Middindi Consulting (Pty) Ltd

Rock Engineering | Geology | Geotechnics

Middling stability in hard rock multi-seam mining

Contents

- Project Setting
- Historical Multi-Seam Mining Studies
- Parameters Investigated
- Numerical Model Setup
- Modelling Results
- Future Work

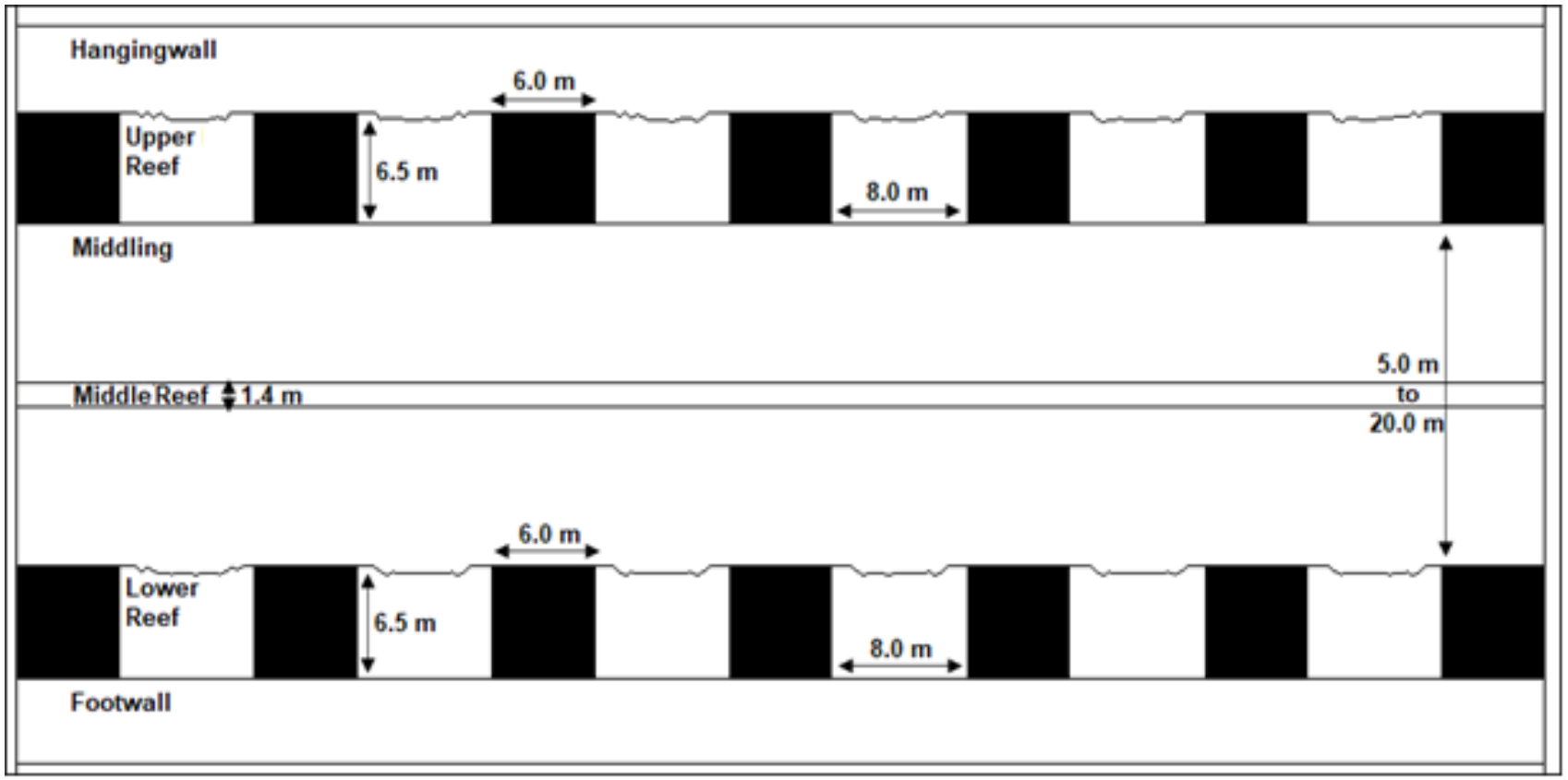
Introduction

- Bord and pillar.
- Upper seam being targeted following complete extraction in the lower seam.
- The purpose of the study was to derive a minimum allowable middling distance between two seams which ensures a hard standing is maintained in the upper seam.
- The analysis was performed using the numerical modelling program UDEC to assess the stability of the middling as well as the pillars on the upper and lower seams.

Project Setting

- Hard rock, meta-sedimentary environment
- Highly jointed rock mass
- Historical bord and pillar mining within the lower seam
- Middling ranges from 5m to more than 20m
- Target upper seam
- Middling seam present

Project Setting



Historical Multi-Seam Mining Studies

Author	Title	Resource	Country	Year
Mark, C.; Chase, F.E.; Pappas, D.M.	Analysis of Multiple Seam Stability	Coal	United States of America	2007
Esterhuyse, J.C. and Malan, D.F.	Some rock engineering aspects of multi-reef pillar extraction on the Ventersdorp Contact Reef	Gold	South Africa	2018
Mthembu, L.L and Meyer, L.D.	Identification of suitable areas for multi-reef operation at Thorncliffe Chrome Mine	Chrome	South Africa	2020
Tati, B.B.	Multi-seam coal mining	Coal	South Africa	2011
Hill, R.W.	Multi-seam design procedures	Coal	South Africa	1994
Chabedi, C.K. and Zvarivadza, T.	Multi-seam mining of the deep Waterberg resources	Coal	South Africa	2016
Singh, N.; Urcan, H.; Naidoo, K.; Ryder, J.; Watson, B.P.; Milev, A.M.; Roberts, M.K.C.	The influence of pillars on the Merensky Reef horizon on stoping operations on the underlying UG2 Reef horizon	PGMs	South Africa	2005
Moolman, . And Canbulat, I.	Economic and safe extraction of pillars and associated reserves using underground mining methods	Coal	South Africa	2003
Jeffery, L.S.	The impact of geotechnical factors on the secondary extraction of coal in the Witbank and Northern Highveld Coalfields, specifically related to safety	Coal	South Africa	2002

Historical Multi-Seam Mining Studies

- Majority investigate coal mining
- Parameters investigated:
  - Stress
  - ERR
  - Seismicity
  - Pillar strength
  - Impact of weak joints/bedding planes
  - Vertical displacement
  - Safety factor
- A previous study by Middindi in a similar environment determined a minimum middling of 9.0m.

