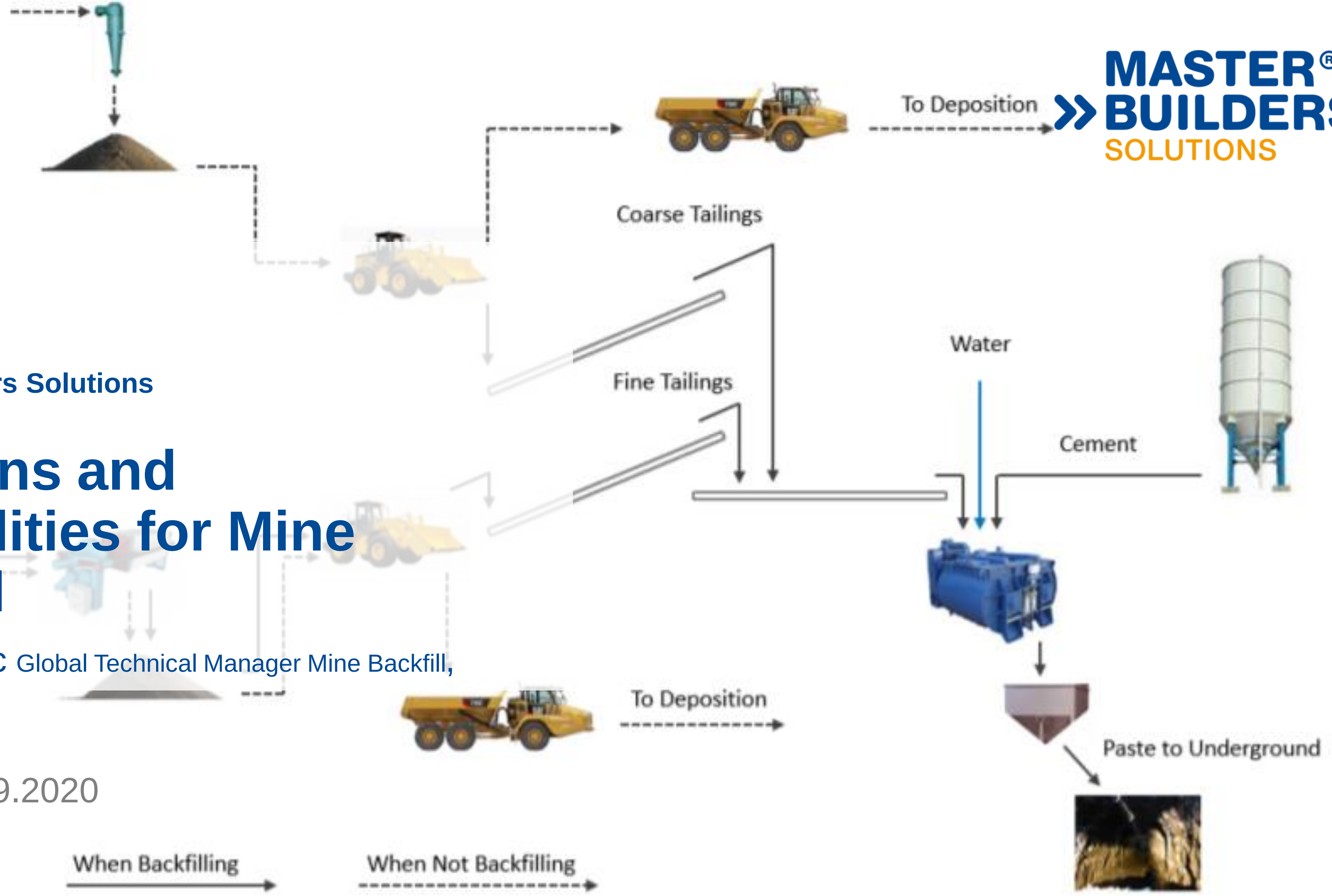


Master Builders Solutions

Solutions and Capabilities for Mine Backfill

Zlatko Martic Global Technical Manager Mine Backfill,

Zurich, 09.09.2020

Mine backfill

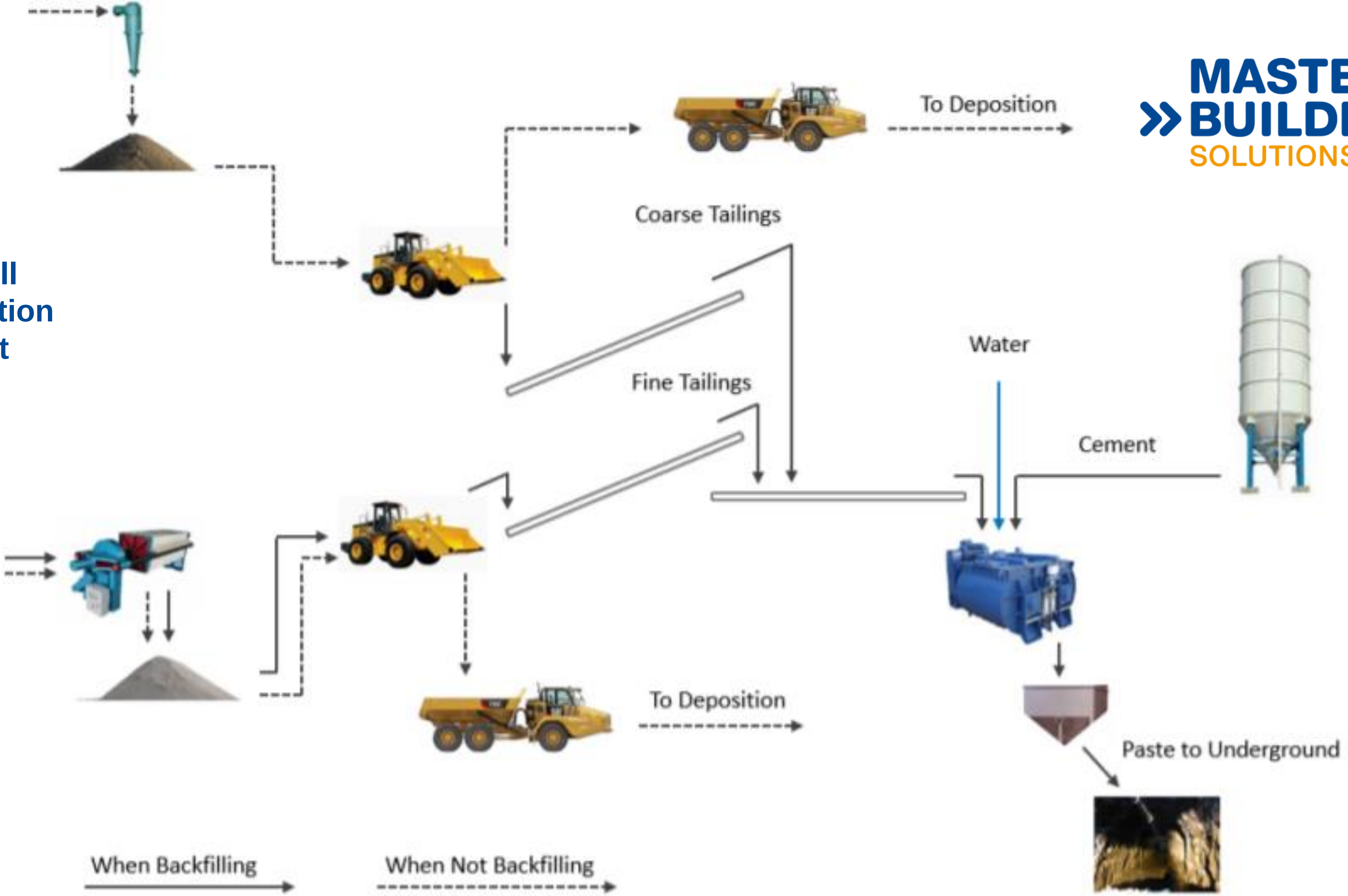
- ***Filing mine cavities with some material or materials in the aim to establish and retain safe working conditions economically - is called backfill. Materials range from rock gravel, quarried sands and to tailings left over from the removal of the valuable minerals from the ore.***
- Backfill in general could be divided into two groups:
  - Uncemented
  - Cemented

- **There are five main types of cemented backfill:**
  - **CRF**
  - **CHF**
  - **CAF**
  - **CPF**
  - **CAP**

Why discussing, educating and optimizing cost in the mine backfill

1. Backfill is representing 25-30% of total mining cost
2. Binder is representing about 70% of backfill cost, but benefits can be related to the other values
3. Operational limitation and maintenance/blockages can become hot operational issue (BF became a bottle neck and/or important cost issue). Total mining cost and mining production can be influenced
4. Once mining cycle well established backfill become first mining operation : ”First you backfill than you mine”
5. Often limitation in expanding mine production related to the backfill capacity or production limitations Very often wrongfully not understood and appreciated “Spending money”
6. Very often with limited recourses and budget, shared recourses but with high expectations

Backfill Operation Layout



Objectives of the Project

Target assignment

Evaluate opportunity for overall cost reduction through: cement optimization, water reduction, tailings storage UG and time/efficiency improvement (cycle)

Screening Technologies – Lab Work

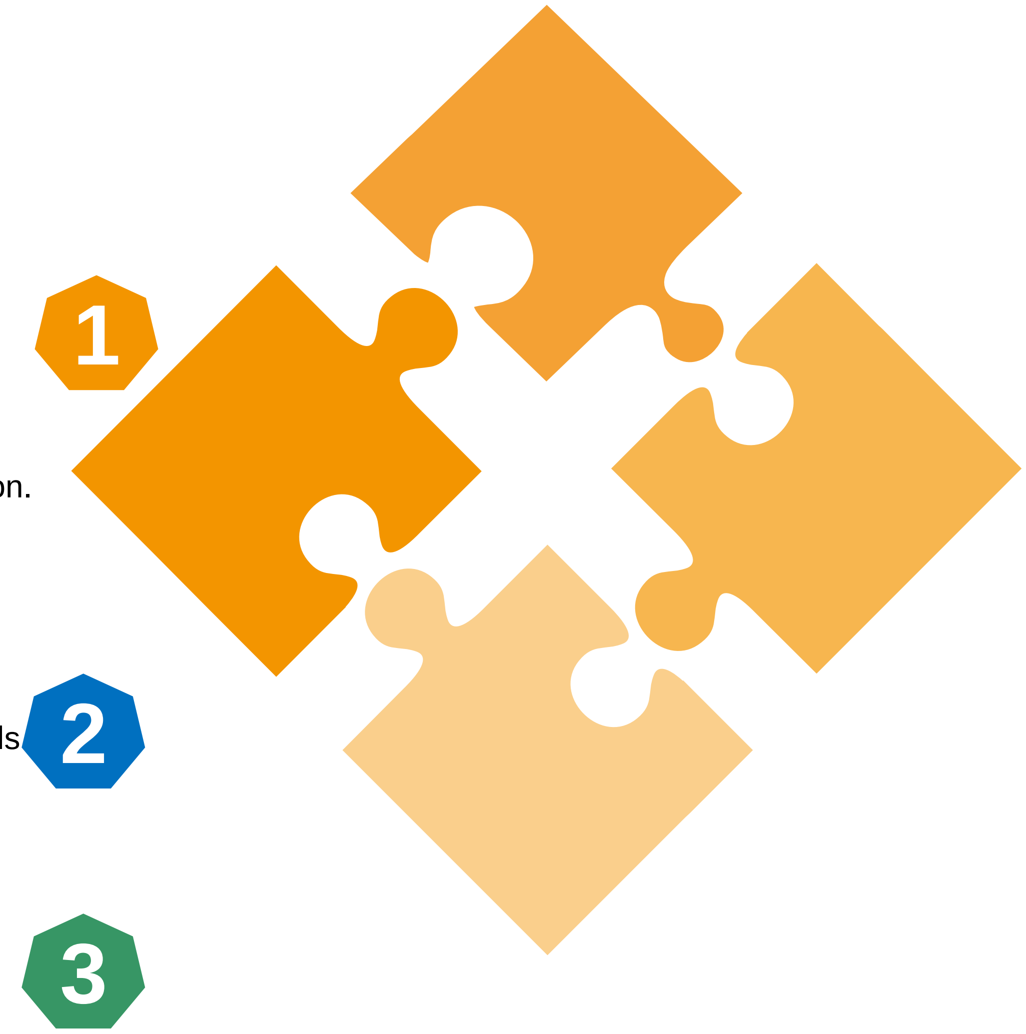
Screening polymer technologies, different mix designs, understanding correlation. Identify through the screening best admixtures candidates for a cost-effective solution. Design tailor made admixtures to fit targets

Evaluate Performance – Full scale testing

Of different admixtures blends and different mix designs. Create different models and value. Opportunities for UCS enchantment and time gain in mining cycle

Techno - Economical feasibility

Prove of concept and real value proposition. Total impact to the mine operation, profitability ,benefits and feasibility.



