A Method of Pre-mining Rib Pillars and Replacing These Pillars with Cemented Aggregate Fill

AfriRock Conference

21-23 July 2025

DAYENU
Mining Consultants

Agenda

DAYENU
Mining Consultants

01 Background, Geology and Mining Environment

02 Problem Statement

03 Method of Pre-mining the Rib Pillar

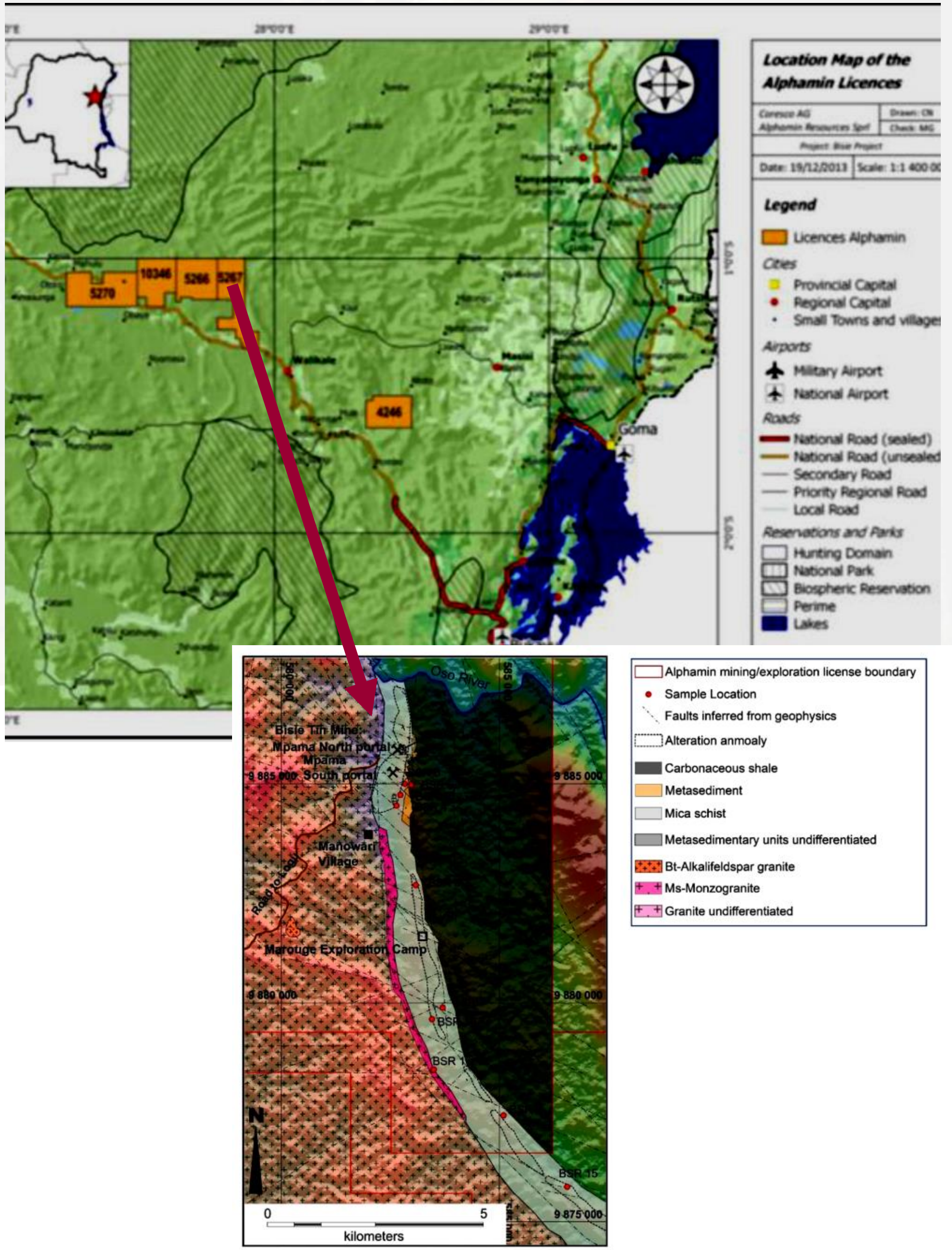
04 Testing Suitable Cemented Backfill Ratios

05 Numerical Modelling - Proof-of-Concept

06 Recommendations and Next Steps

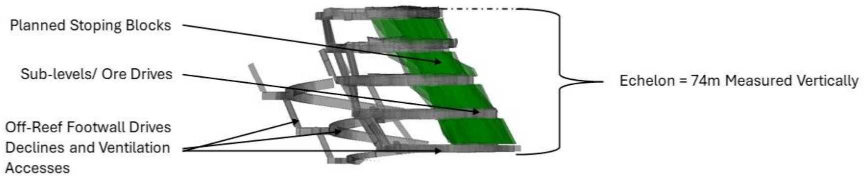
Background and Geology

- Bisie Mine, owned by Alphamin Resources, has one of the highest-grade tin deposits globally.
- The mine started exploration around 2013/2014, commenced plant and boxcut construction at Mpama North in 2015/2016 and commenced with production in 2018/2019.
- The mineralisation occurs within the Amphibolite Schist, with Mica Schist forming the primary host rock.
- At Mpama North, the orebody is structurally controlled, with a major hangingwall shear present along the contact.
- The orebody itself is hosted in more competent Amphibolite Schist, although the presence and orientation of major shear zones influence the structural integrity of the rock.
- The orebody dips steeply, at angles ranging between 50° and 70°.