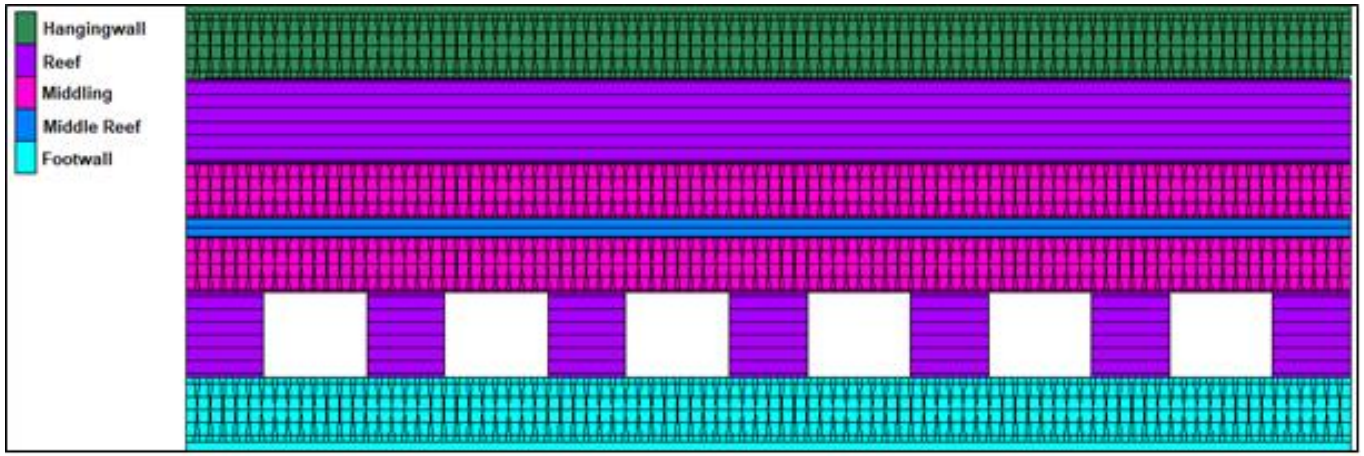
Parameters Investigated

- Tensile Height in the Middling
- Probability of Failure
- Middling Stress
- Average Pillar Stress (APS)
- Pillar Scaling
- Extent of Opening Joints

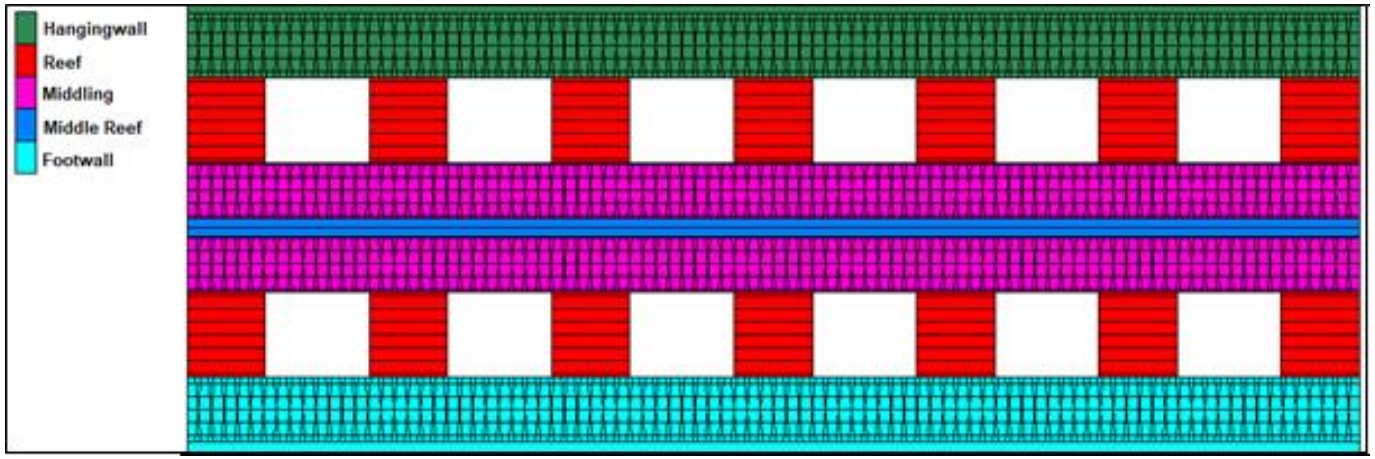
Model Setup

- 2D model in UDEC
- Depth at 300mbs and 400mbs
- 6.5m mining height, 6.0m pillars, 8.0m bords
- Middling at 5.0m, 7.0m, 10.0m, 15.0m, and 20.0m
- 3 joint sets (2 sub-vertical, 1 lamination)
- Support was not included
- Model variations included:
  - Unexcavated upper seam – baseline
  - Superimposed pillars
  - Offset pillars

Baseline
-Extract Lower Reef



Superimposed



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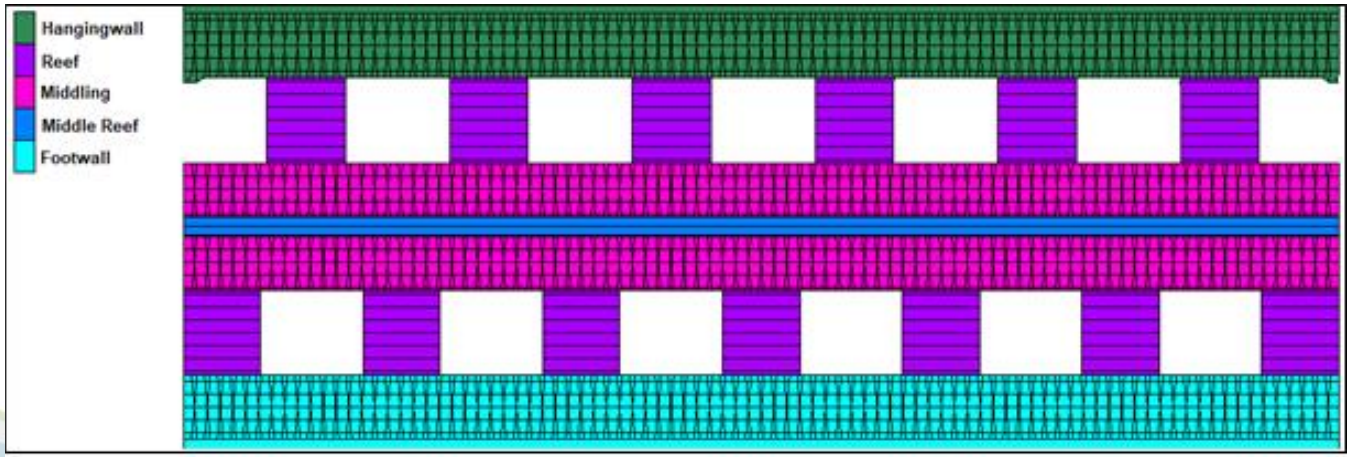