Material characterization

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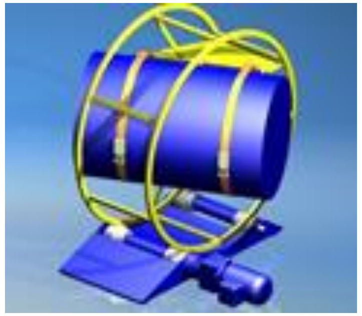
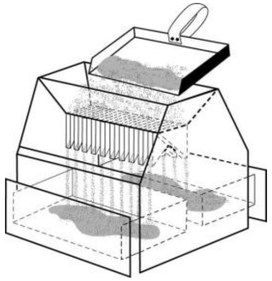
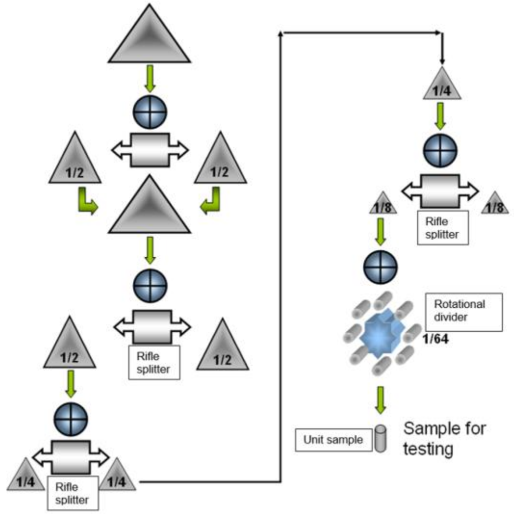
Sample preparation

- Observation
  - Every new arrived sample has to be observed and examined visually all information and remarks have to be inserted in remarks.
- Drying
  - Total sample weight divide into smaller portion in several pans,. Dry in the oven at 50 °C for 48 hours.
- Disaggregating
  - Sample should be disaggregated gently to avoid braking grains and change in
- Blending-Homogenizing
  - Blending homogenizing with drum mixer
  - Jones Riffle technique
  - Rotating sample divider



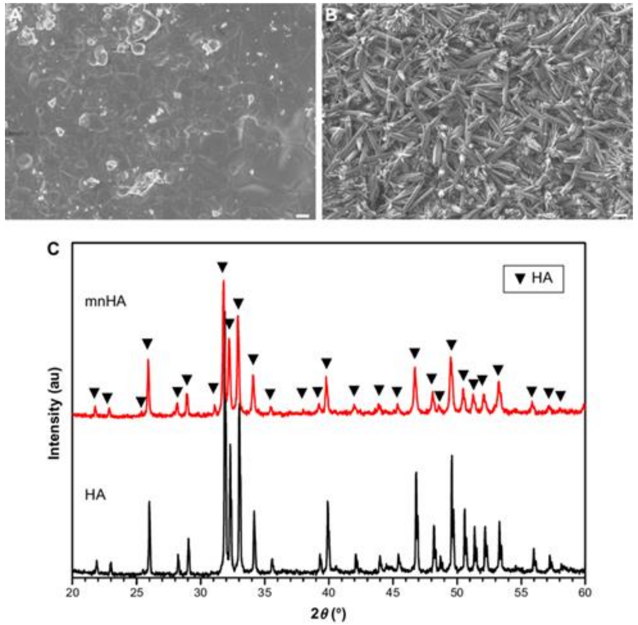




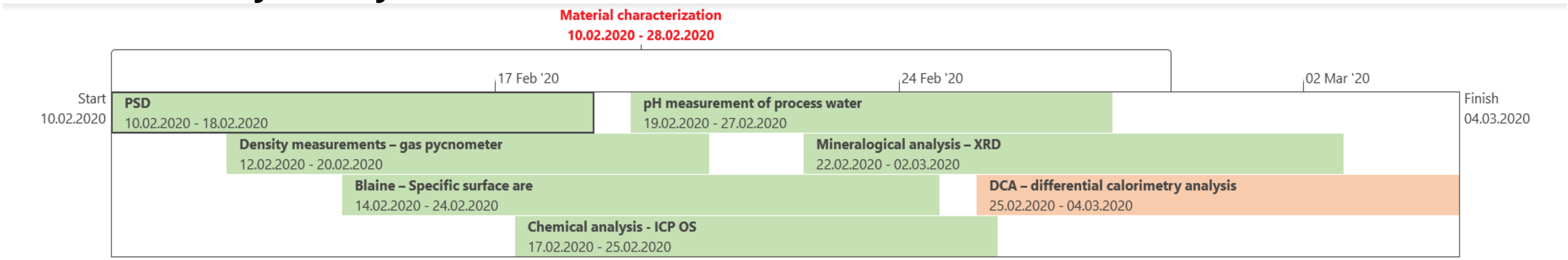
Material characterization

- Material characterization is an important part of project development and admixture formulation. It is performed in any of our project/product development process in order to analyse most important physical, chemical and mineralogical properties/characteristics of backfill materials in understand and identify most important interactions within the mix in terms of:
  - Rheology (flowability and flow retention of the backfill mix)
  - Placement and strength gain (consolidation)
  - Safety aspect of cemented backfill (flow retention, early and final strength etc)
  - Admixtures performances and choice
  - Formulation concept and development path

Material characterisation



- PSD - particle size distribution
- True density measurements – gas pycnometer
- Blaine – Specific surface area
- Chemical analysis - ICP OS
- Mineralogical analysis – XRD
- pH measurement of process water
- DCA – differential calorimetry analysis



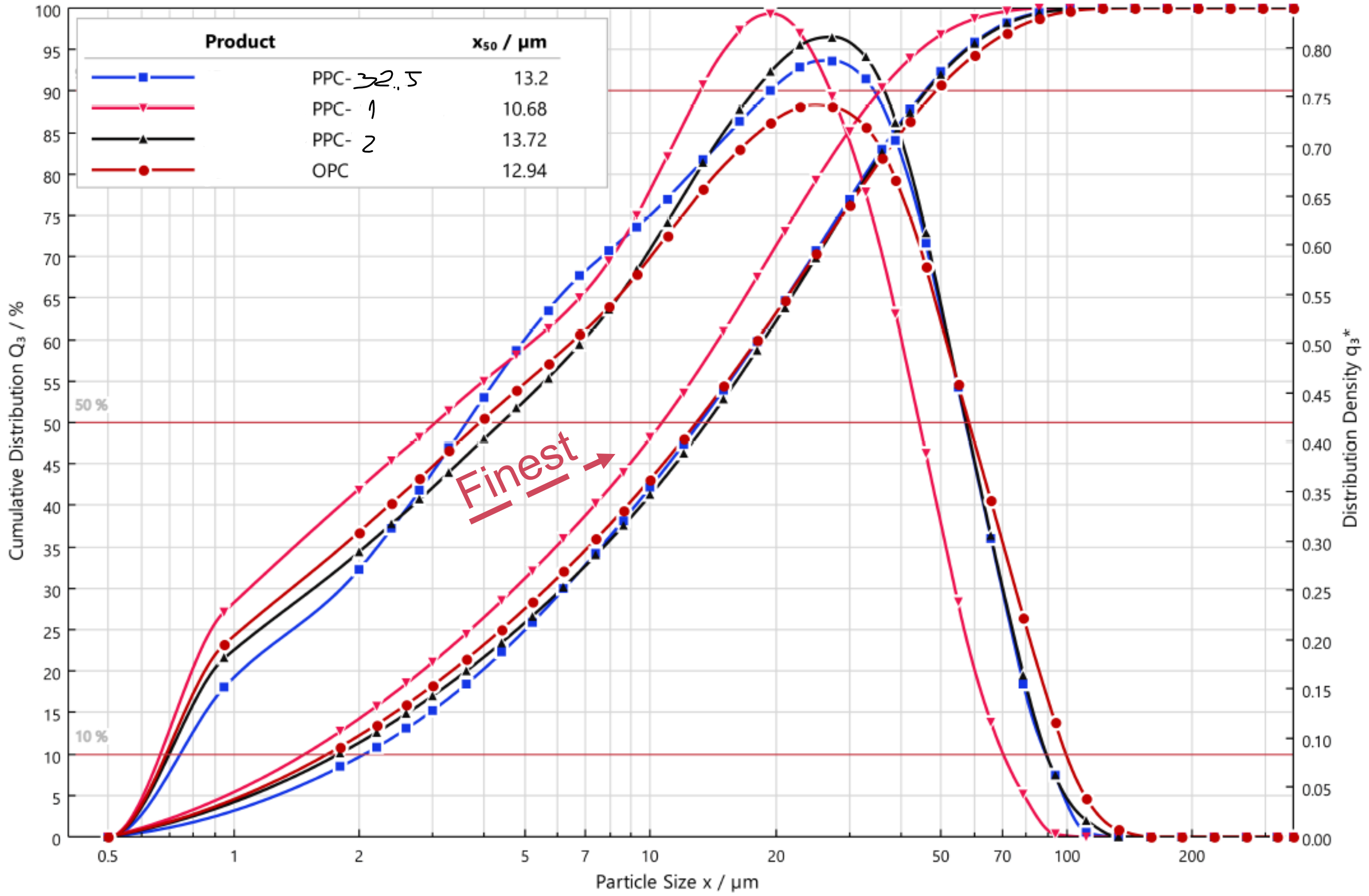
Process water – Analytical report

Process water properties	
Appearance	Clear
Odor	Unobjectionable
pH Value @ 20°C pH	7.4
Electrical Conductivity @ 25°C µS/cm	1320
Total Dissolved Solids mg/L	806
Turbidity NTU	0.2
Total Hardness mg/L	159
Bicarbonate mg/L	144
Carbonate mg/L	<1
Total Alkalinity	118

Metals mg/L			
Aluminium	<0.01	Copper	<0.01
Antimony	<0.005	Iron	<0.01
Arsenic	<0.01	Lead	<0.01
Barium	<0.01	Magnesium	**12.5**
Boron	0.72	Manganese	<0.01
Cadmium	0.002	Nickel	<0.01
Calcium	**43.3**	Phosphorus	**3.25**
Chromium	<0.005	Potassium	**12.3**
Selenium	<0.01	Sodium	**193**
Zinc	0.02	Silica	**13.7**
Mercury	**(Hg)**	**µg/L**	**<0.030**