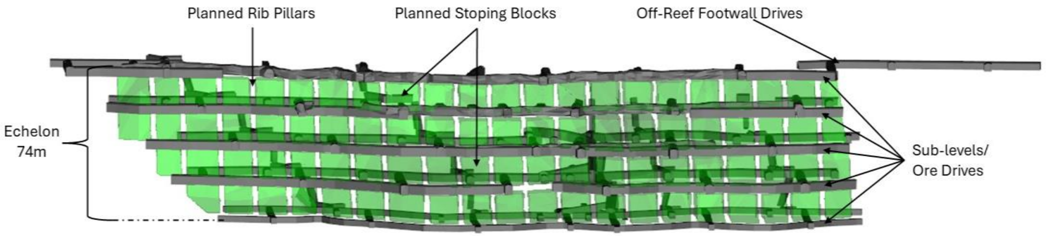


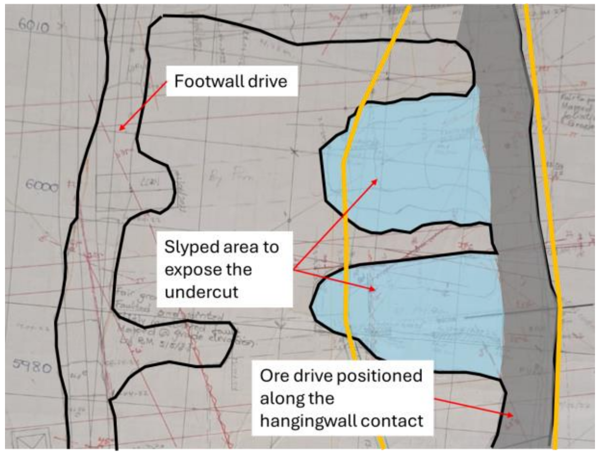
Mining Environment

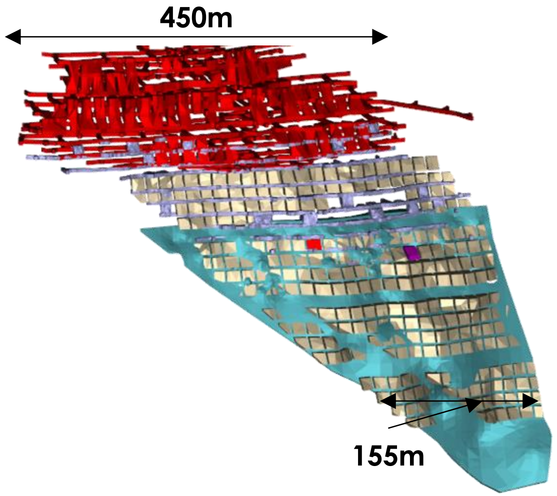
Cross Sectional view of the Mining Layout