Modelling Results

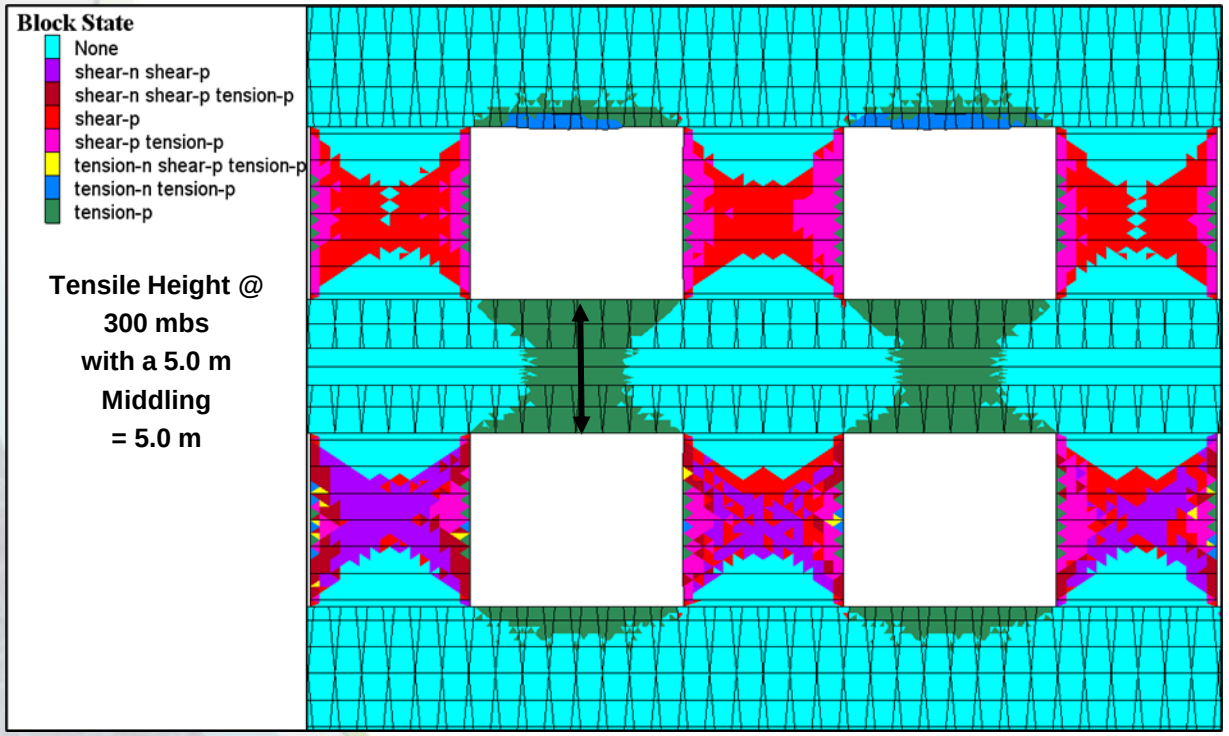
- The results extracted from the models that were used to comparatively assess the suitability of the middling thickness are:
  - Tensile height within the middling
  - Probability of failure
  - Stress within the middling
  - Pillar performance (scaling, factor of safety)
  - The extent of opening joints

Tensile Height in the Middling

- Tensile cut-off of 1.89m was used, as prescribed by the mine COP and is based on the 95% fall-out height and critical bond length.