Anions mg/L			
Chloride	223	Nitrite	<0.5
Nitrate	<1.0	Sulphate	143

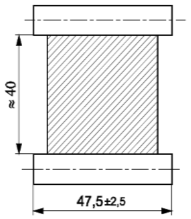
Cement Particle size analysis



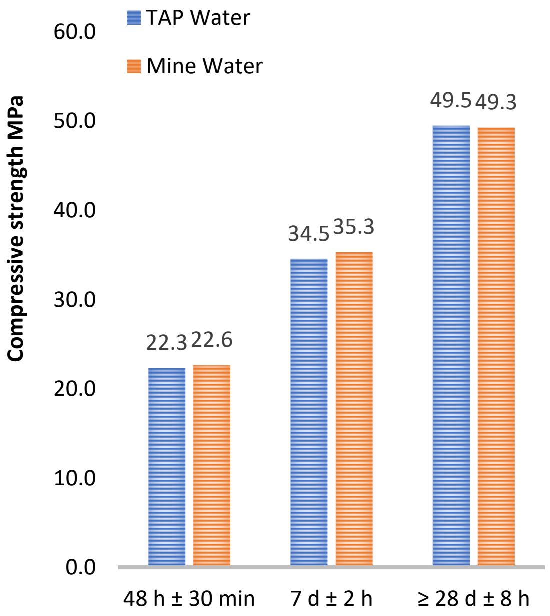
Trial Name	From PSA Analyser					
	SSA,cm^2/g	R45µ	R32µ	X10,µm	X50,µm	X90,µm
OPC	3753.27	12.01	21.90	1.70	12.94	48.66
PPC-32.5N	3822.83	10.80	21.56	1.79	13.72	46.37
PPC- 1	4520.19	5.00	13.10	1.52	10.68	35.60
PPC- 2	3613.33	10.54	21.04	2.06	13.2	45.95

The strength class of the cement was determined according to EN 196-1

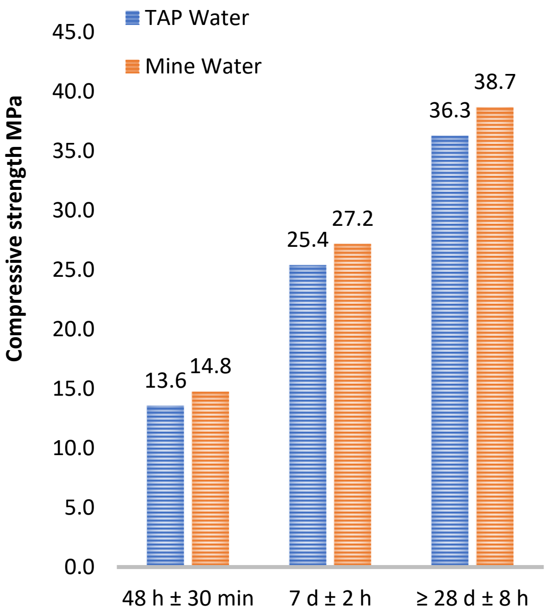
Dimensions in millimeters
Testing sample - front view
Testing sample - side view



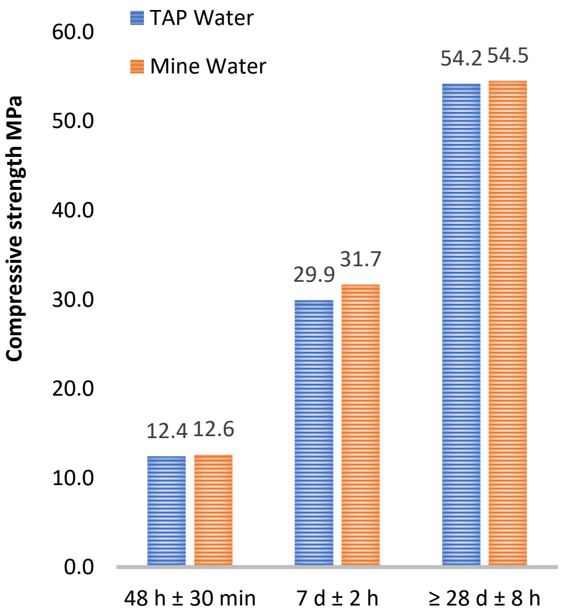
OPC



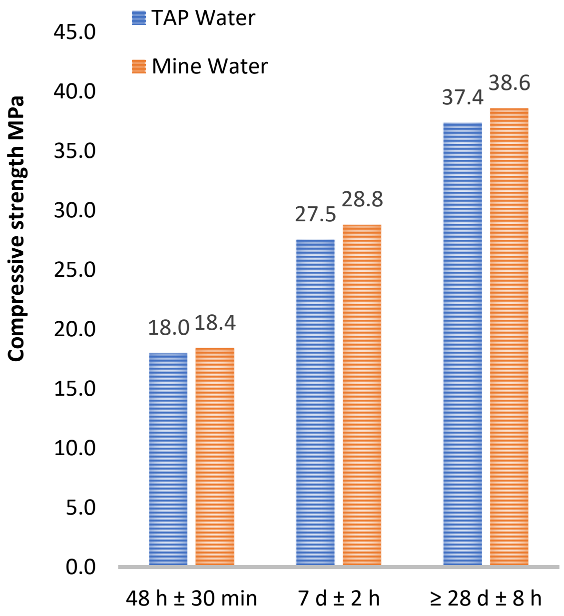
PPC 32.5N



PPC- 1



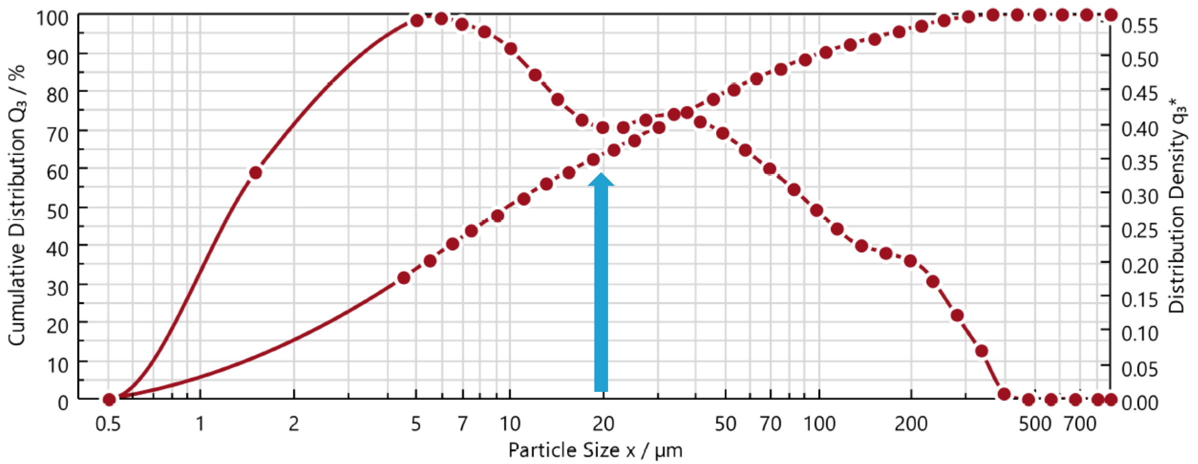
PPC-2

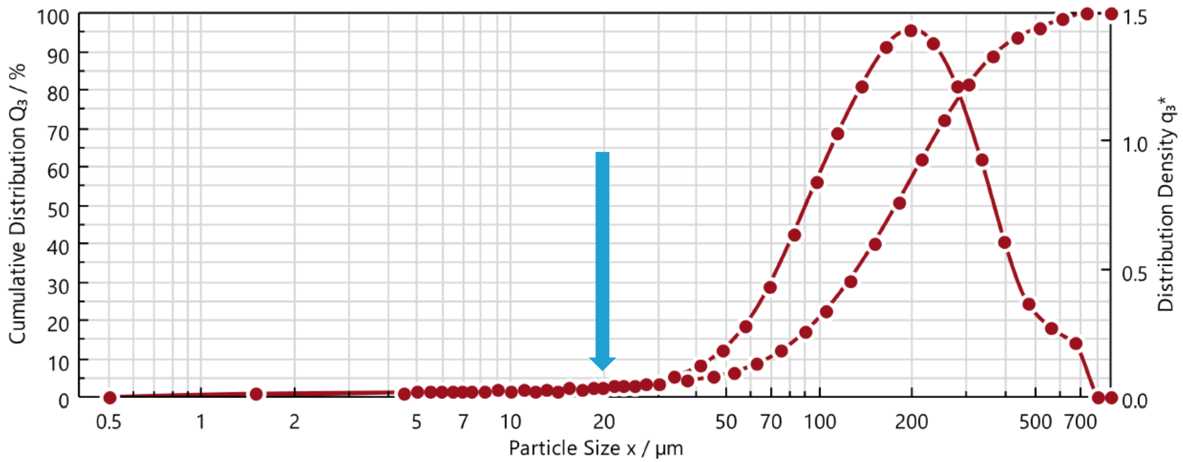


Mine Tailings
PARTICLE SIZE DISTRIBUTION

particle size distribution Tailings Fine Fraction			
x10,3 = 1.77 µm	x50,3 = 9.91 µm	x90,3 = 102.91	Mm x60,3=16.27µm
SSA(cm2/g)= 3890.27	45µm=77.97%	32µm=71.81%	3µm=19.68%
R90= 11.59%	R45= 22.03%	R32=28.19%	Density = 2.65

particle size distribution Tailings - Coarse			
x10,3 = 67.56 µm	x50,3 = 177.40 µm	x90,3 = 380.74 µm	x60,3 = 208.61 µm
SSA(cm2/g)= 303.57	45µm=5.27%	32µm=3.74%	3µm=0.76%
R90= 82.94	% R45= 94.73%	R32=96.26%	Density=2.65





Rheology & UCS Testing

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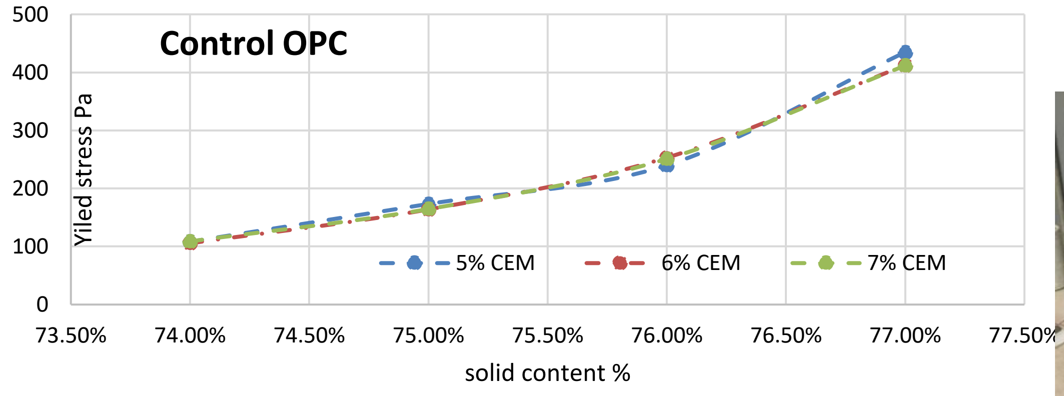
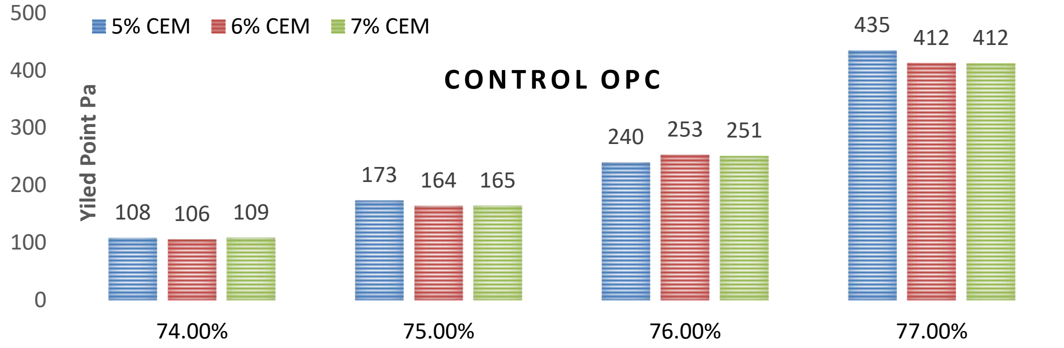
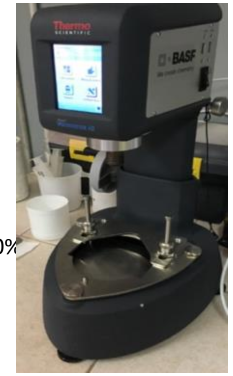
Yield stress – Control Sample

Control sample – Basic Rheology
yield stress (Pa)

A number of different mix designs (with various solids content) were prepared and tested in the rheometer for the determination of yield stress. With this standard method, different solids mass fractions ranging from 74 to 77% solid content were tested.

