

Investigating the effect of aggregate type on the strength and energy absorption of shotcrete in Block Cave Mining.

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Introduction



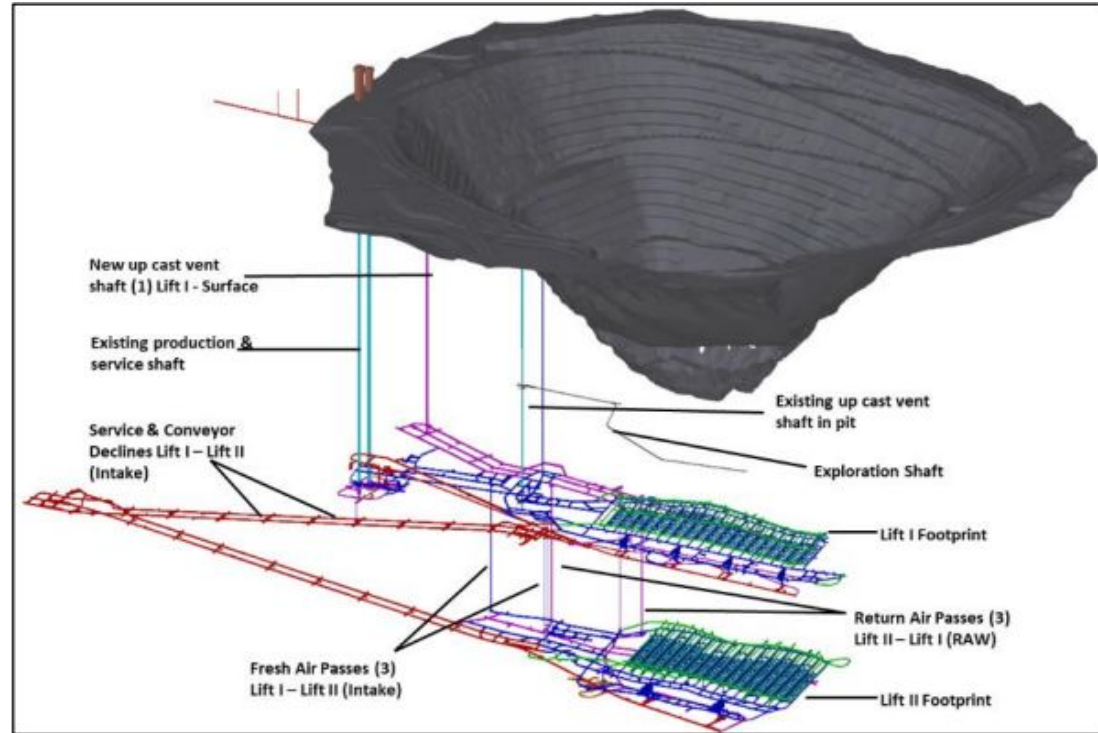
PILLARS OF MoU BETWEEN PMC & UNISA

#	Pillar Type	Pillar Description	Pillar Update
1	Research and Development for Postgraduate Studies	Support and enable PMC employees to partake in industry-based research through MSc & PhD studies	❖ 10 Employees for MEng (1 Completed) ❖ 1 Employee for PhD
2	Work Integrated Learning (WIL)	Assist UNISA students gain practical work experience	❖ 3 Mining Eng Students on-boarded in 2024 & for 2025 plan is 4 ❖ 1 Mine Survey Student on-boarded in 2024
3	Short Learning Programs (SLP) at above NQF Level 4	Accelerate development of employees by elevating their knowledge and skills	❖ 3x SLP's active (Management Essentials, Mining & Mineral Processing)
4	Higher Certificate in Supervisory Development (NQF Level 5)	Enable Supervisors to properly lead, inspire and guide their teams	❖ Programme may start in Jan 2028
5	Recognition of Prior Learning (RPL)	Provide opportunities for employees who have gained experience with no qualification to obtain formal qualification	❖ 16 employees admitted through RPL
6	Collaboration in Research, Innovation, Commercialization and Technical Support	Drive business sustainability to build strong technical pipeline or internal pool of experts	❖ 5 papers published in different journals and conferences ❖ 1 JRP call between SA/China (through NRF)
7	Exchange of educators, learners, administrators and advisors to participate in conferences, symposia and seminars	Provide platform for professional development and networking	❖ Digital Transformation in Mining Conf (2025) – 1 PC & 1 UNISA presentations ❖ AFriRock conference (2025) – 2 papers presented

❖ Work being presented in this SANCOT Symposium falls in Pillars #6 and #7.