Tensile Height in the Middling

Superimposed



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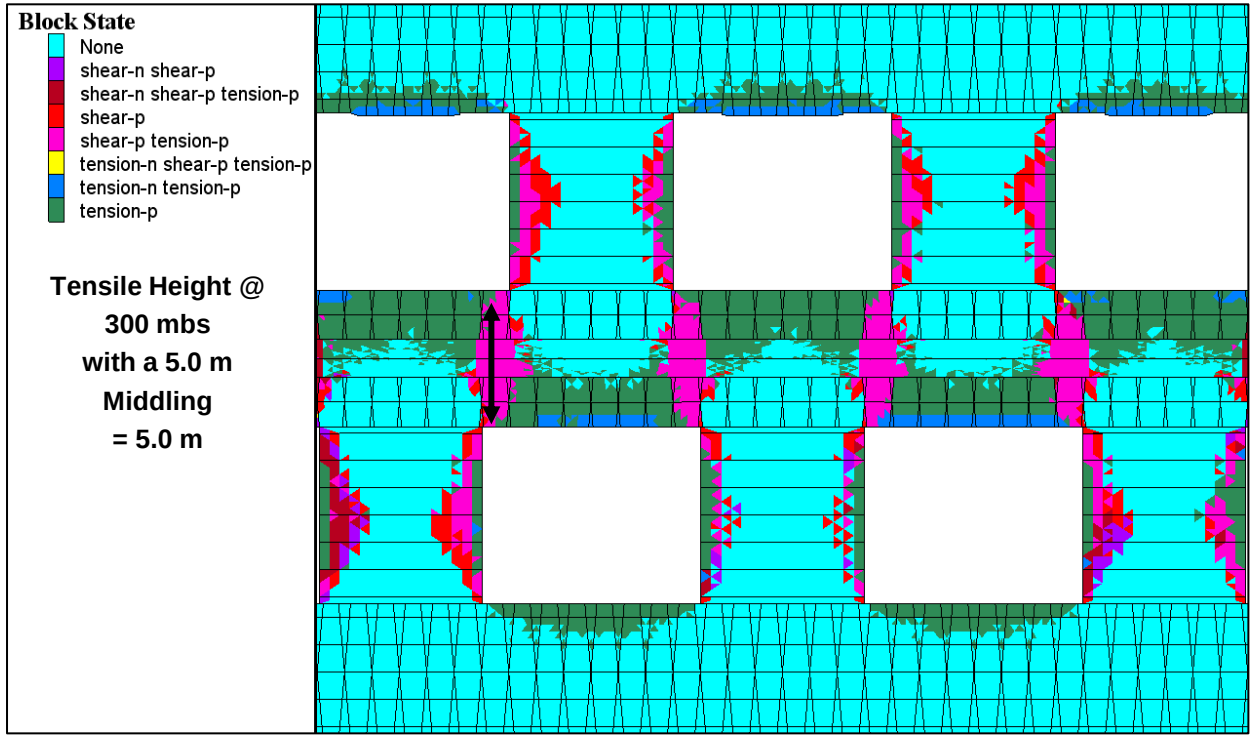
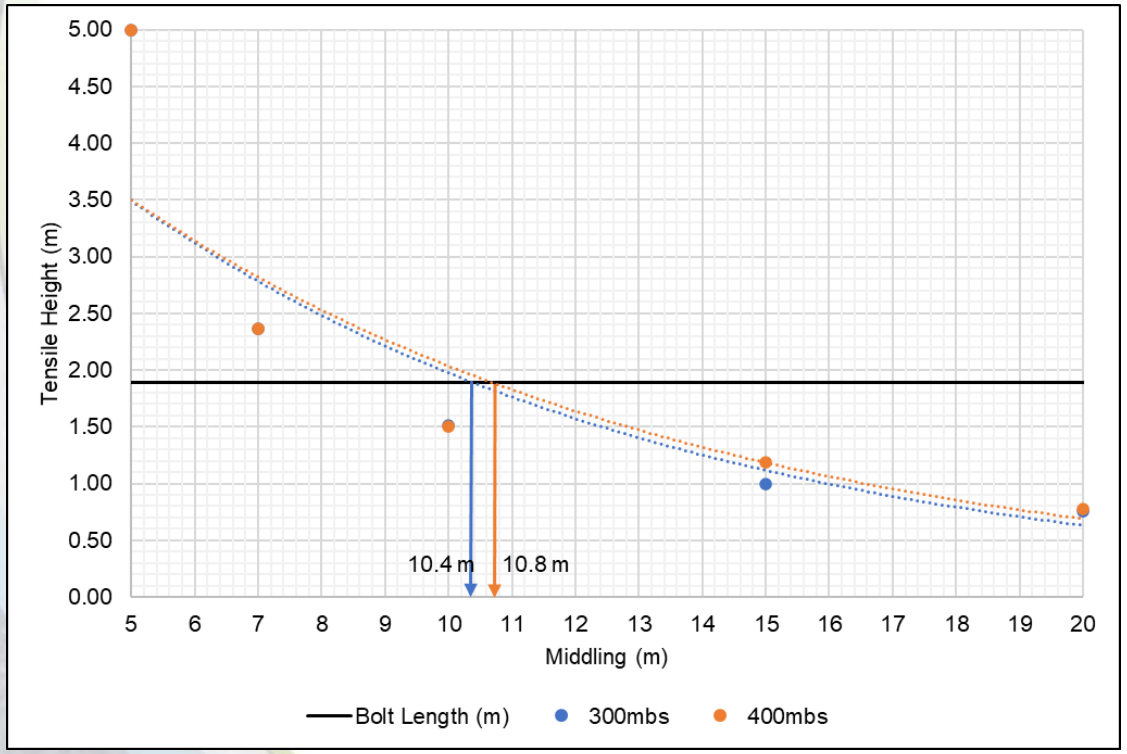