Longitudinal view of the Mining Layout

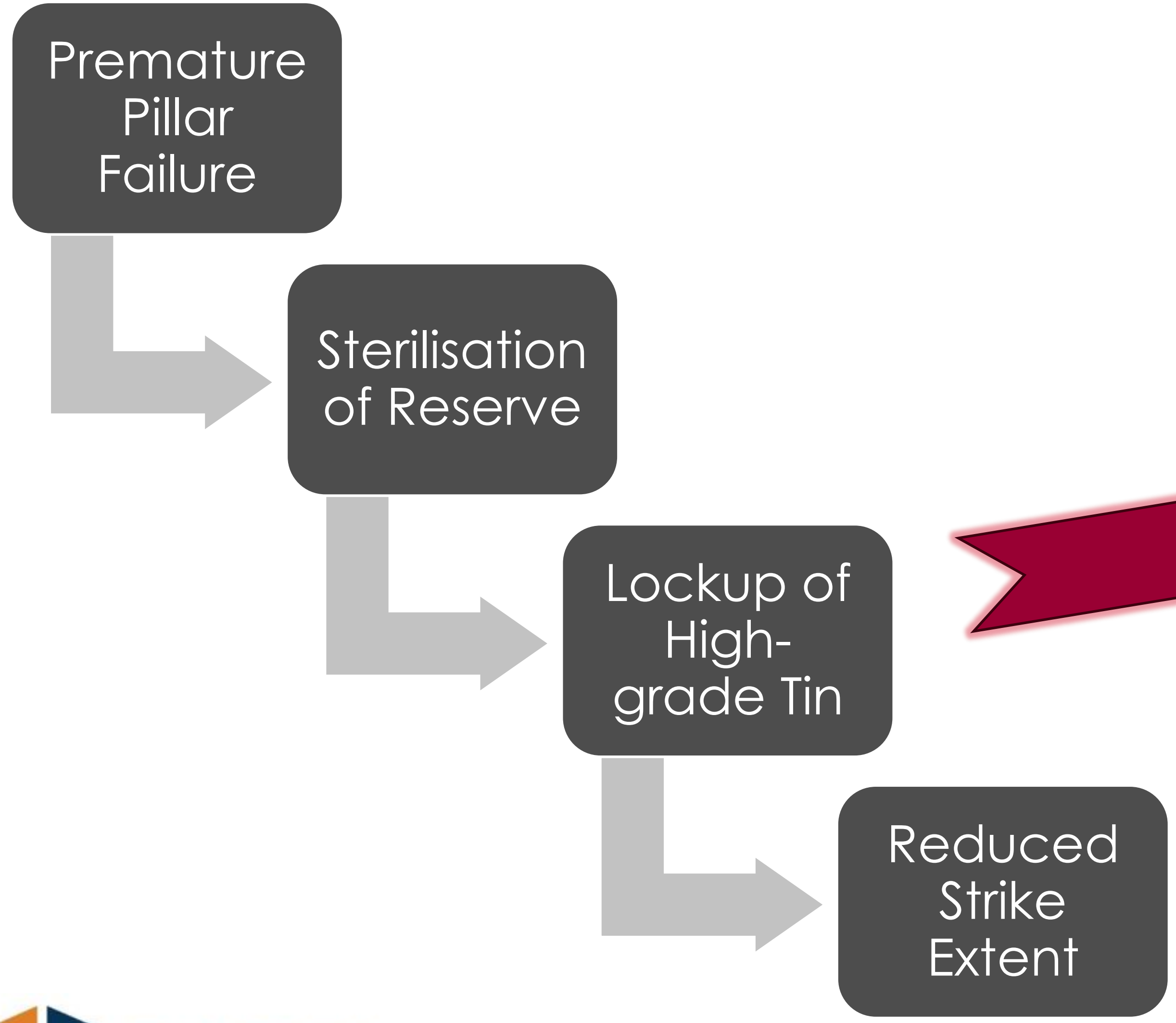


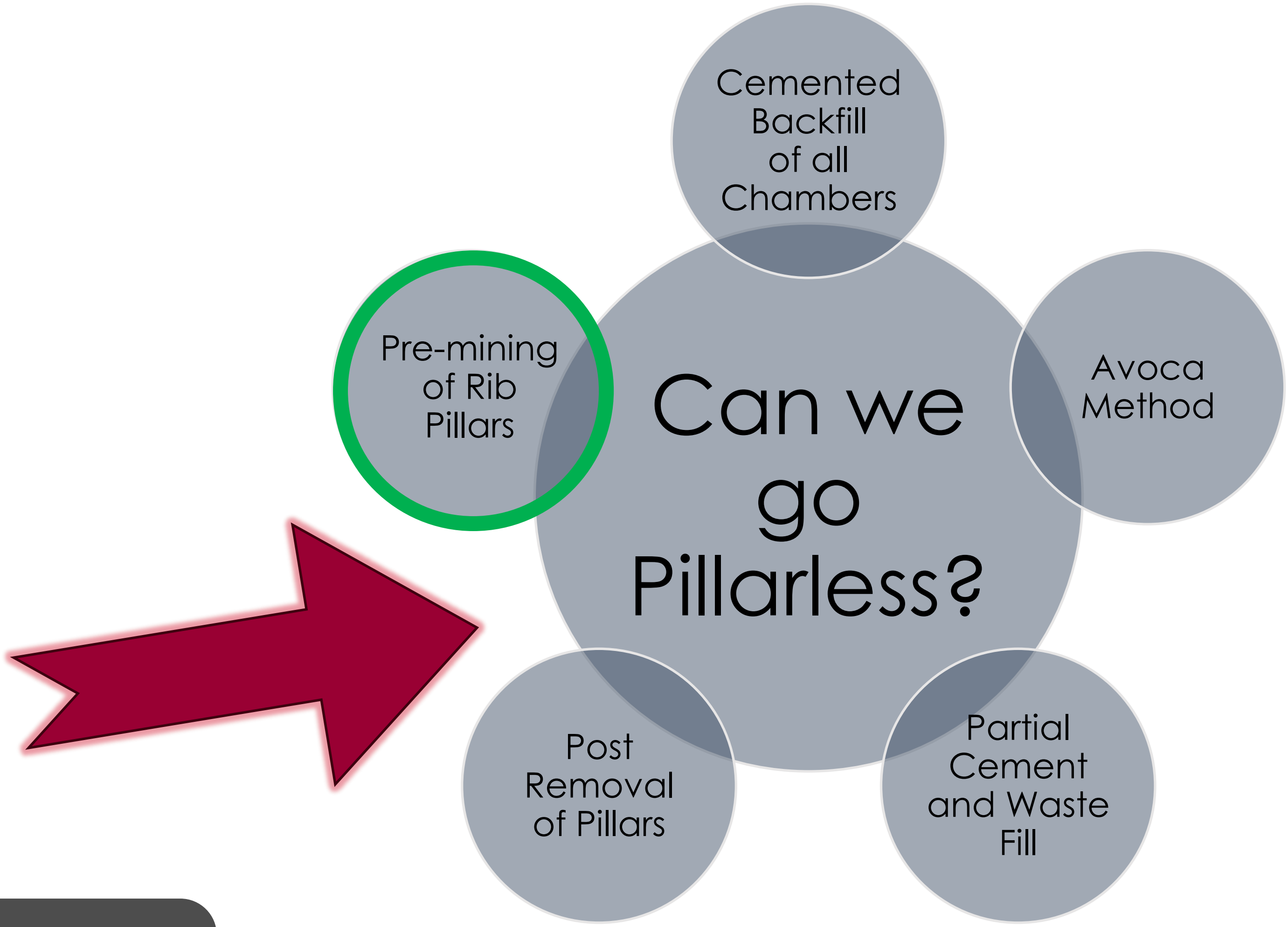




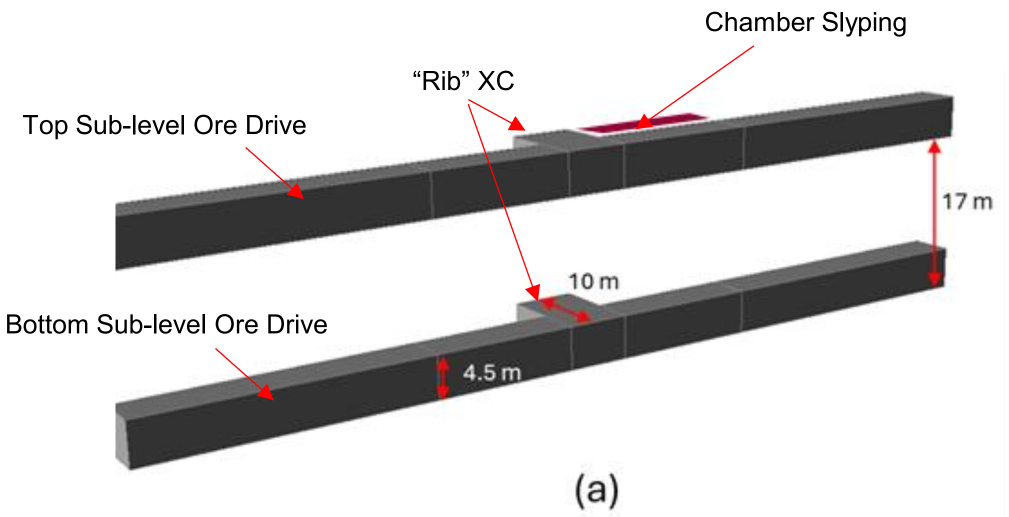
- Mining at Mpama North is conducted using the long-hole open stoping mining method with backfill.
- Footwall infrastructure includes a decline developed approximately 40 m from the stoping horizon and loading drives spaced roughly 25 m from the stopes.
- The strike extent of the stoping ranges between 450 m and 150 m (at depth +-600 mbs).
- The stoping horizons are divided into Echelons, where 5 sublevels are developed within each Echelon. Each Echelon is approximately 74 m high (vertical),
- On-reef longitudinal development is undertaken to expose the orebody and validate the width and grade.
- Individual mining chambers vary from 15 m to 25 m with a vertical height of around 17 m. Orebody widths range between 5 m to 25 m – with an average of 10m.
- Sliping of the chambers is conducted to match the full width of the orebody. This approach ensures accurate drilling, optimises the stope geometry, and allows for adequate blasted ore volume to be achieved.
- Rib pillars between adjacent chambers are typically between 3.0 m to 5.0 m wide (depending on depth), while sill pillars range from 6 m to 13 m, and increase with depth.