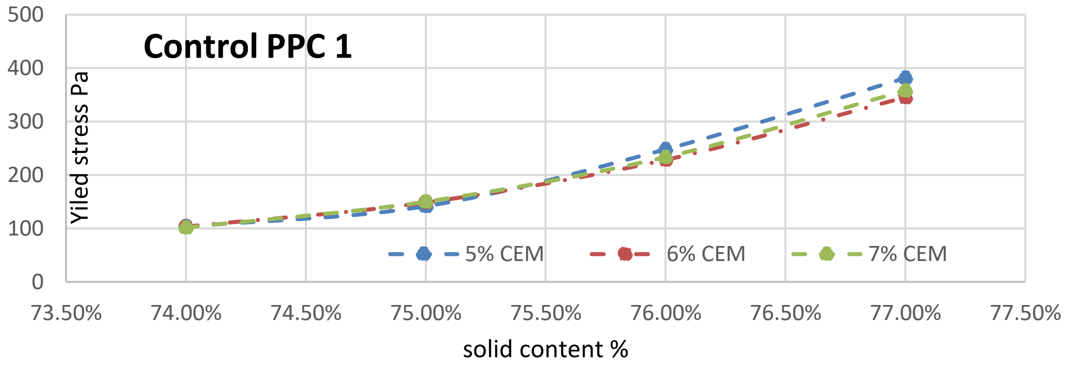


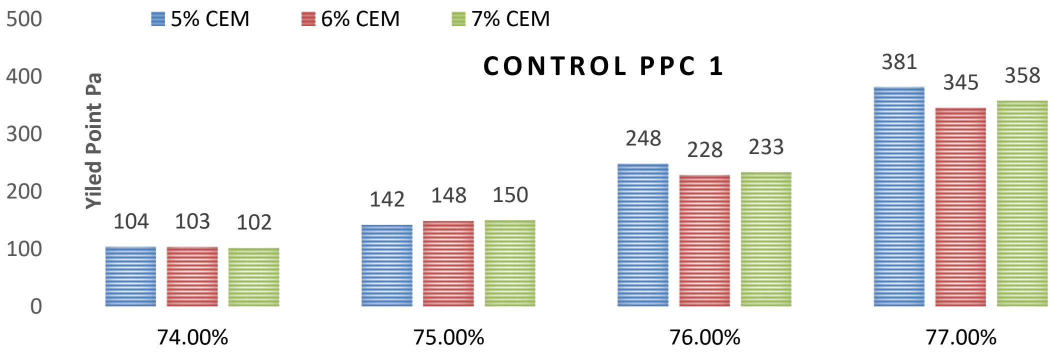




Effect of solid content and binder content

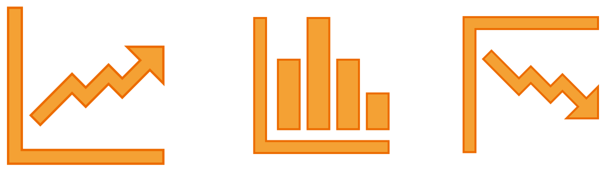
The solid content and the binder content play an important role on the yield stress and the strength development of backfill paste. The dependence of the yield stress on the solids is exponential. Increasing the solids, the yield stress rises. Increasing the binder content from 5.0 to 7.0 %, the yield stress do not have significant impact on yield stress (almost same trend)

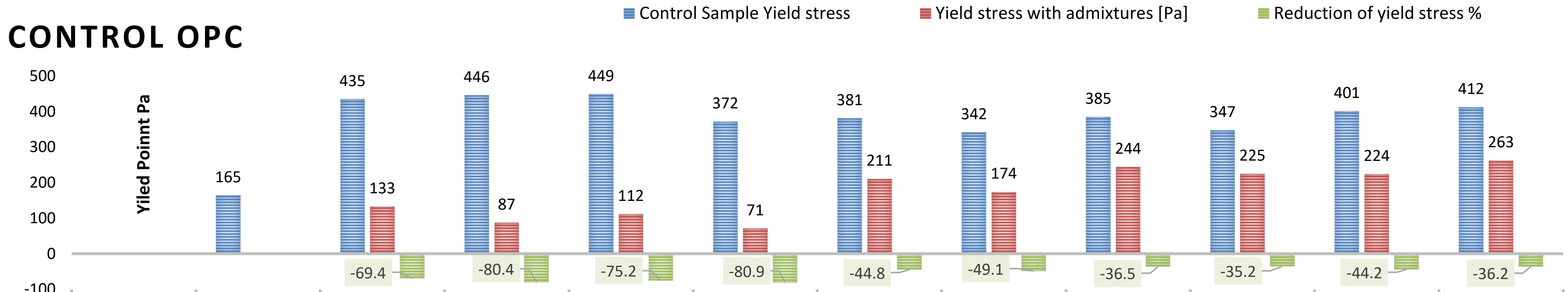




Technology Screening OPC Cement

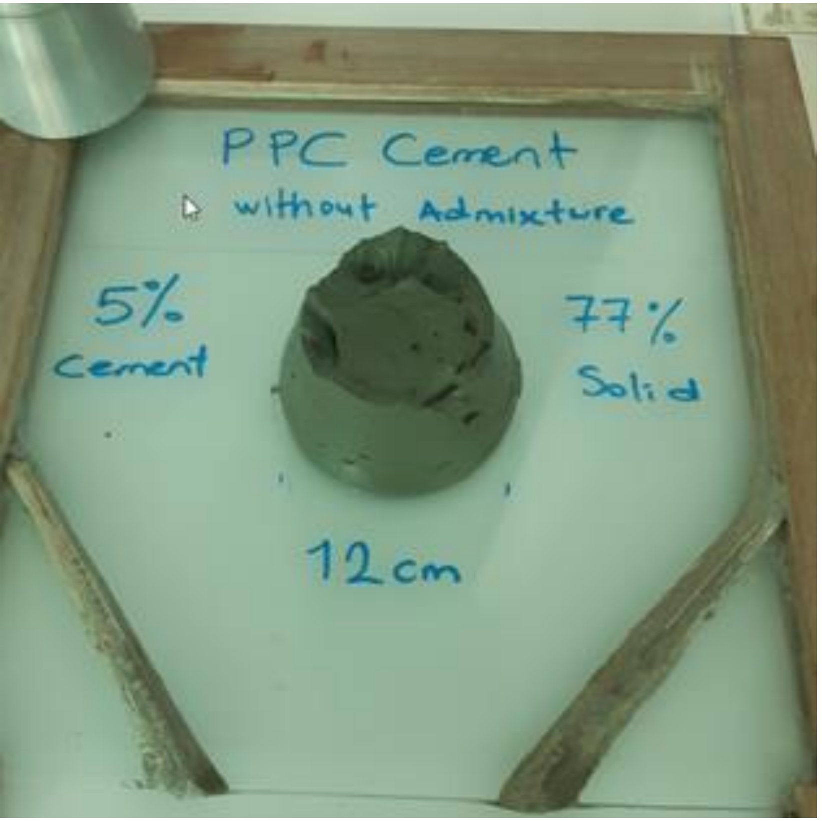
Observations:
Various polymers screened in order to identify most effective one in terms of performances but also cost benefits
R+D 10 and R+D 31 shows the best results compared to other admixtures
R+D 31, R+D 23, and R+D 24, even with the lower dose its showed great effects in the sense of yield point reduction
MasterRoc MMF 701 and MasterRoc MMF 710 as standard products and with large doses work but with limited effect

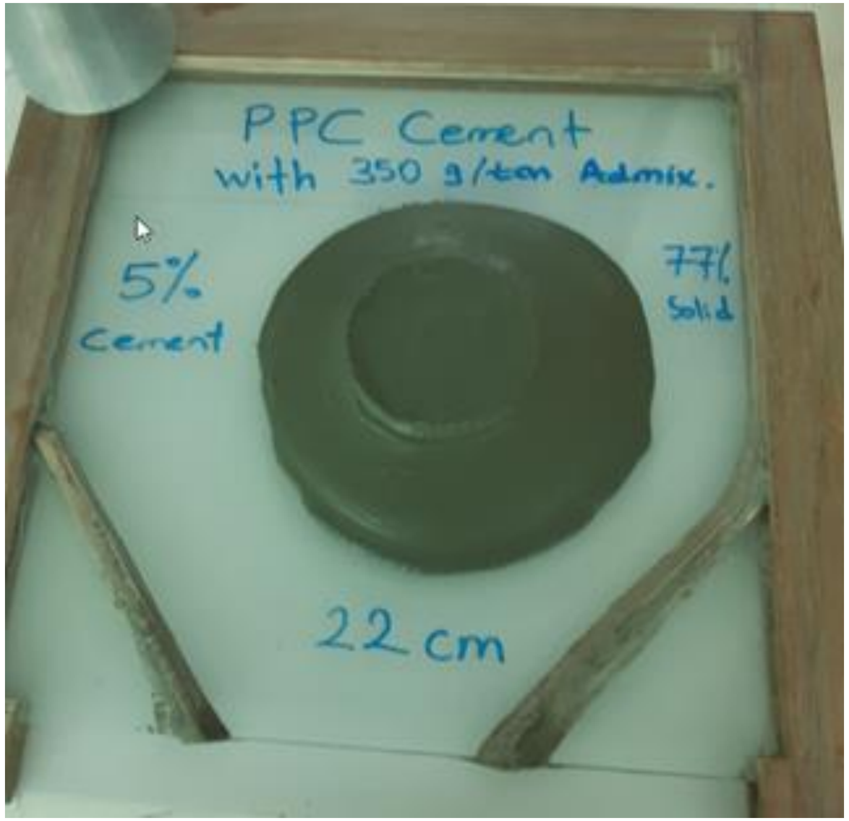


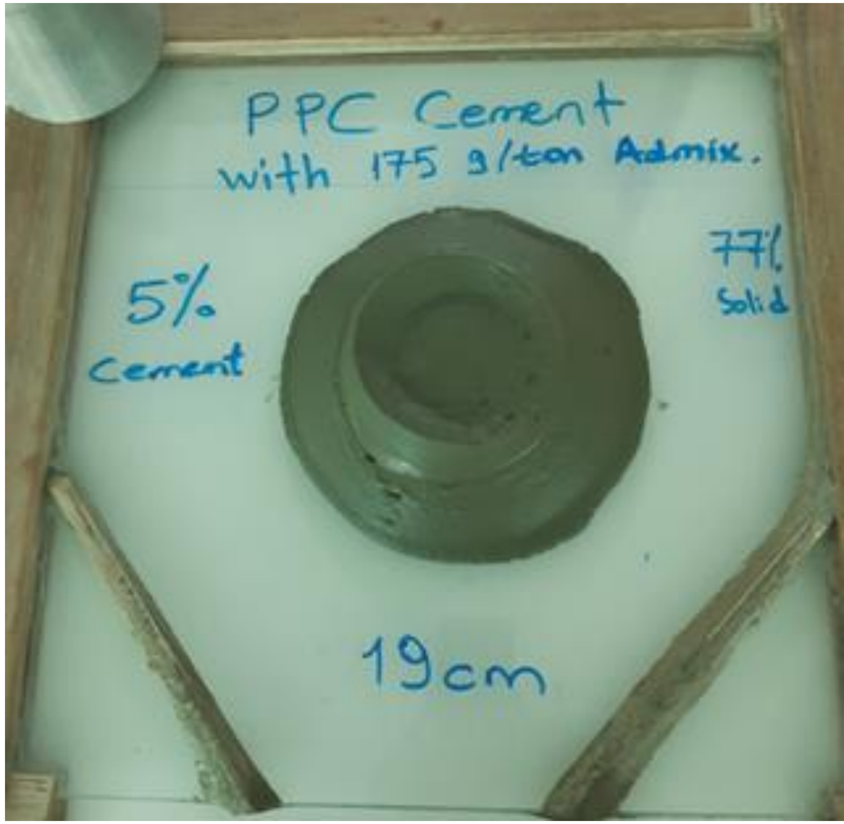


Cem.Cont. [%]	7	5	5	5	5	5	5	5	5	5	5
Dosage of admix. [ml/t]	0	350	350	350	350	350	350	400	400	500	500
Mix design	Control Sample	R+D 24	R+D 31	R+D 23	R+D 10	R+D 74	R+D 96	R+D N.Lg-Dom	R+D BNS Li.	MMF 701	MMF 710
Solids content [%]	75.00%	77.00%	77.00%	77.00%	77.00%	77.00%	77.00%	77.00%	77.00%	77.00%	77.00%