Introduction

- ❖ Palabora Copper Mine's Lift II block cave development (1650m depth) is progressing towards a breakthrough into Lift I (1200m depth)
- ❖ The Palabora Copper (PC) Igneous Complex is an Archaean Foskorite-Carbonatite Pipe complex with an area of 20 km²
- ❖ **Shotcrete** forms integral part of support required for life mine excavations and to curb against seismic damages, with average of volume of 1600m³ per month.
- ❖ To achieve this shotcrete demands and concrete, the underground batchplant was constructed similar to surface plant.
- ❖ Shotcrete quality control system was in place to ensure the batch quality is to design.
- ❖ The quality control results were used as indicator of the quality of the mix.



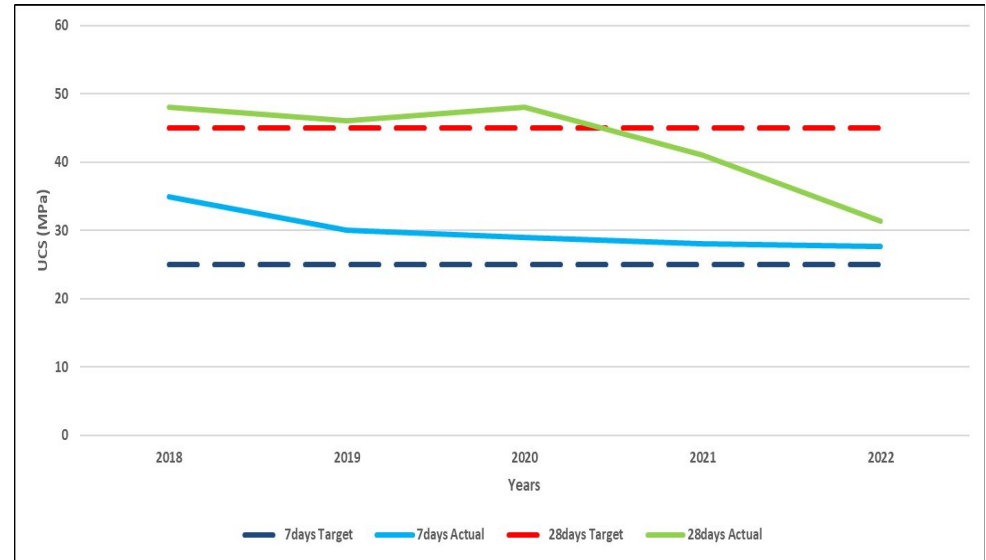
- ❖ The purpose of the study is to evaluate the effect of aggregate type on the strength and energy absorption of shotcrete in Block Cave Mining.

Shotcrete Design

- ❖ Shotcrete mix was designed to satisfy set performance criteria for wet and hardened shotcrete, including workability (wet-mix) and final strength.
- ❖ The mix constituents and proportioning was to ensure minimum rebound, reduce potential shrinkage problems and surface cracking and suitability to the block cave mining operational requirements.
- ❖ Shotcrete as areal support coverage at PMC block cave mine is required to provide stability of excavation for the life of mine and must withstand variable stress changes over different phase of mining.
- ❖ Design changes must thus follow systematic process to ensure rock engineering set performance requirements are met without risking the Health and Safety of employees.

Shotcrete Mix Problem

- ❖ In July 2021, the mine experienced a substantial shotcrete quality issues that included loss of open time/workability, mix segregation, and poor performance.
- ❖ The cube test results and energy absorption results dropped significantly below the minimum target at 28 days, confirming poor shotcrete mix.
- ❖ The investigation revealed that there was a change in the type aggregates used without trial process.
- ❖ The crusher dolerite sand was changed to a mica rich dolerite from neighbour mine.
- ❖ The low clay content river sand was changed to a high fine, high clay content river sand source.
- ❖ This change resulted in high water demand which influenced overall performance.