Tensile Height in the Middling

Superimposed



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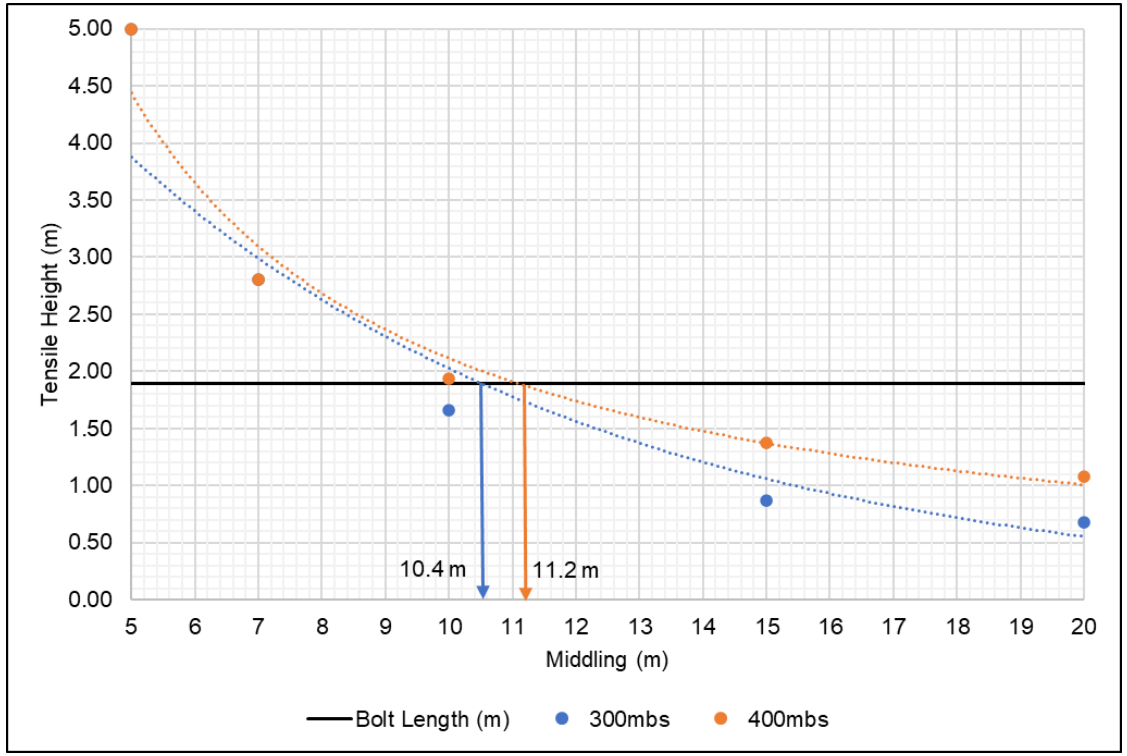
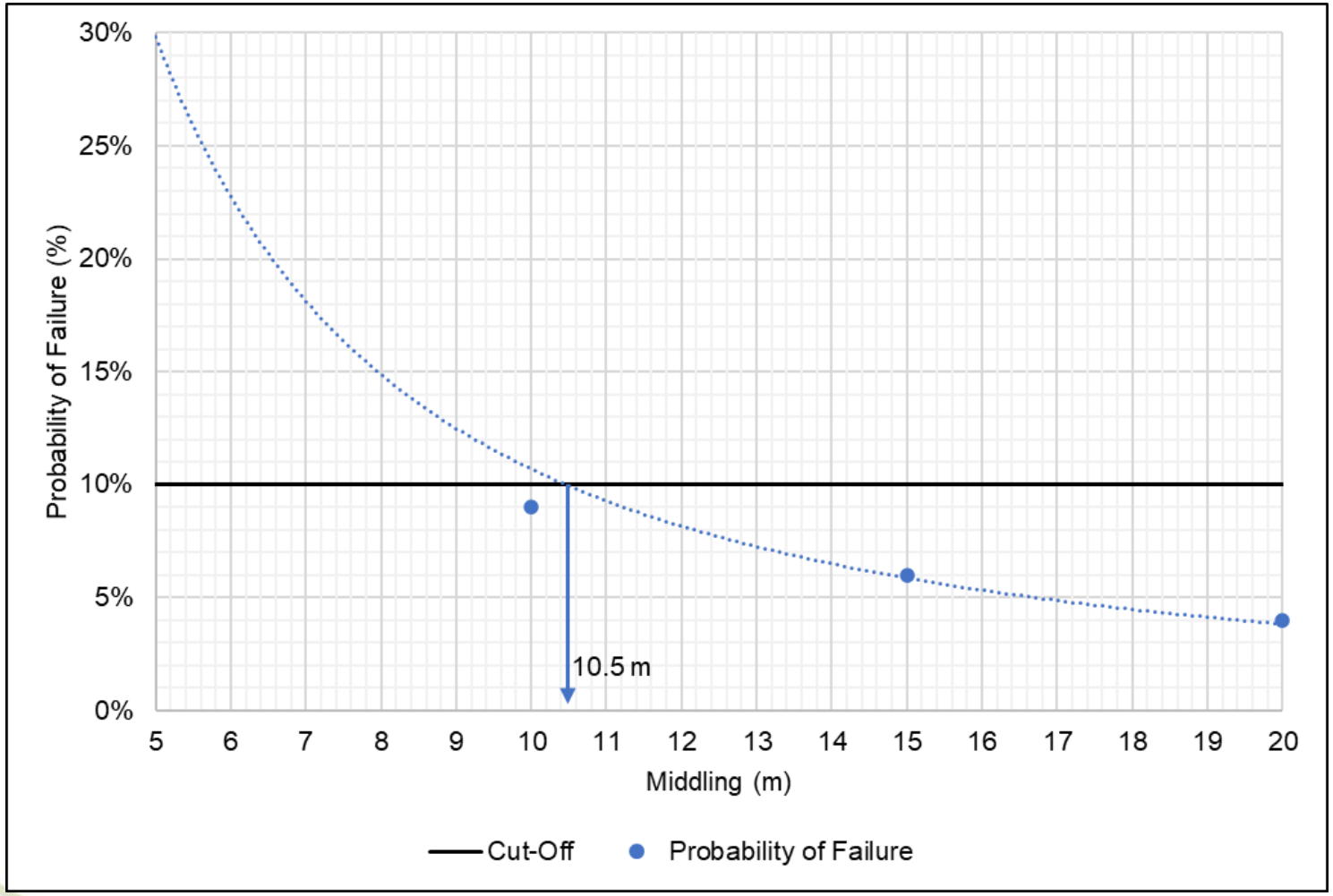


Probability of Failure

- The number of finite elements in the models which were in tension or at failure was used to derive a probability of failure for each model.
- The cut-off for the allowable probability of failure was set to be 10.0%, which is an industry-accepted figure for short to medium-term excavations in open pit mining (Read & Stacey, 2009) as well as crown pillar design (Carter, 2014).