Slump



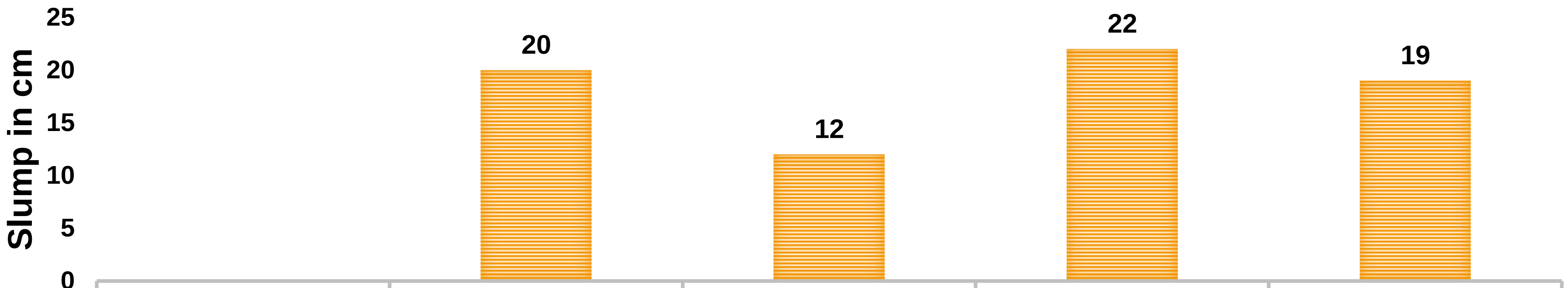




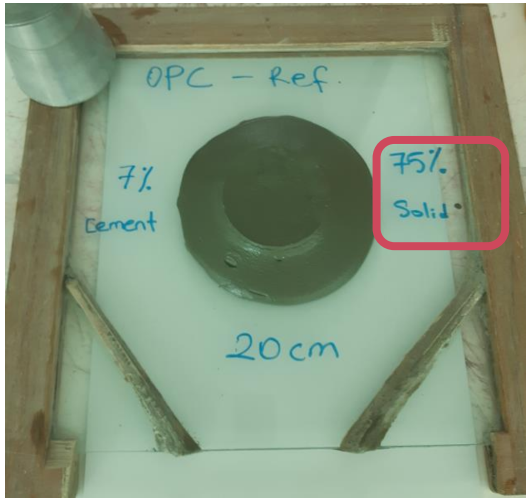
Visible effect of admixture performances on flowability of the CPF as a condition for Cement and cost optimization

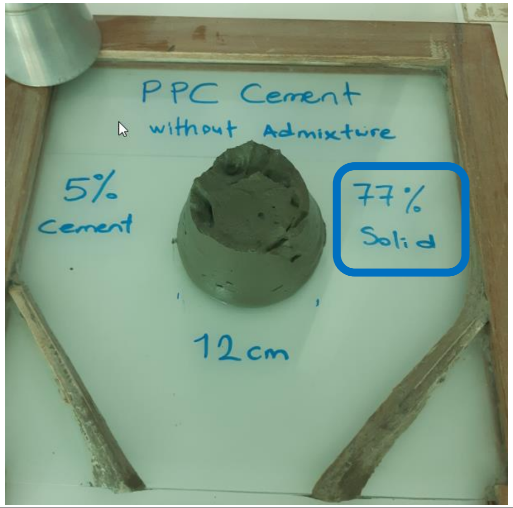
Control sample with OPC & PPC cement Vs. Admixture samples

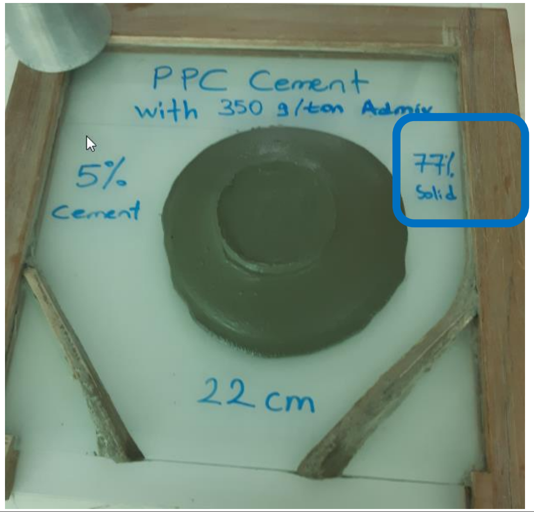
SLUMP TESTING

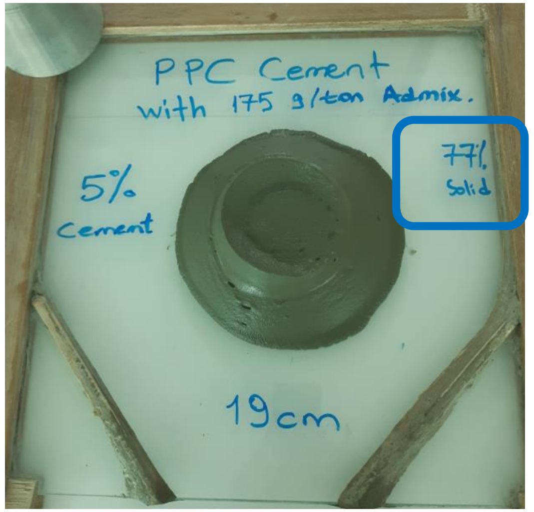


cement content	7%	5%	5%	5%
admixture dosage	0 ml/t	0 ml/t	350 ml/t	175 ml/t
Mix design	Control OPC	Control PPC 1	Combination -1(PPC)	Combination -1(PPC)
solids content	75.00%	77.00%	77.00%	77.00%

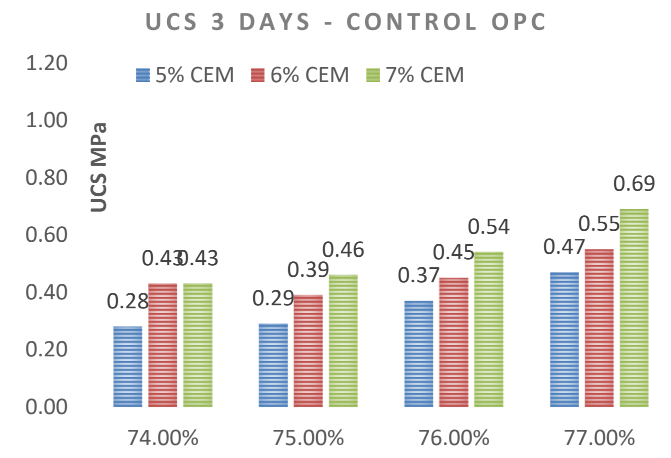


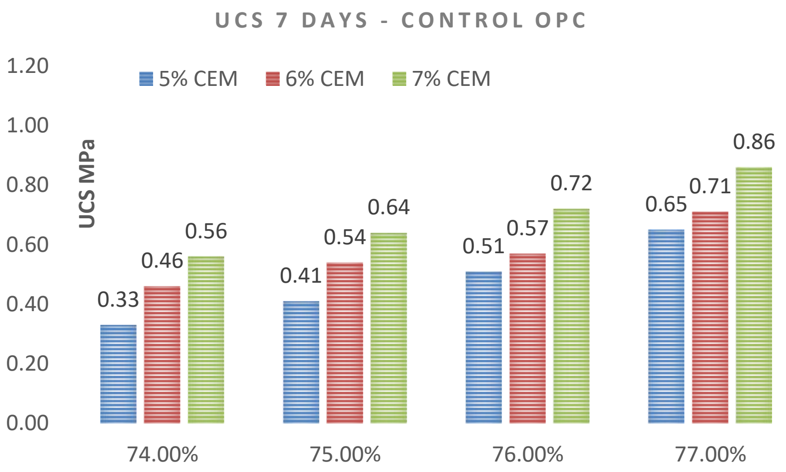


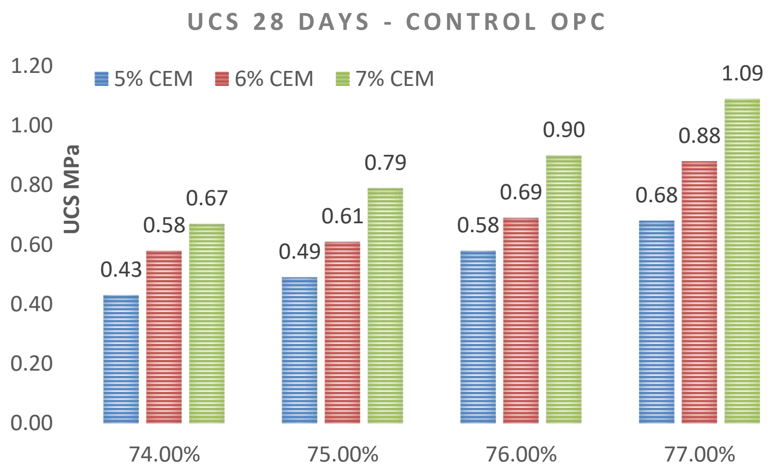


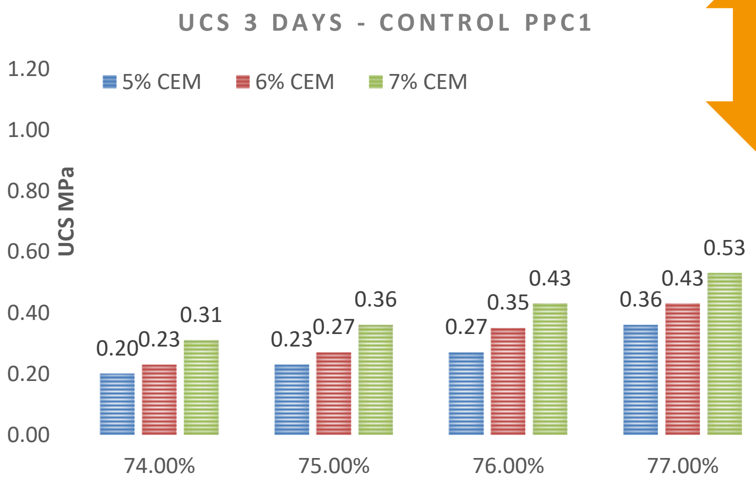


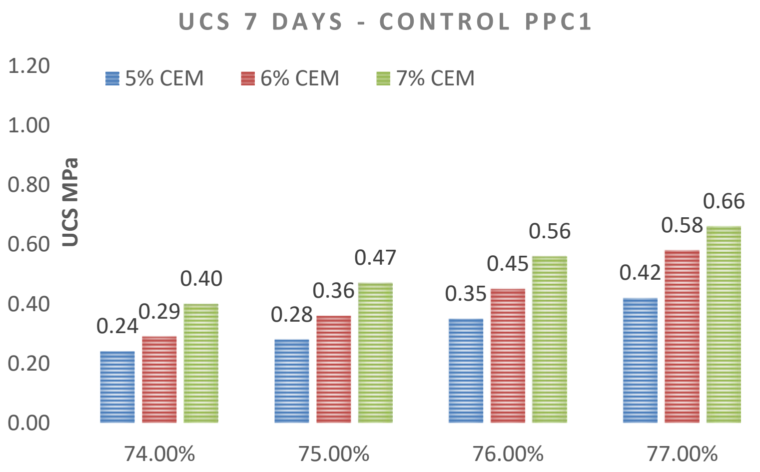
UCS - Control sample with OPC vs PPC1 cement