Problem Statement

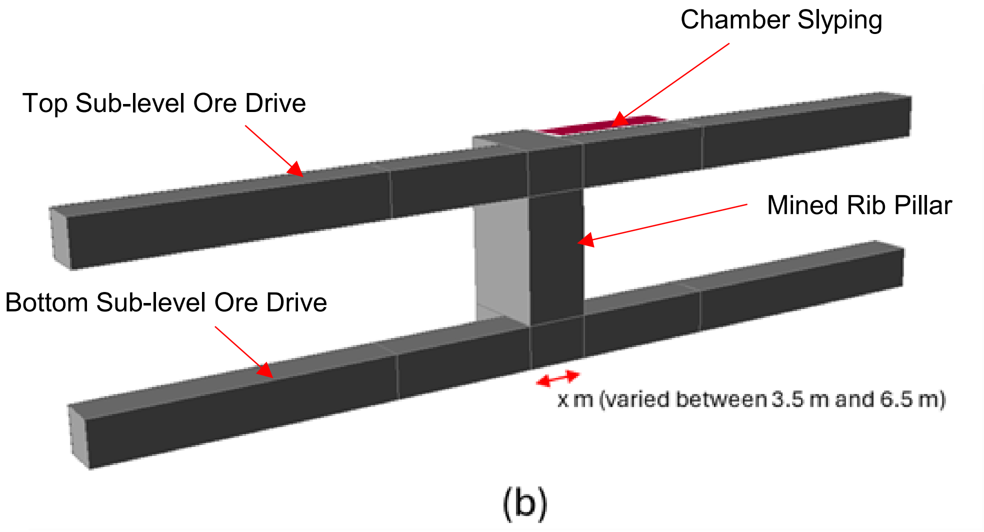




Method of pre-mining the Rib Pillar



(a)



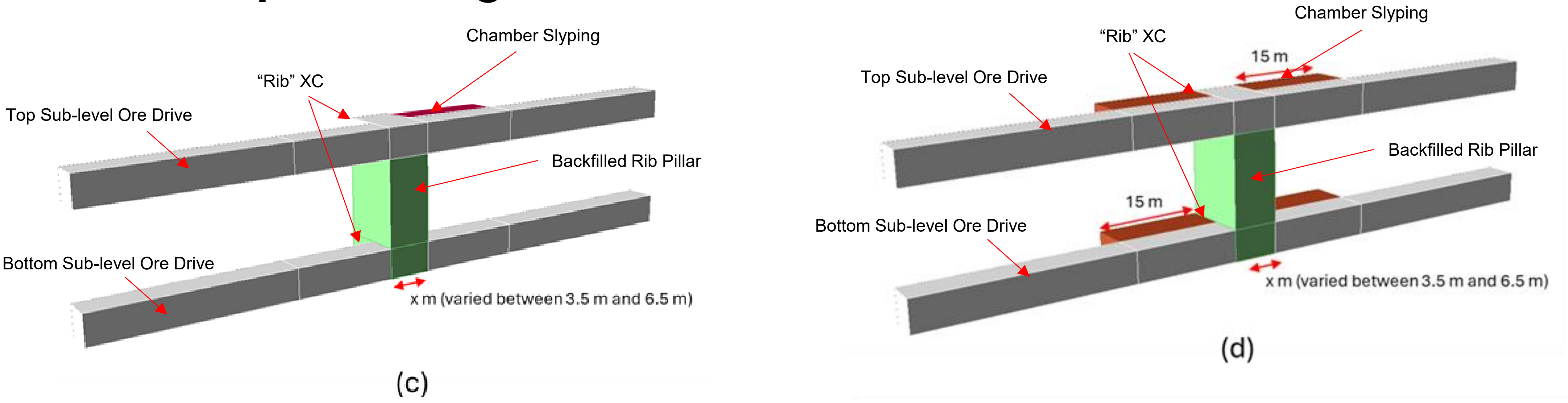
(b)

- Ore drive development using mechanised equipment is completed in advance of pillar mining.
- A crosscut, referred to as the "rib" crosscut, is developed out off the ore drive at the planned pillar location.
- The rib crosscut is developed to the design width and can range between 3.5m to 5.5 m – in the proof-of-concept a 4.5m rib was simulated
- Development proceeds toward the footwall, extending up to the orebody footwall contact.
- This development is completed on both the upper and lower sub-levels.
- Following completion of the rib crosscut, slyping of one chamber is required to facilitate cement backfilling of the pillar void.

- Once slyping is completed, a slot is drilled and blasted to provide the initial free breaking point of the pillar
- After successful slot removal, the entire pillar is drilled to its full length and width.
- The pillar is then blasted, and the resulting ore is mucked out, leaving a void in place of the pillar.