Probability of Failure

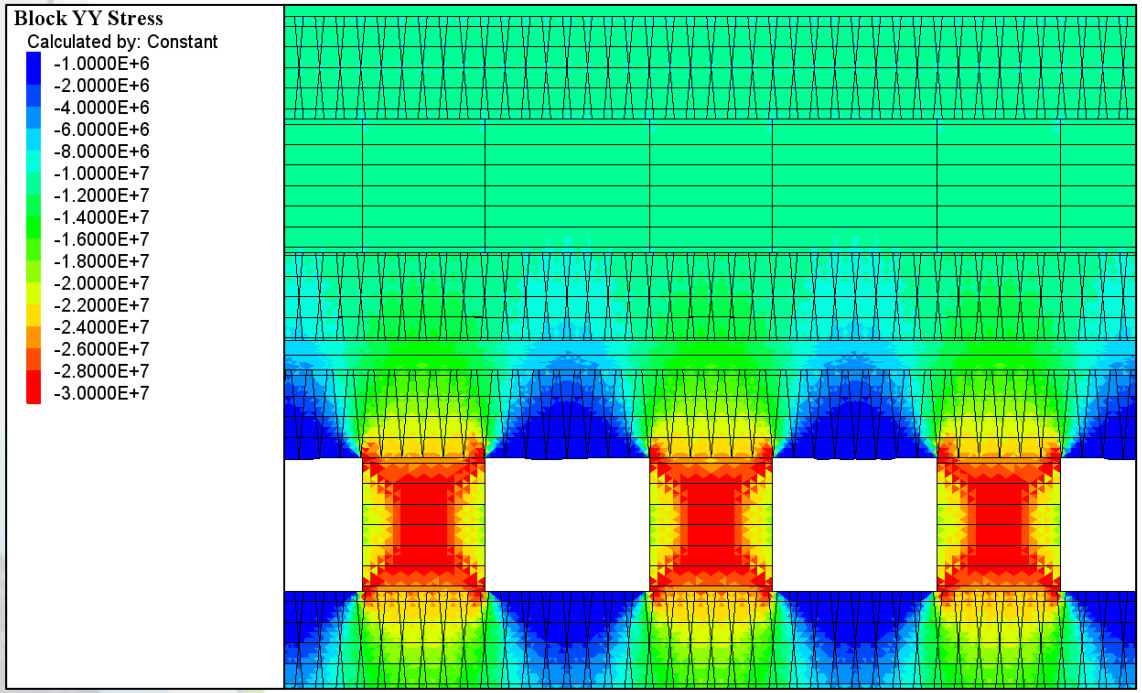


Middling Stress

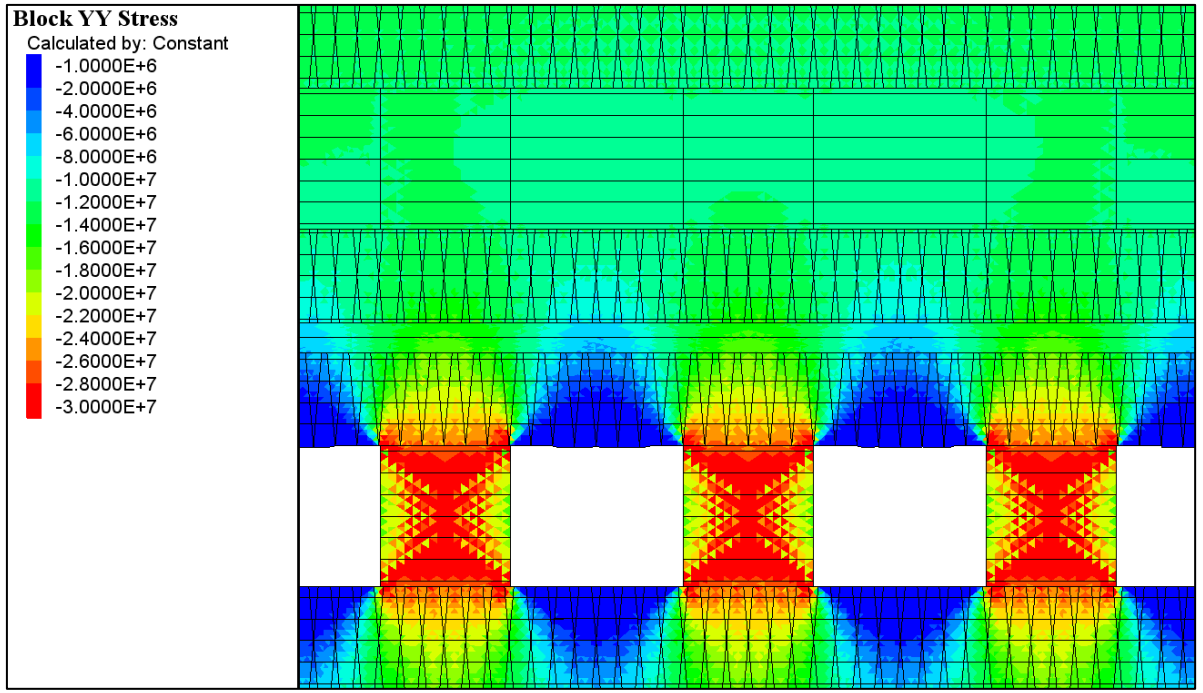
- The stress acting within the middling is impacted by the middling thickness as the stress interaction is more significant with a narrower middling.
- A baseline model wherein the upper seam is unmined was set up to compare with the various models wherein the upper seam is mined out.
- The baseline model, therefore, represents the current stress state with the lower seam mined out and the upper seam unmined.