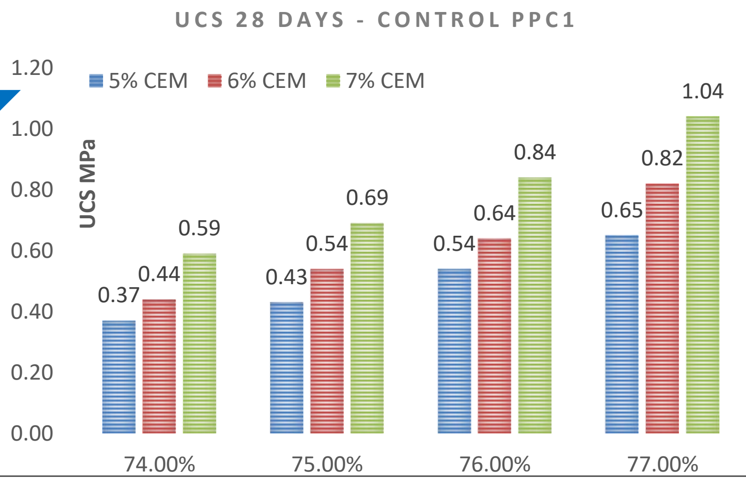












Cement reduction – Cost optimization through tailored formulation

Economical feasibility

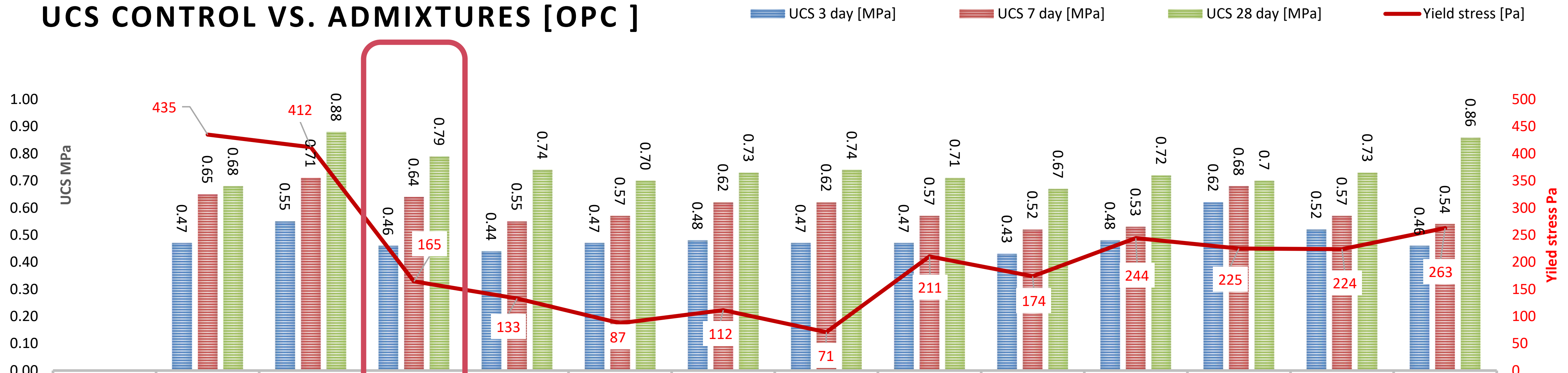
Prove of concept and real value proposition. Total impact to the mine operational and profit and benefits.

MBS Lab Lima, 2020

OPC Cement

OPC Cement	Yield stress [Pa]	UCS [MPa]
Control sample with different cement and different solid content in comparison with admixture samples with **77%** solid content and **5%** cement content with different polymer technologies		

UCS CONTROL VS. ADMIXTURES [OPC]



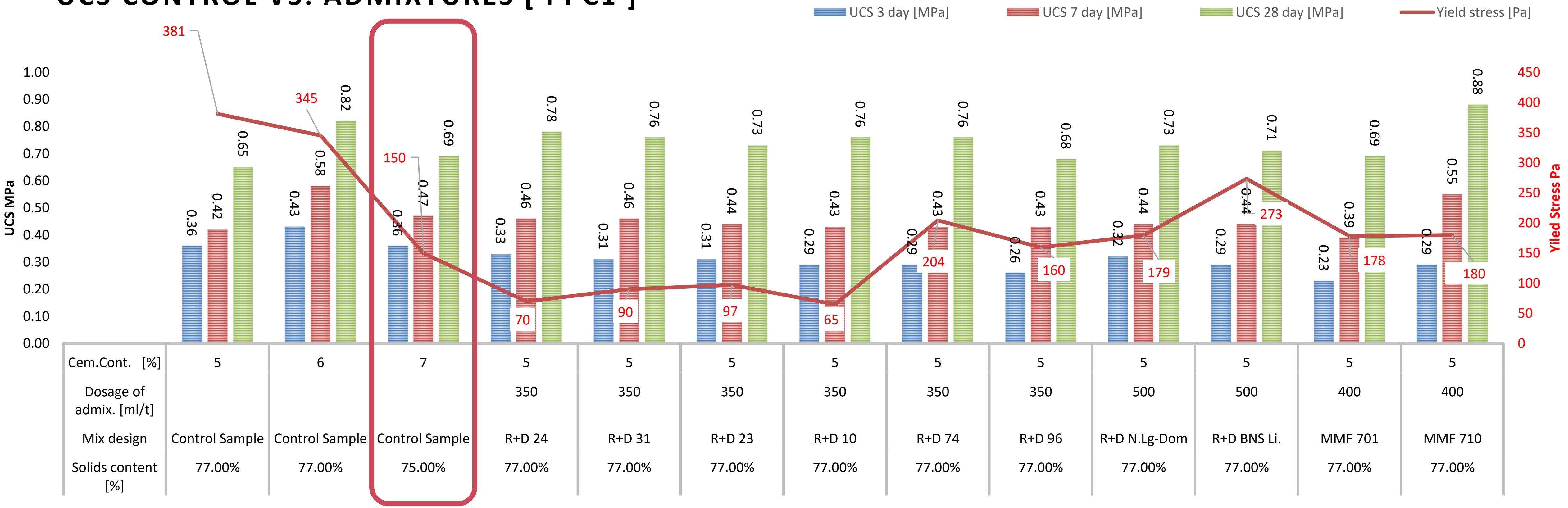
Cem.Cont. [%]	5	6	7	5	5	5	5	5	5	5	5	5	5
Dosage of admix. [ml/t]	0	0	0	350	350	350	350	350	350	400	400	500	500
Mix design	Control Sample	Control Sample	Control Sample	R+D 24	R+D 31	R+D 23	R+D 10	R+D 74	R+D96	R+D N.Lg-Dom	R+D BNS Li.	MMF 701	MMF 710
Solids content [%]	77.00%	77.00%	75.00%	77.00%	77.00%	77.00%	77.00%	77.00%	77.00%	77.00%	77.00%	77.00%	77.00%

PPC Cement

PPC Cement	Yield stress [Pa]	UCS [MPa]

Control sample with different cement and different solid content in comparison with admixture samples with **77%** solid content and **5%** cement content ad different polymer technologies

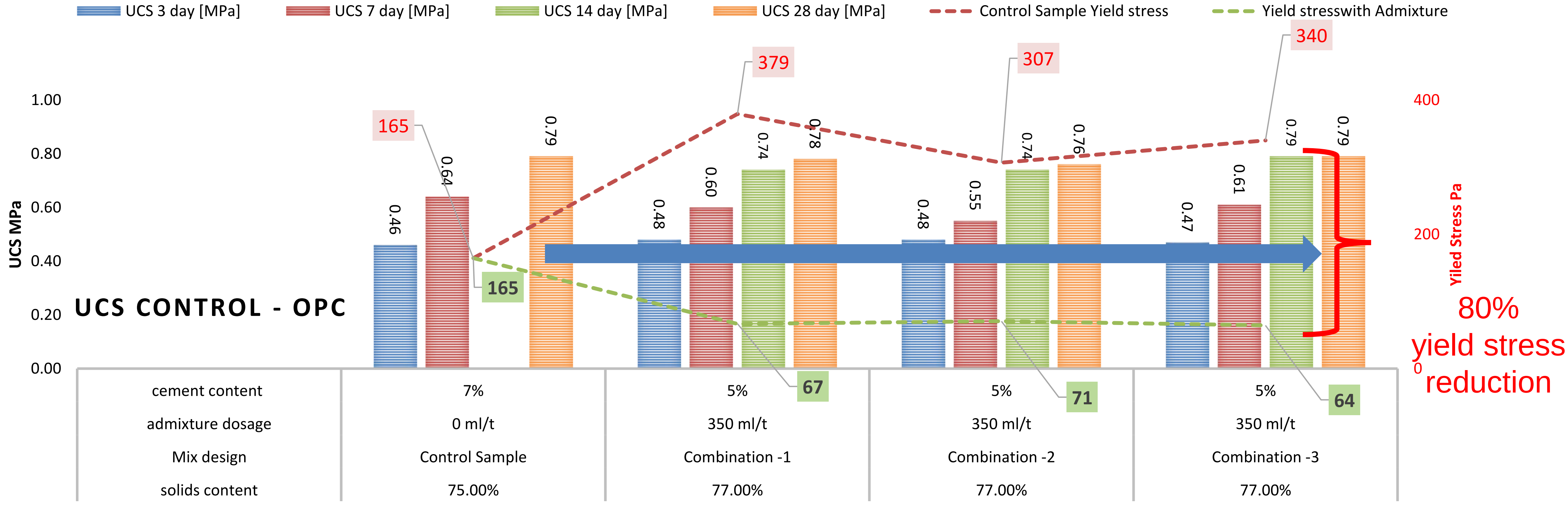
UCS CONTROL VS. ADMIXTURES [PPC1]