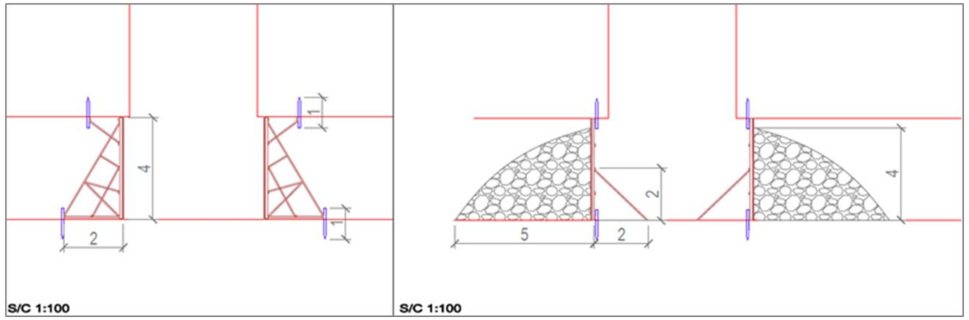
DAYENU Mining Consultants

Method of pre-mining the Rib Pillar



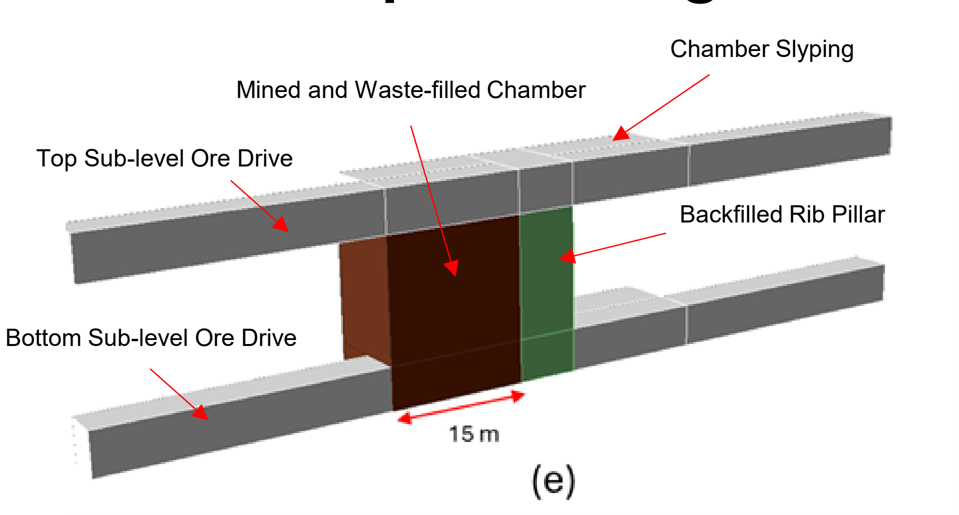
- Shuttering is first constructed at the base of the rib pillars to contain and support the cemented fill.
- Once the shuttering is in place, sump mixing of the backfill material is conducted.
- The fill is then placed into the mined pillar void, with grab samples collected during each mixing stage for cube strength testing.
- An initial 4.5 m high layer of fill is placed and allowed to cure for one day. This acts as a strengthened plug to support the shuttering and resist deformation under the weight of the remaining backfill (up to 17 m high).
- After curing, the remaining fill is placed, continuing up to the floor level of the upper ore drive.

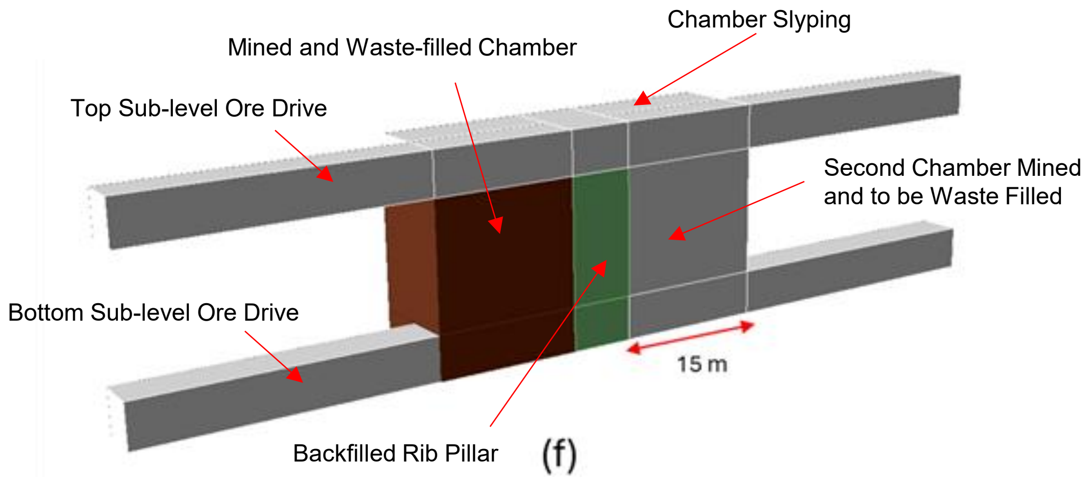
- The cemented backfill is allowed to cure for a minimum of 28 days to achieve the required strength.
- Once curing is complete, the shuttering is removed.
- The remaining sections of the ore drive requiring slyping are then completed to achieve the final excavation dimensions.



DAYENU Mining Consultants

Method of pre-mining the Rib Pillar





- Once all slyping and support installation is completed, the chamber can be drilled according to the current standard and blast design.
- The slot is positioned away from the cemented pillar to minimise potential damage.
- After the slot is successfully mined, the entire chamber is blasted and mucked out.
- Once all ore material is removed, the chamber is then backfilled with waste.

- Once the first chamber has been completed and backfilled, the same extraction and backfilling process is applied to the second chamber adjacent to the cemented pillar.

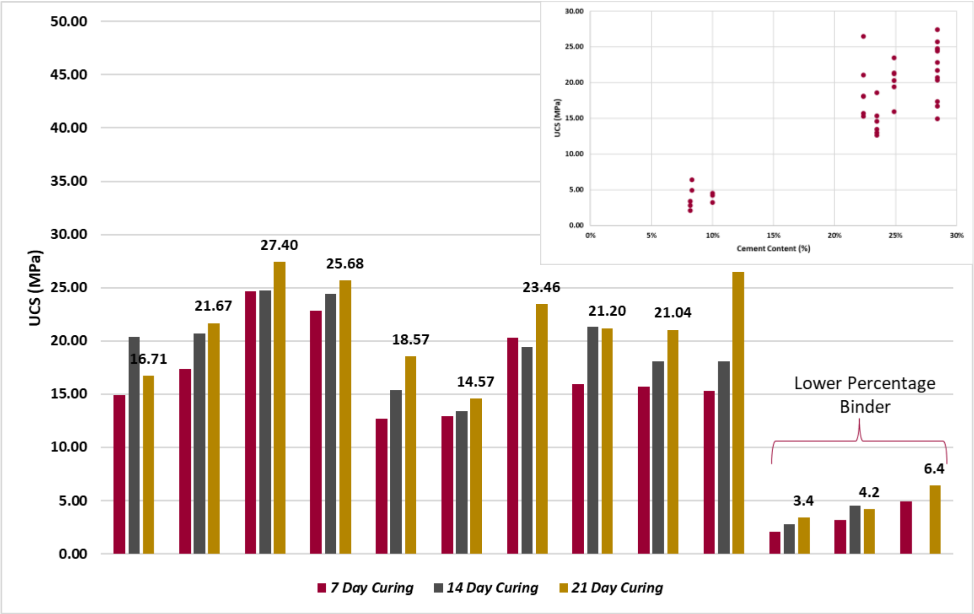
Testing Suitable Cemented Backfill Ratios

- The initial objective was to achieve backfill strengths of at least 75% of the host rock strength, with uniaxial compressive strength (UCS) values for the host rock ranging between 35 MPa and 47 MPa.
- A total of 50 test cubes were cast using various cement content mixes.
- A review of industry literature indicates that the required backfill strength for pillar replacement using Cemented Rockfill (CRF) can range from 400 kPa to as high as 10 MPa, depending on the specific application and design criteria.
- At the Ballarat Gold Mine (Sainsbury & Sainsbury, 2014), where a similar methodology was employed, CRF samples achieved compressive strengths ranging from 620 kPa to 1.42 MPa for a 3% cement content after 7 days. Increasing the cement content to 5% resulted in strengths exceeding 2 MPa.