Middling Stress

300mbs



400mbs

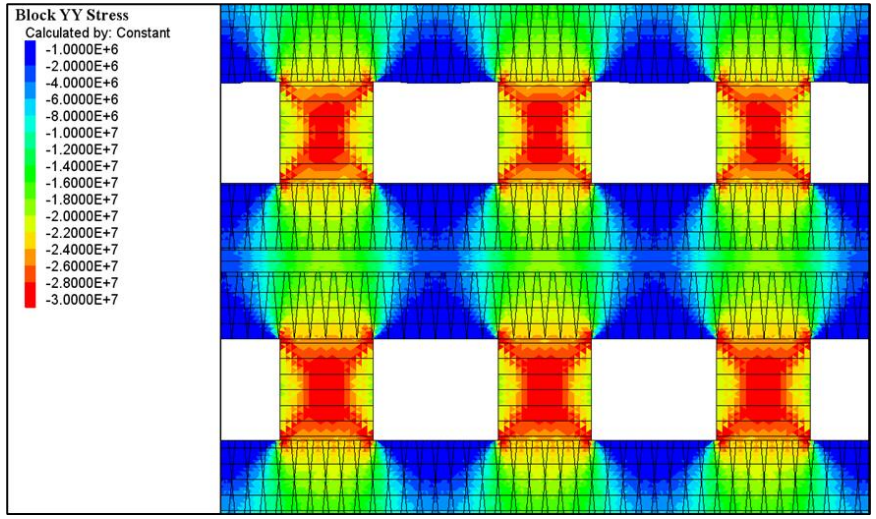


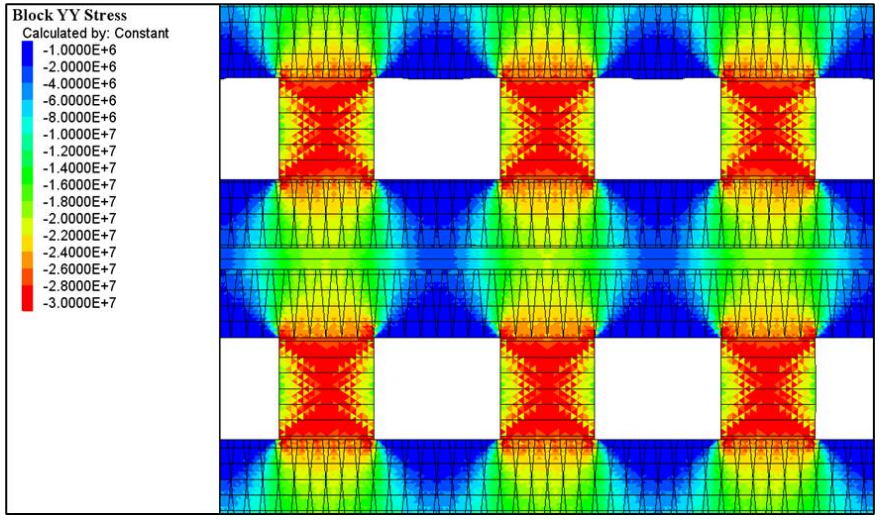
Middling Stress

300mbs

400mbs

Superimposed





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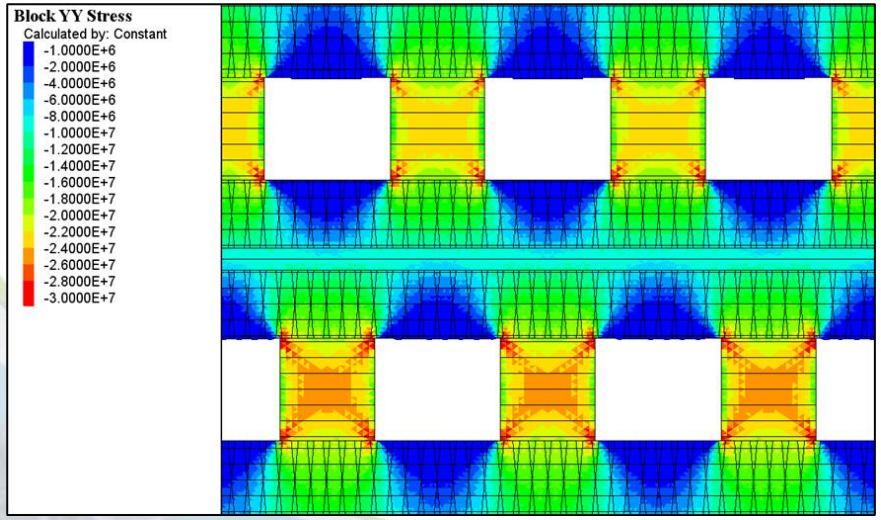
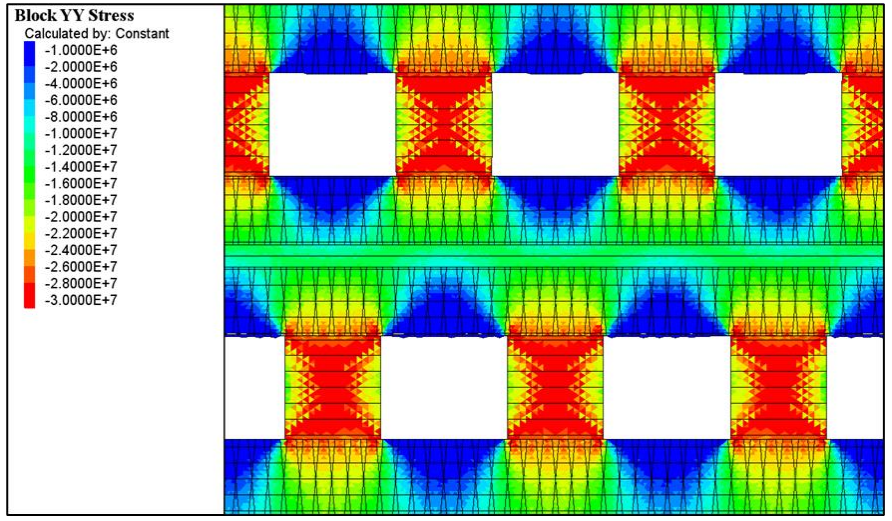




Middling Stress

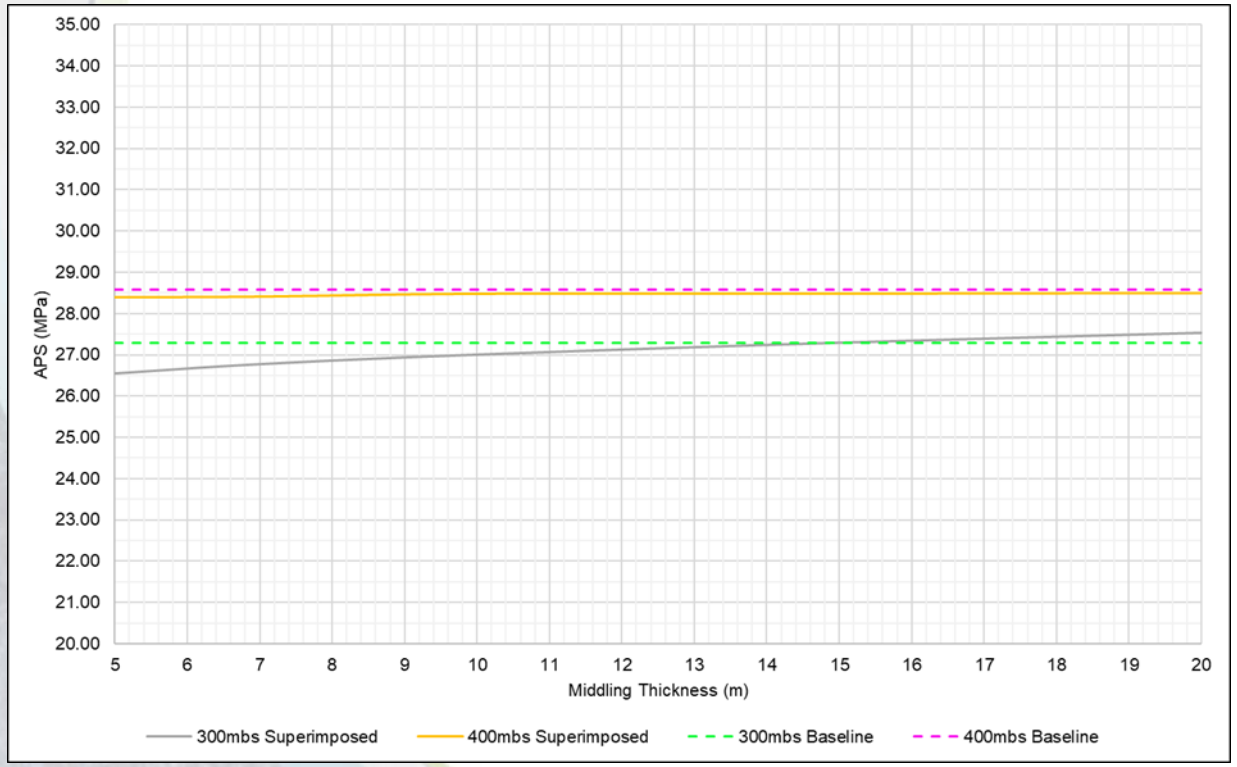
- Complete interaction of stress when the middling is < 10m, distinct separation when >10m.

Average Pillar Stress

- The average stress exerted on the pillars was assessed to determine the suitability of the middling thickness. The method used to evaluate the average pillar stress (APS) was to find the baseline APS when the upper seam is unmined, compare it to the APS when the upper seam is mined, and determine the pillar factor of safety (FOS).