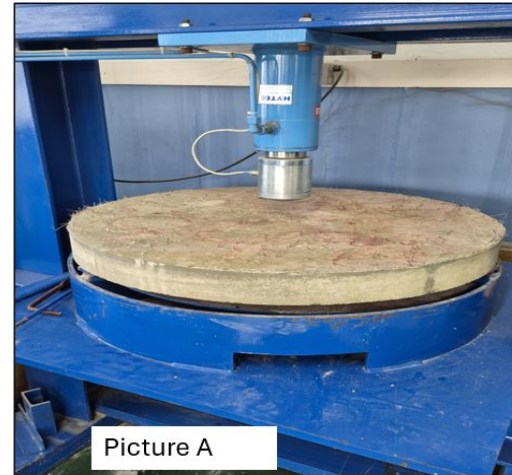
Investigation Methods

Initial Investigation:

- ❖ Looked at the mix design currently used compared to the original for any discrepancies including dosing process.
- ❖ Assessed all the constituents of the mix and their proportion against the design.
- ❖ Assess conditions led to sourcing out of mine crusher dyke sand.

Laboratory Testing:

- ❖ A comprehensive laboratory test programme to evaluate effects of change in aggregate type on quality and shotcrete performance.
- ❖ Systematic evaluation of batching process to assess plant calibration, accuracy and consistency.
- ❖ Daily sample preparation in accordance with ASTM C1140 Standards (7 & 28 days UCS tests).
- ❖ Energy absorption tests in accordance to ASTM C109 and ASTM C1550.



Picture A



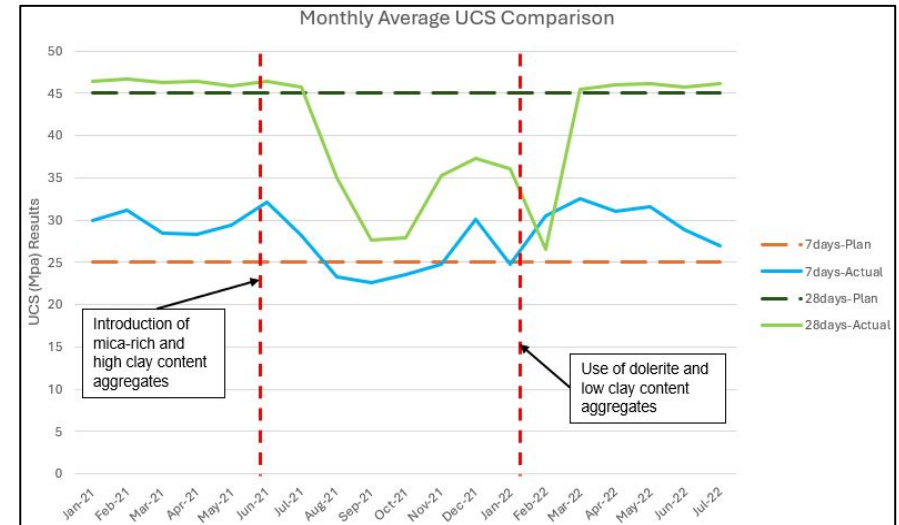
Picture B

Results and Discussion

- ❖ The results cover three distinct periods: pre-aggregates change, during the use of combination of mica-rich crusher sand and high clay content river sand, and post intervention (use of uncontaminated crusher dyke and low clay river sand)

Evolution of compressive strength of shotcrete over time:

- ❖ Pre- June 2021 the standard shotcrete UCS complied to defined specifications.
- ❖ A sudden drop in performance and subsequently strength was observed in July 2021.
- ❖ This was attributed to change in aggregates adopted as part of commissioning new batchplant.
- ❖ New aggregates resulted in increased water demand in the mix (more than standard w:c 0.45 – 0.5).

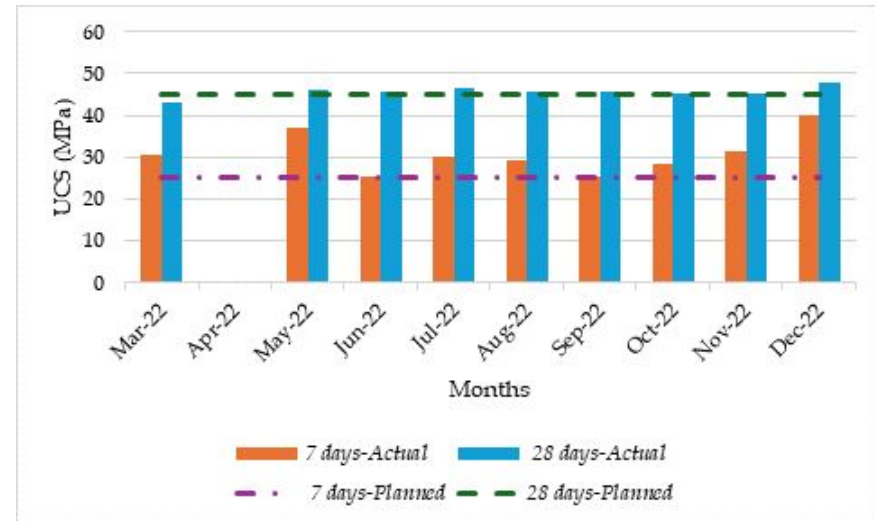


- ❖ These affected workability by creating segregation, reduced open time and affect the hardened strength.
- ❖ Clay creates shrinkage and surface cracks creating increased permeability.