1:3:6 – 10% Binder

1:2.25:9 – 8% Binder

1:3:8 – 8% Binder

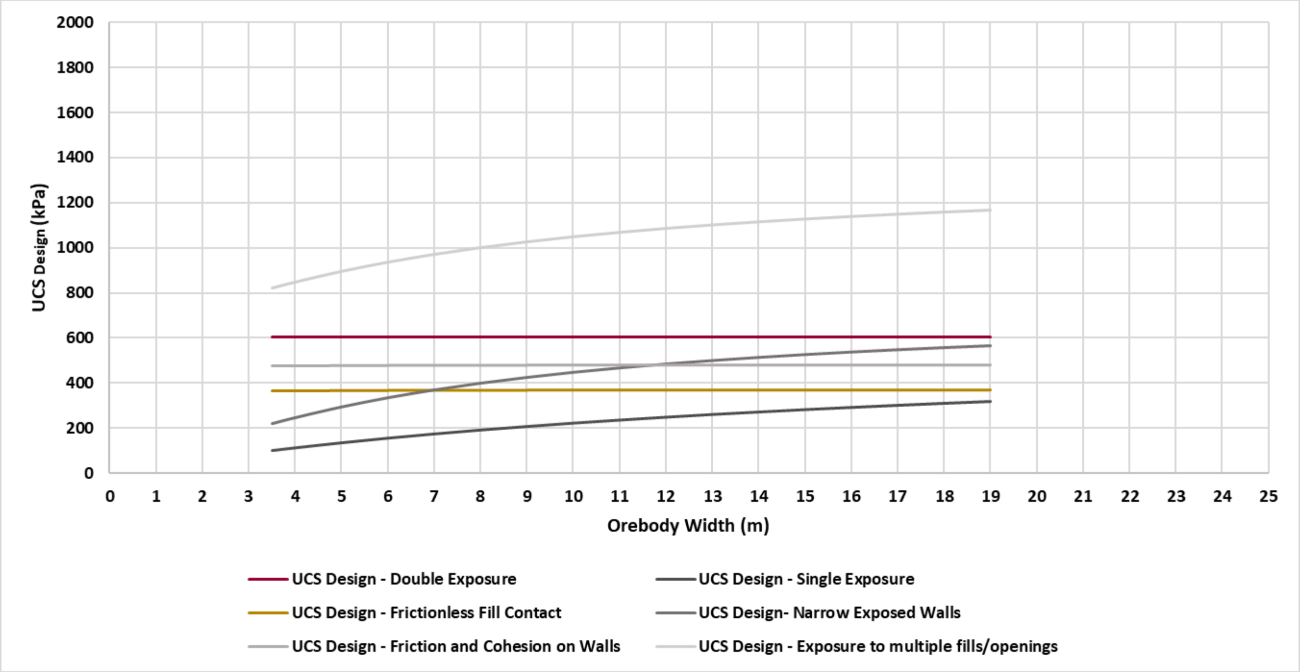


- Testing was conducted using the current tailings material, primarily due to logistical constraints in sourcing suitable sand and aggregate for delivery to site.
- Initial tests using cement and tailings only were unsuccessful, yielding poor strengths due to segregation of the cement within the mix.
- Subsequent tests incorporated a Cement:Sand:Aggregate mix. An initial ratio of 1:3:8 was selected, which yielded a compressive strength of approximately 4 MPa.

DAYENU Mining Consultants

Testing Suitable Cemented Backfill Ratios

- Empirical methods proposed by Askew et al. (1987), Mitchell et al. (1982), Belem & Benzaazoua (2004), and Abdelhadi et al. (2018) were used to estimate a range of required backfill strengths.
- For these empirical estimates, a friction angle of 44° and material densities ranging from 2100 kg/m³ to 2500 kg/m³ were applied.
- Both single and double exposures, as well as frictionless contact conditions (as a conservative case), were considered. These assessments indicated that the required backfill strength ranged from approximately 120 kPa to 1200 kPa, depending on the exposure conditions and assumptions used.