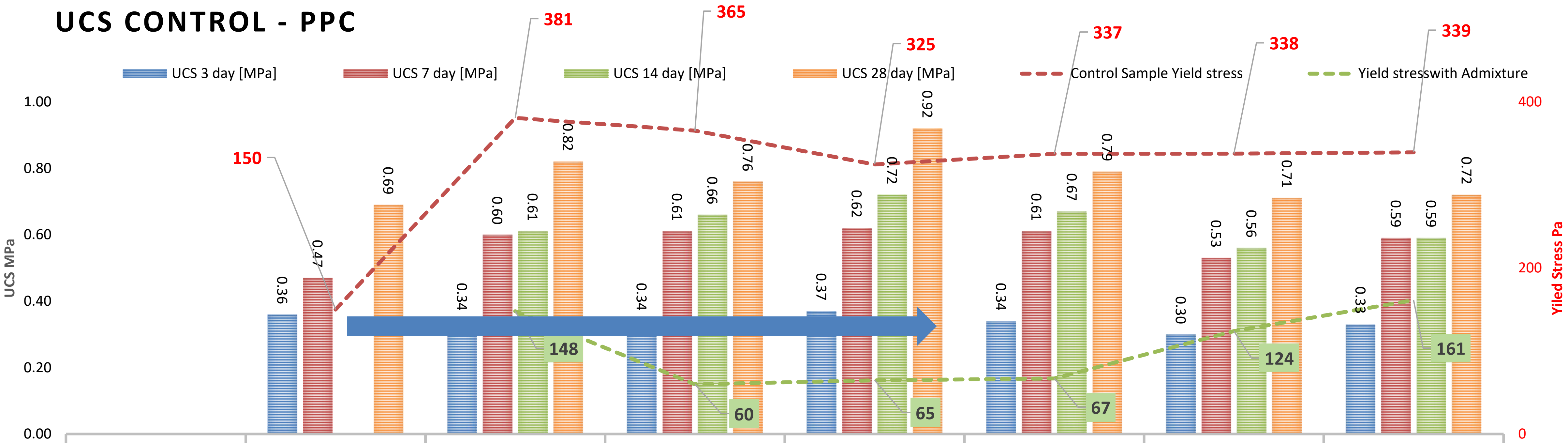
OPC Cement - reformulation

OPC Cement	Yield stress [Pa]	UCS [MPa]

Control sample **75%** Solid content and **7%** Cement content in comparison with admixture samples with **77%** solid content and **5%** cement content

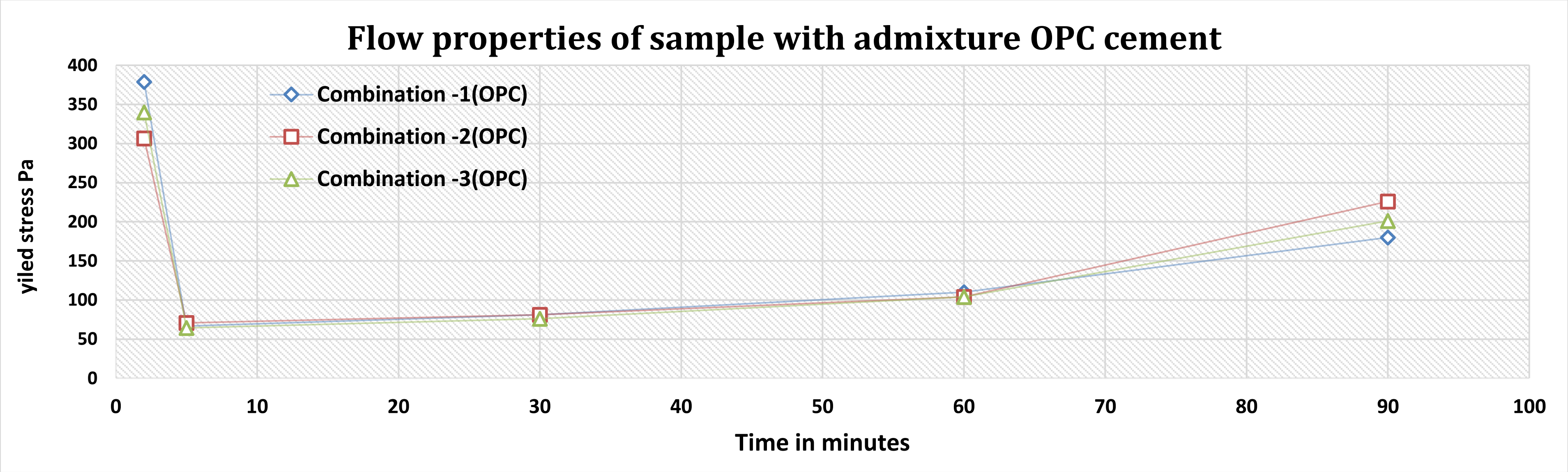


PPC Cement



cement content	7%	5%	5%	5%	5%	5%	5%
admixture dosage	0 ml/t	175 ml/t	350 ml/t	350 ml/t	350 ml/t	185 ml/t	350 ml/t
Mix design	Control PPC	Combination -1	Combination -1	Combination -2	Combination -3	R+D 10	R+D 14
Solids content	75.00%	77.00%	77.00%	77.00%	77.00%	77.00%	77.00%

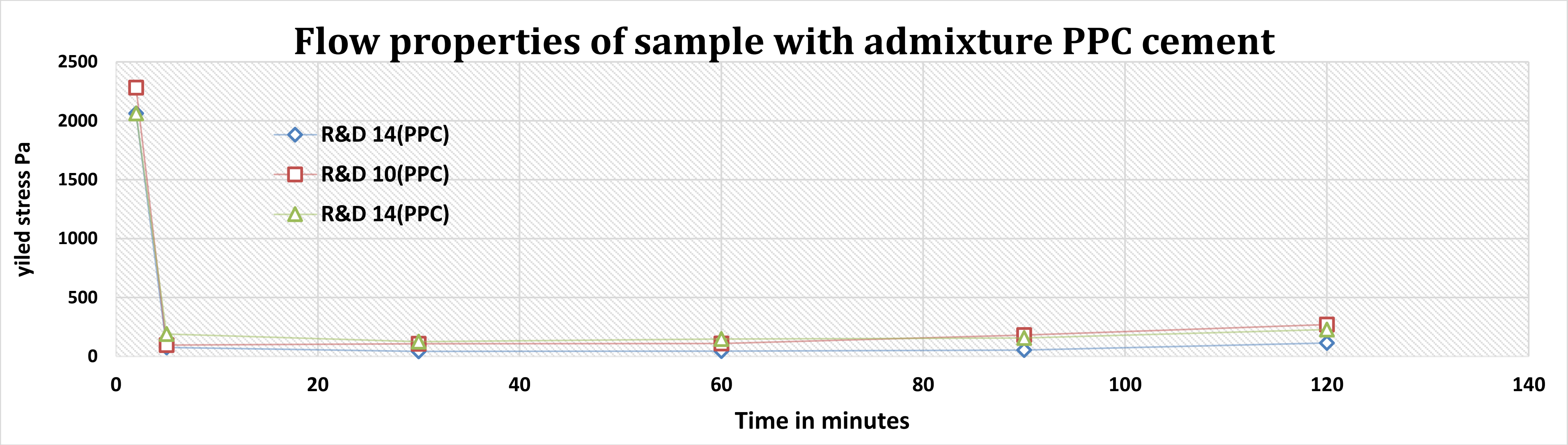
Flow retention measurements of best candidate’s for OPC cement



Flow retention measurements
open time or working time
The retardation of initial setting time by the use of admixture is affected by different factors, for example, the ambient temperature, the dosage used, or the time of adding admixtures to the tailings…
Retardation of setting time is also influenced by the type of used admixtures in the Backfill operation

Flow retention measurements OPC Cement
Solid content 77%
Cement content 5%
Admixture dosage 350ml/t

Flow retention measurements of best candidate's PPC Cement



Flow retention measurements			
solid content	Mix design	admixture dosage	cement content
80.00%	R&D 14(PPC)	**1300 ml/t**	**3%**
80.00%	R&D 10(PPC)	**800 ml/t**	**3%**
77.00%	R&D 14(PPC)	**1000 ml/t**	**3%**

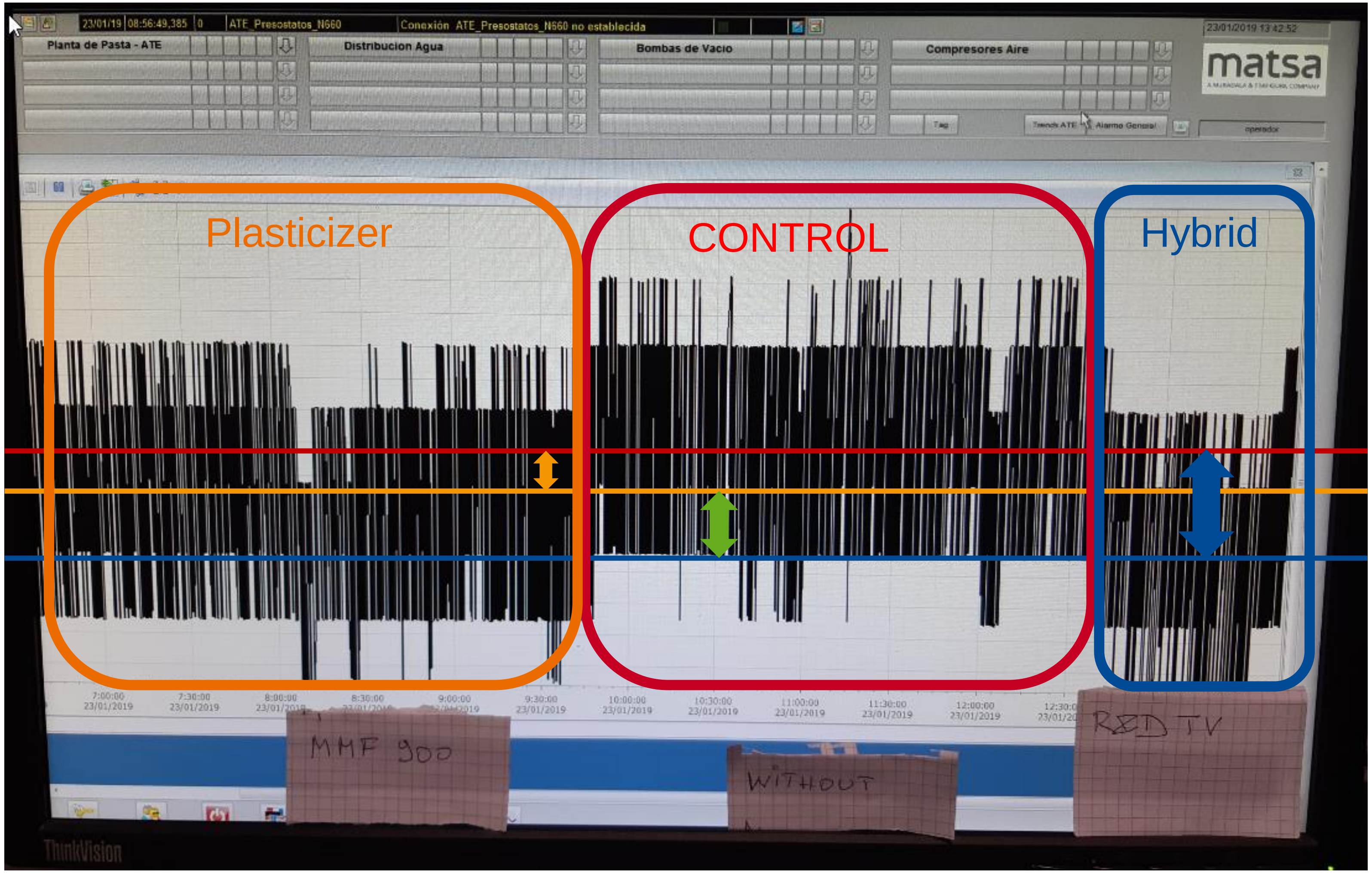
Conclusion and recommendation

- Material properties are defining behavior and performances of the CPF
- They also influence selection of chemistry and indicates formulation strategy
- Tailor made admixture significantly improve rheology (flowability) of the mix vs standard admixtures
- Admixture also can significantly change consolidation and hardening of the CPF material
- It is possible in both cases (for both cement types) to optimize cement content and overall cost of operation providing better performances of the mixes
  - Results for 5% mixes with admixtures absolutely fulfilled requirements as compared to equivalent control mixes at 7% cement without admixtures.
  - As results better, additional portion of cement can be taken
- Full scale testing will be recommended as a prove of concept
- Various range of admixtures dosage may be experienced for better cost optimization