Results and Discussion cont.

Evolution of compressive strength of shotcrete over time:

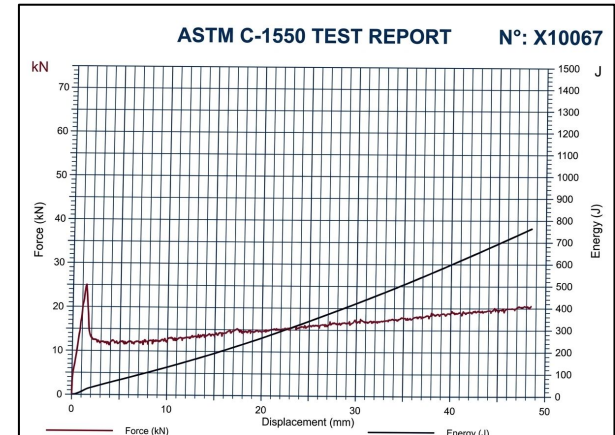
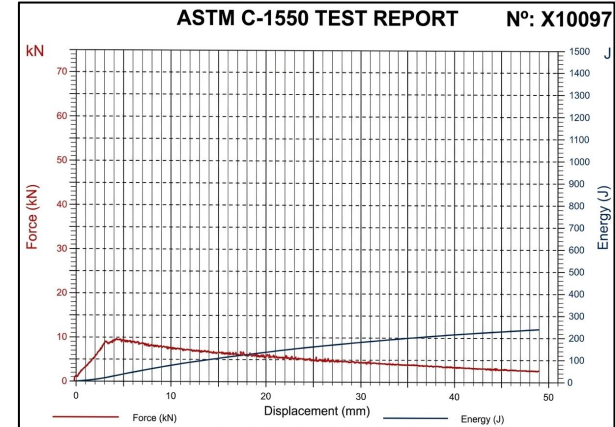
- ❖ Following the investigations, the mine reverted back to uncontaminated crusher dyke and low clay content river sand.
- ❖ In March 2022 onwards, the 7- and 28- days the shotcrete showed improved UCS results.
- ❖ These indicates the significant effects the aggregates type have on the shotcrete quality an performance.



Results and Discussion cont.

Energy absorption comparison of both mix designs:

- ❖ The energy absorption of shotcrete refers to its ability to absorb energy from external/dynamic loading, such as rock bursts and seismic events, thereby preventing rock failure (Khosh and Atapour, 2024).
- ❖ The area under the curve from 0 – 40 mm denotes the energy absorption of shotcrete.
- ❖ In March 2022 onwards, the 7- and 28- days the shotcrete showed improved UCS results.
- ❖ The energy absorption value read off from the ASTM panel test graph at 40mm deflection is multiplied by 2.5 to convert to the EFNARC standard (Morton et al, 2009).
- ❖ Sample (RDP) X10097 shows shotcrete performing below minimum target of 900J from the clay and mica rich aggregates mix.
- ❖ Sample (RDP) X10067 shows shotcrete performance of 1500J EFNARC above minimum target of 900J from low clay and mica aggregates mix.



Conclusion

This study delved into described the effect of aggregate type on the strength and energy absorption of shotcrete in Block Cave Mining. The findings of this the study are summarized as follows:

- ❖ Mica-rich aggregate reduces the energy absorption of shotcrete, which also represents its toughness. Consequently, low energy absorption means weak shotcrete, increasing the likelihood of cracking and compromising tunnel stability.
- ❖ Like mica, superfines and high clay content in sand increases increase the water demand of the mix. This may make the mixture appear workable initially but effectively raises the water/cement ratio and potentially reduces strength.
- ❖ Clay affects durability, as it interferes with proper binder hydration and bonding, creating a more porous and weaker internal structure. This reduces resistance to moisture ingress and long-term deterioration, particularly in aggressive environments.
- ❖ Changing any of the shotcrete mix design constituents without following due process does not only affect the mix design performance, but it also affects operational schedule and has high-cost implications on the business.

Acknowledgements



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Thank You