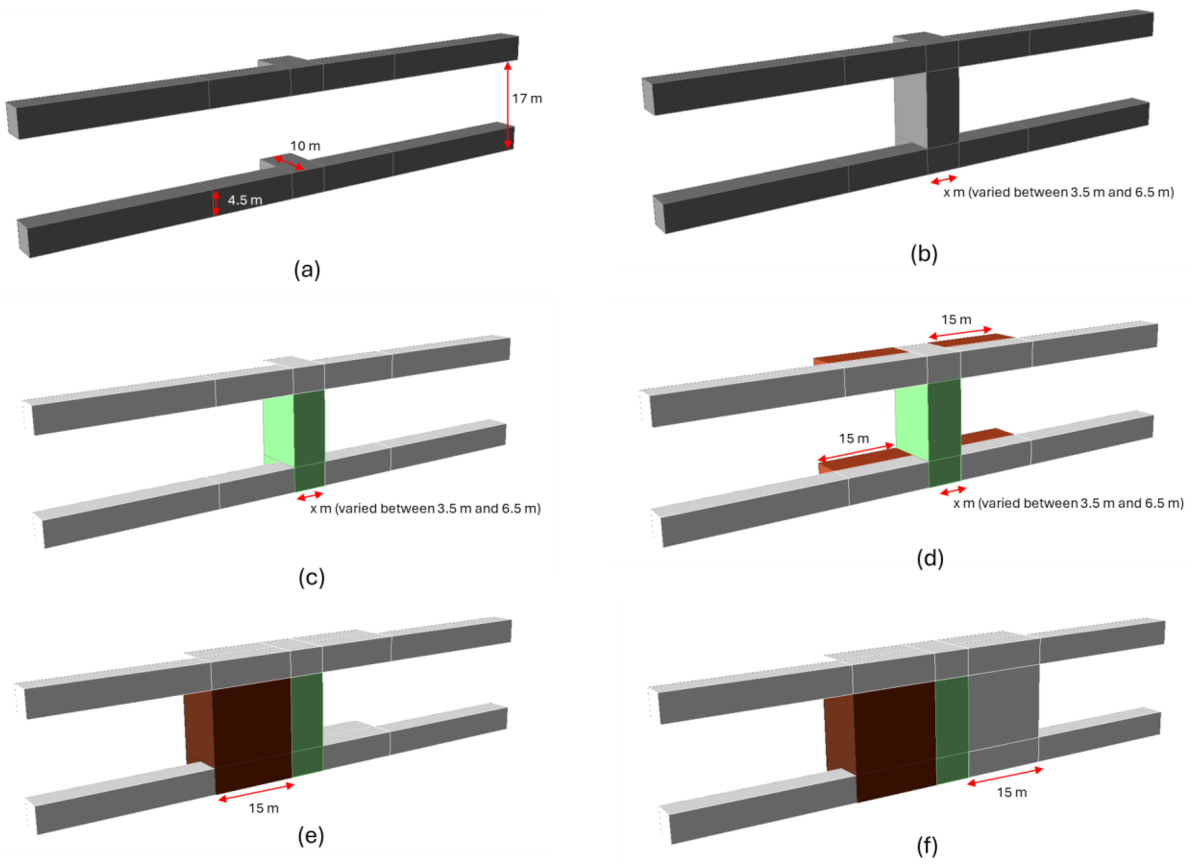
DAYENU Mining Consultants

Numerical Modelling - Proof-of-Concept

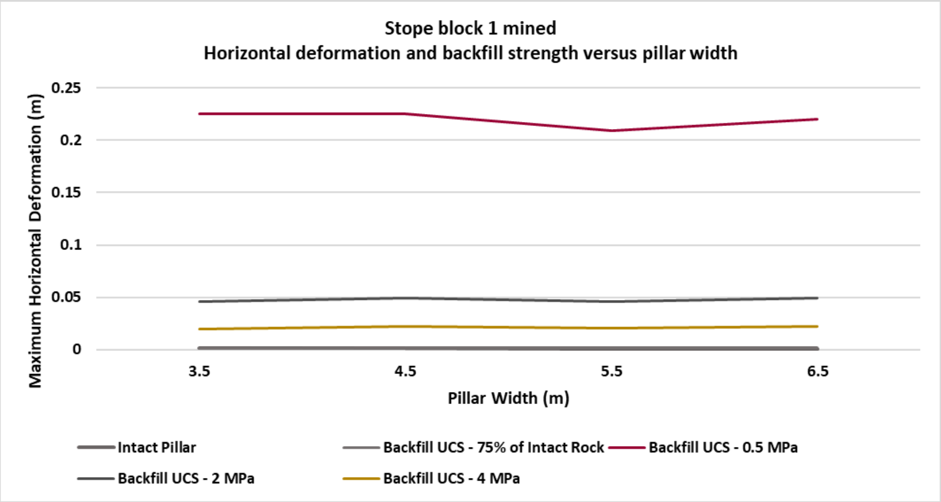
- At the time of the numerical analysis, RS3 was the software available to carry out the parametric study. While it is acknowledged that RS3 may not be the most appropriate tool for detailed backfill behaviour modelling, it was considered sufficient for a proof-of-concept analysis.
- The goal was to obtain initial deformation estimates, which could later be validated with observed field data. Once the actual material properties of the backfill are confirmed, more advanced modelling tools such as FLAC or UDEC can be used to refine the analysis and validate underground performance.
- The numerical modelling aimed to evaluate expected horizontal deformations, particularly for cases where lower-strength cemented backfill is applied. A parametric assessment was conducted, varying both the pillar widths (ranging from 3.5 m to 6.5 m) and backfill strengths (ranging from 500 kPa to 4 MPa).
- In the absence of backfill-specific elastic properties, these parameters were estimated using empirical formulas derived from a comprehensive database of test results from other mining operations.

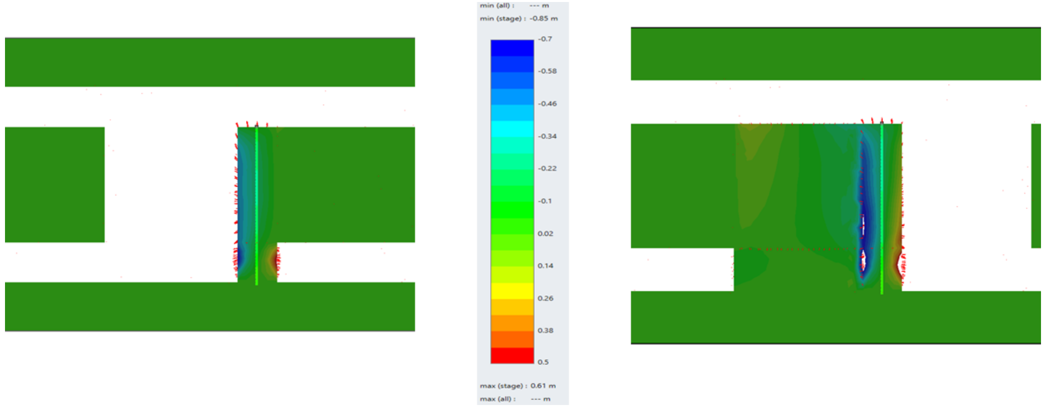
Elastic Backfill Modulus = 150 x UCS

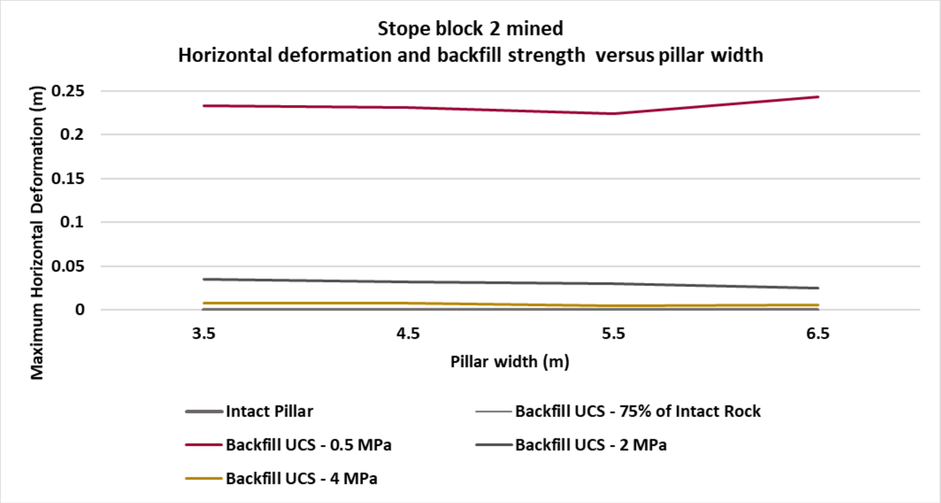
- The Poisson's ratio was kept constant at 0.25, and a fixed friction angle was assumed. Cohesion values were then calculated using Mohr–Coulomb failure criteria.
- As a first-pass approach, the analysis focused on horizontal deformations as a primary performance indicator, given their relevance to stability and their measurability during implementation.