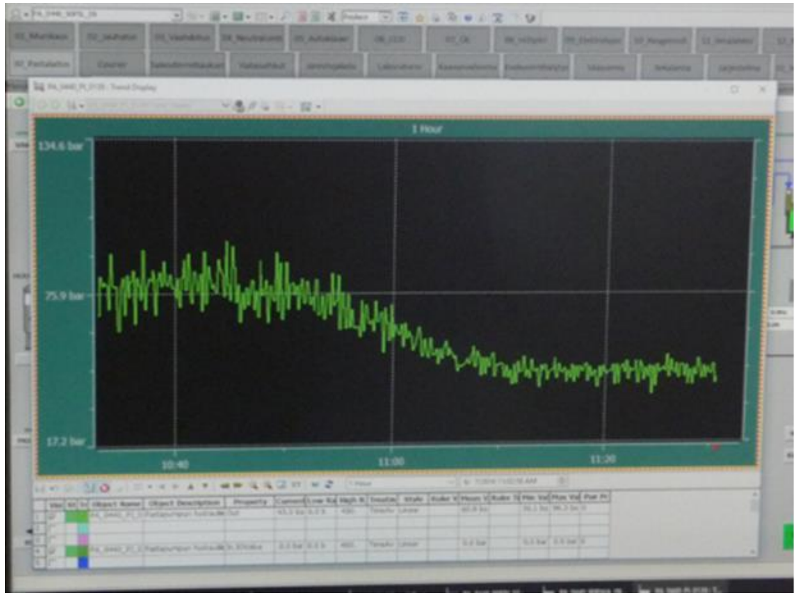
Further savings

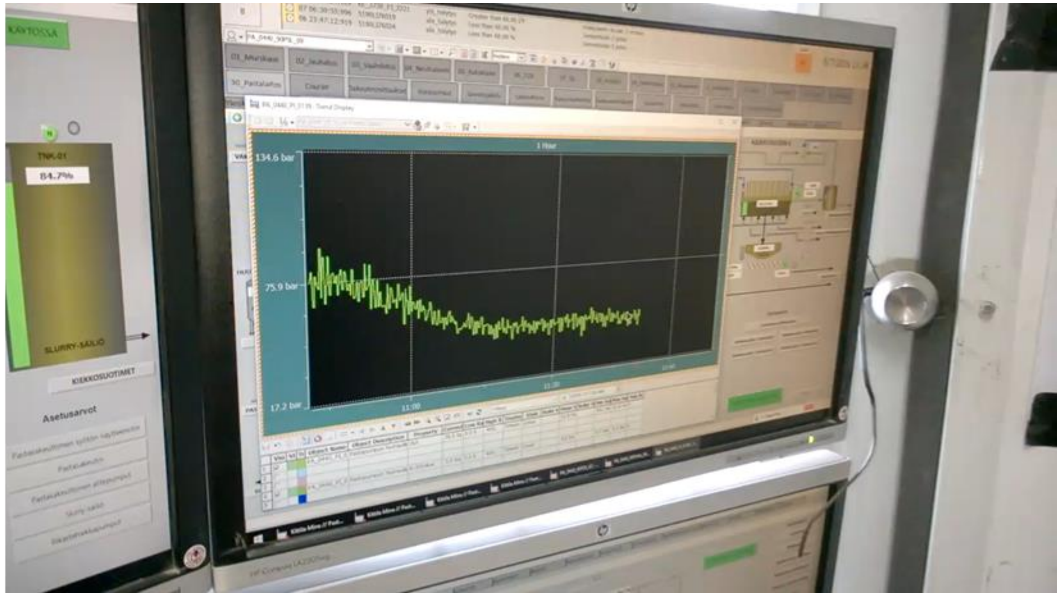
- According to our study at least 26% cement can be reduced
- Estimated cost savings including cost of admixture (into the pocket) are 0.25 $/t of backfill
- As water cost is also counting according to our calculation and results from the lab we can also indicate that 0.11$/t savings can be estimated (20L per tone of backfill)
- With cement reduction cost and water reduction we can expect at least 0.35 to 0.4$/t direct savings
- As flowability better with admixture higher productivity of the plant to be achieved (from experience at least 10% higher) what is additional cost savings due to same fix and labor cost for greater production rate
- Also as lower viscosity of the paste, lower energy consumption possible (mixer) but also maintenance
- We also estimated according to lab result that more tailings can be placed UG as compared to recent situation
  - Our calculation says that with for mix 75%solids and 7%cement replaced with 77%solids and 5% cement increase in tailings UG will be 4.87%
  - Cement reduction is 26.7%

Full scale testing Mixer energy consumption



Admixtures test MasterRoc MF

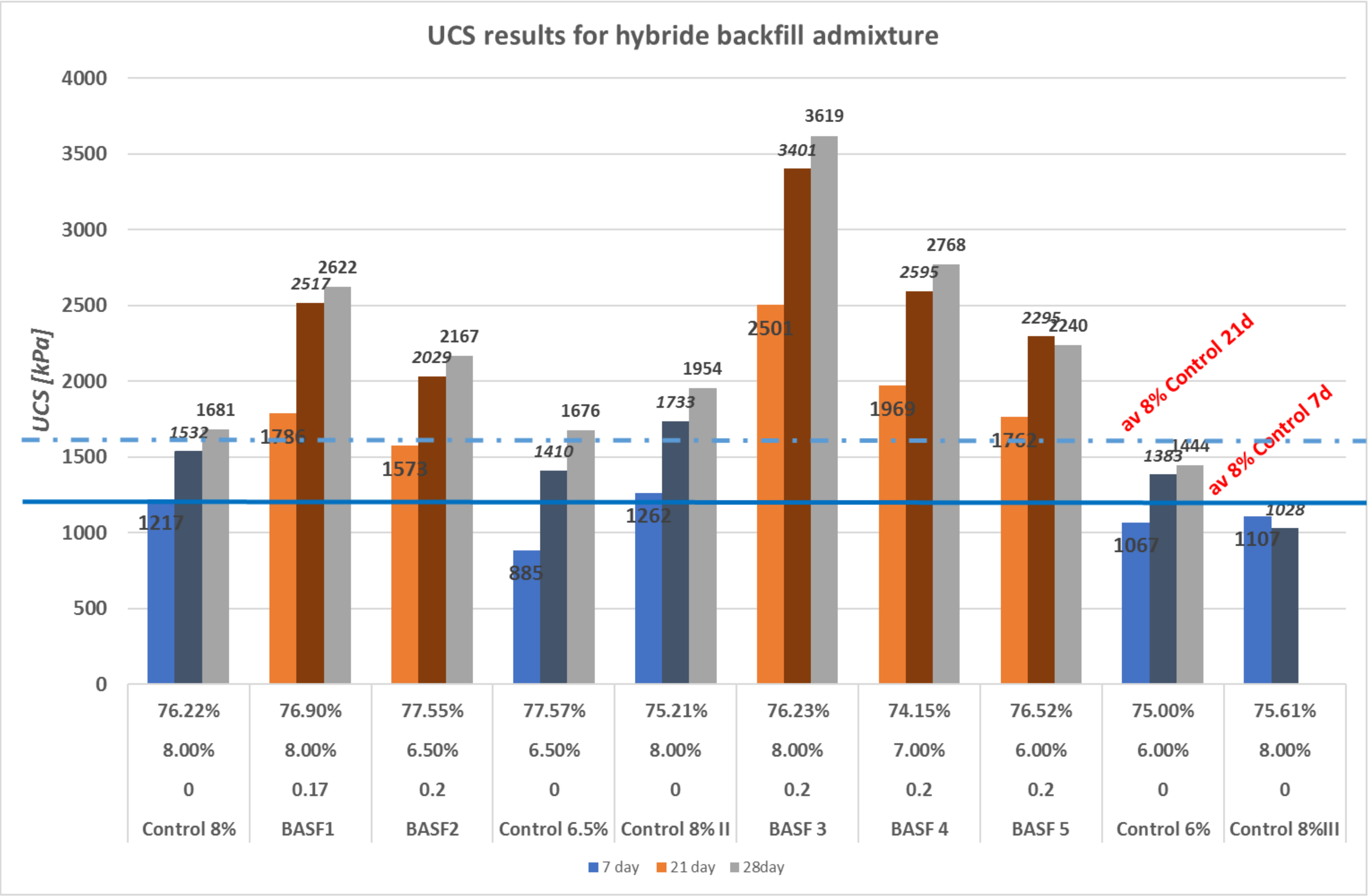




- From control mix without admixture, admixture added and pressure drop observed (from 85 bar down to 40 bar – approximately)
- Admixture dosage kept constant over entire testing program at 300 mL/t
- Process fluctuation much lower as compared to control sample for the same mix design parameters

Full scale test

» Full scale testing with new designed admixture for high cement content mix design
   » Admixture tailor made to provide enhanced rheological characteristic
   » Chemical design of Admixture provide outstanding strength and cost reduction at the same time
   » Unique and patented BASF polymer for first time used in this application



Mass flow chart

Binder	Mix design	Mine Backfill capacity	Dry Tailings	Binder mass	Binder reduction	Water	Water reduction	Total solids mass	Density of backfill [kg/m3]	Thickened Tailings to surface pond %	Density of tailings to pond [kg/m3]	SG Tailings [kg/m3]	SG Binder [kg/m3]	Average SG	Mine water SG [kg/m3]	Water savings m3	More tailings UG T/year	Volum of additional slurry to be disposed on surface m3	surface required for 0.5 m thickeness	Football field 100x70
5.00%	Control	3,000,000	2,194,500	115,500	24%	690,000	9%	2,310,000	2454	55.00%	1739	4,400	3,200	4,340	1000	60,000	87,810	50,491	100,982	**14.4**
3.70%	Admixtures	3,000,000	2,282,310	87,690		630,000		2,370,000	2555	55.00%	1739	4,400	3,200	4,356	1000					

with admixture

without admixture

Backfill benefits MATSA

Potential increase in production rate

Tailor made Hybrid Admixture alternative mix design value

Summary and next steps in …

0.25$/t
+
0.11$/t

Cost Savings

Mix design cost can be reduced

24%cem
+4.8% Tails UG
9% H_2O

Reduction in Cement & more Tails

Significant Cement reduction.
Water demand can be reduced
More tailings UG, less Surface cost

Eco-Impact
CO_2 print

More Solids UG

Less tailings on the surface more UG, Lower surface print of the tailings pond, lower CO_2 print, eco taxes

Improvement in operation

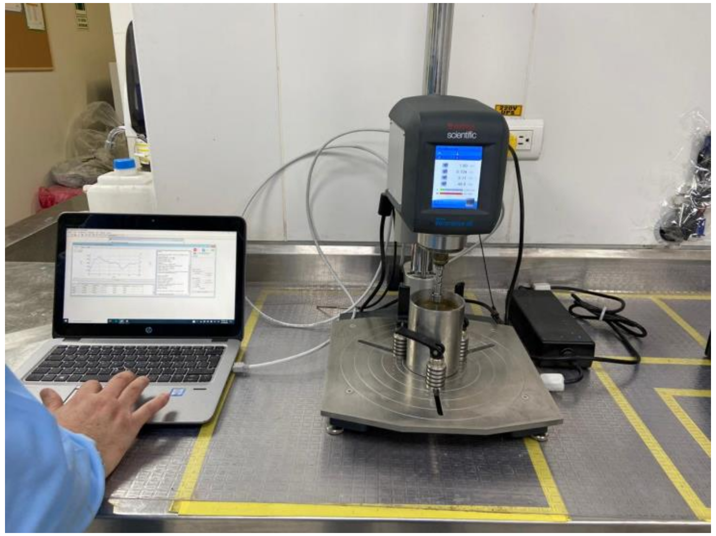
Enhanced Rheology (flow/flow retention)
Cheaper mix, lower shrinkage, lower energy due to lower viscosity. Higher output possible

What's next?

- **Lab Prove of concept completed**
- **Prove of concept on the site**
- **Results documentation & publication**
- **Knowhow sharing and long term relationship development**

What always win is a TEAM

Peru backfill lab equipment

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