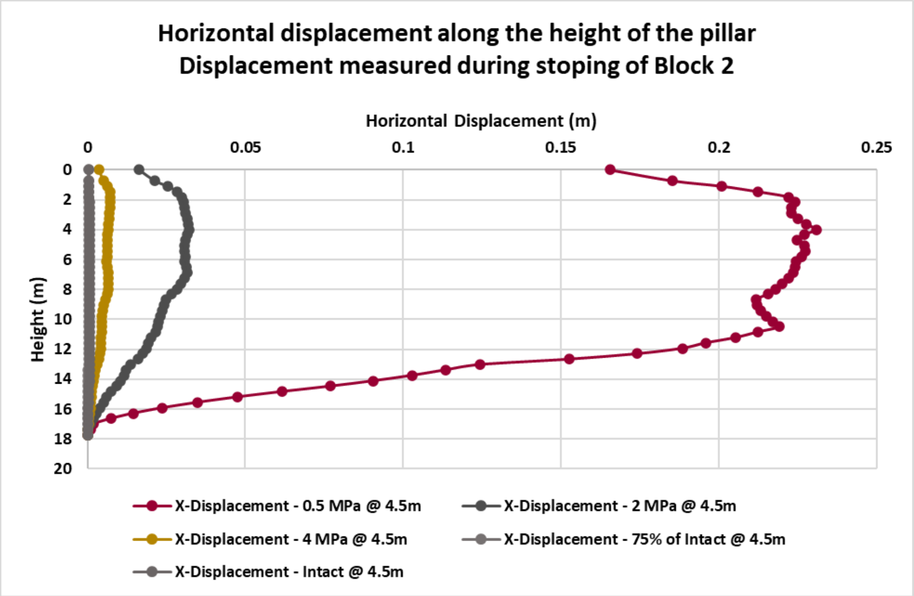


Numerical Modelling - Proof-of-Concept





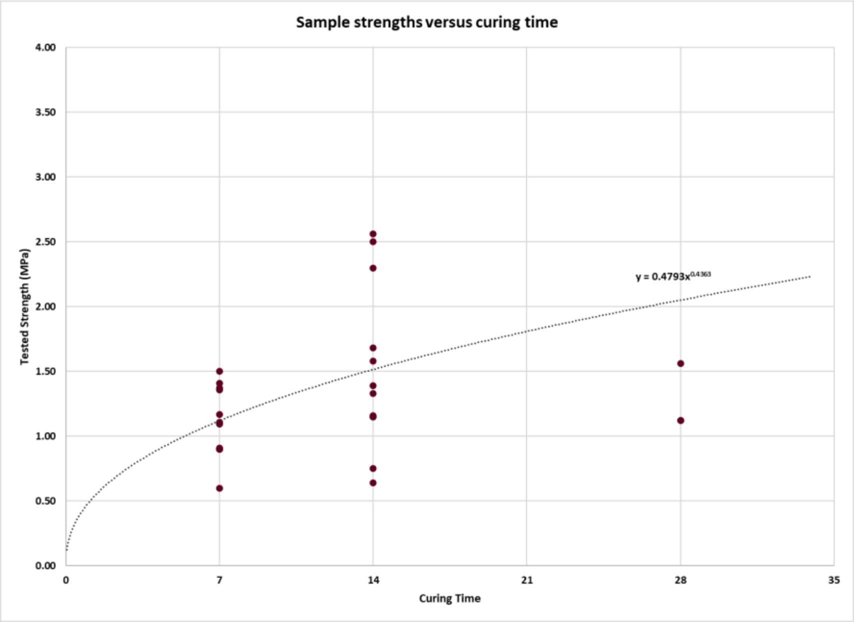




DAYENU Mining Consultants

Recommendations and Next Steps

- Based on both the laboratory test data and numerical modelling results, a cemented backfill strength of 2 MPa is recommended for implementation during the proof-of-concept (POC) phase.
- Referenced case studies used to benchmark Bisie Mine's backfill performance indicate that the proposed strength and estimated stiffness (moduli) are significantly higher, supporting the use of a more competent and stiffer fill material.
- A minimum pillar width of 4.5 m is recommended for all backfilled pillars.
- In situ grab samples (test cubes) should be taken during mixing and placement to track strength development as the fill is placed in layers.
- Where possible, core samples of the placed backfill should also be extracted for laboratory testing to validate achieved strength and stiffness parameters.
- Laboratory tests should include uniaxial compressive strength (UCS), triaxial compressive strength (TCS), and tensile strength to establish a complete mechanical profile.
- Advanced numerical modelling using distinct element (UDEC) or finite difference (FLAC) methods is recommended to further assess the interaction between the backfill, excavation geometry, and surrounding rock mass conditions.



QUESTIONS

?

DAYENU
Mining Consultants

MINING ENGINEERING SERVICES

Hans Dippenaar

+27 (0) 82 335 9167

hans@dayenu.co.za

GEOTECHNICAL ENGINEERING SERVICES

Ronny Arlow

+27 (0) 82 416 3952

ronny@dayenu.co.za

Info@dayenu.co.za

www.dayenu.co.za

CONSULTING SERVICES

Jarno van Vuuren

+27 (0) 82 663 6324

jarno@dayenu.co.za

CONTACT US

BLACK ECONOMIC EMPOWERMENT LEVEL 2 BBBEE

ACCREDITATION, AFFILIATION & REGISTRATION

Our combined offering is accredited, affiliated and registered with:

AMMSA
OSHAS 18001
SAIMM
ISO 9001
ECSA
IODSA