Average Pillar Stress

Superimposed



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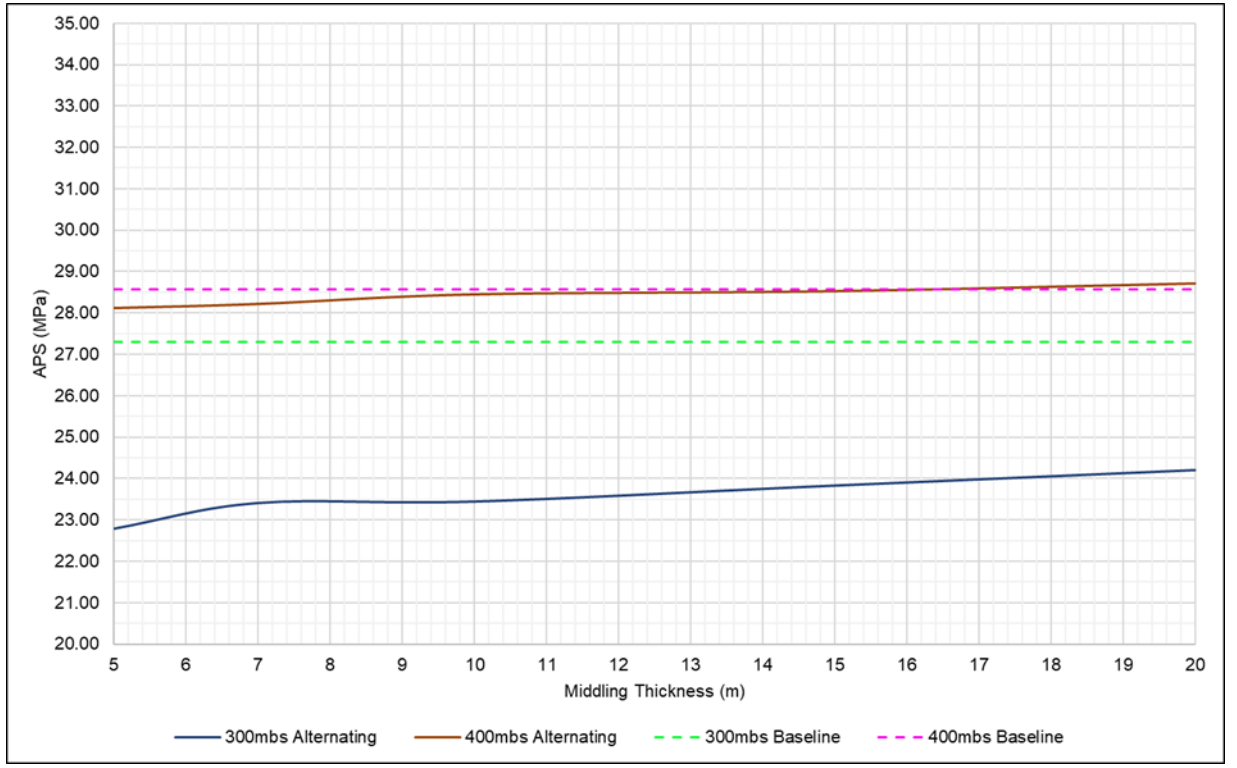
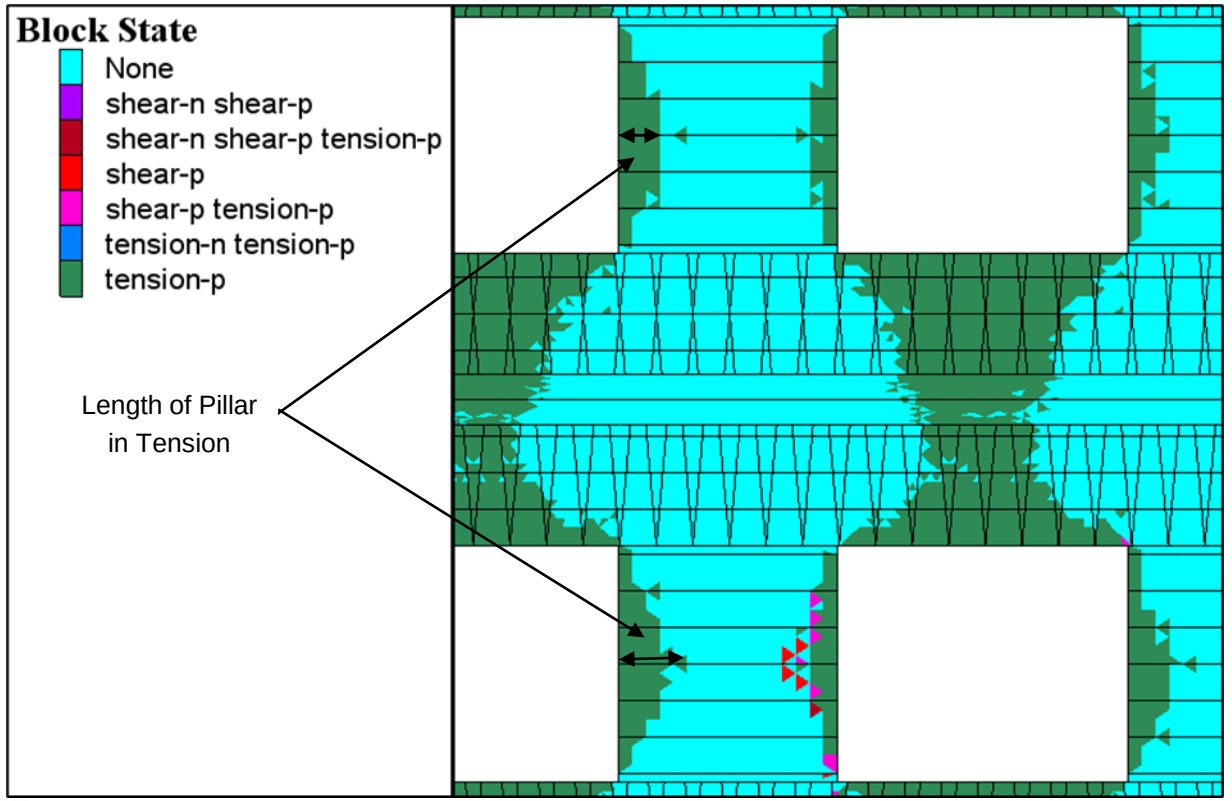


Average Pillar Stress

- The APS values are seen to remain fairly consistent with increasing middling thickness, this is due to the stress environment not being significantly impacted by the increase in middling thickness.
- The APS is seen to be consistently below the baseline APS due to the destressing effect that the upper seam has on the lower seam.
- The larger the middling becomes, the stress environment begins to approach the baseline condition.

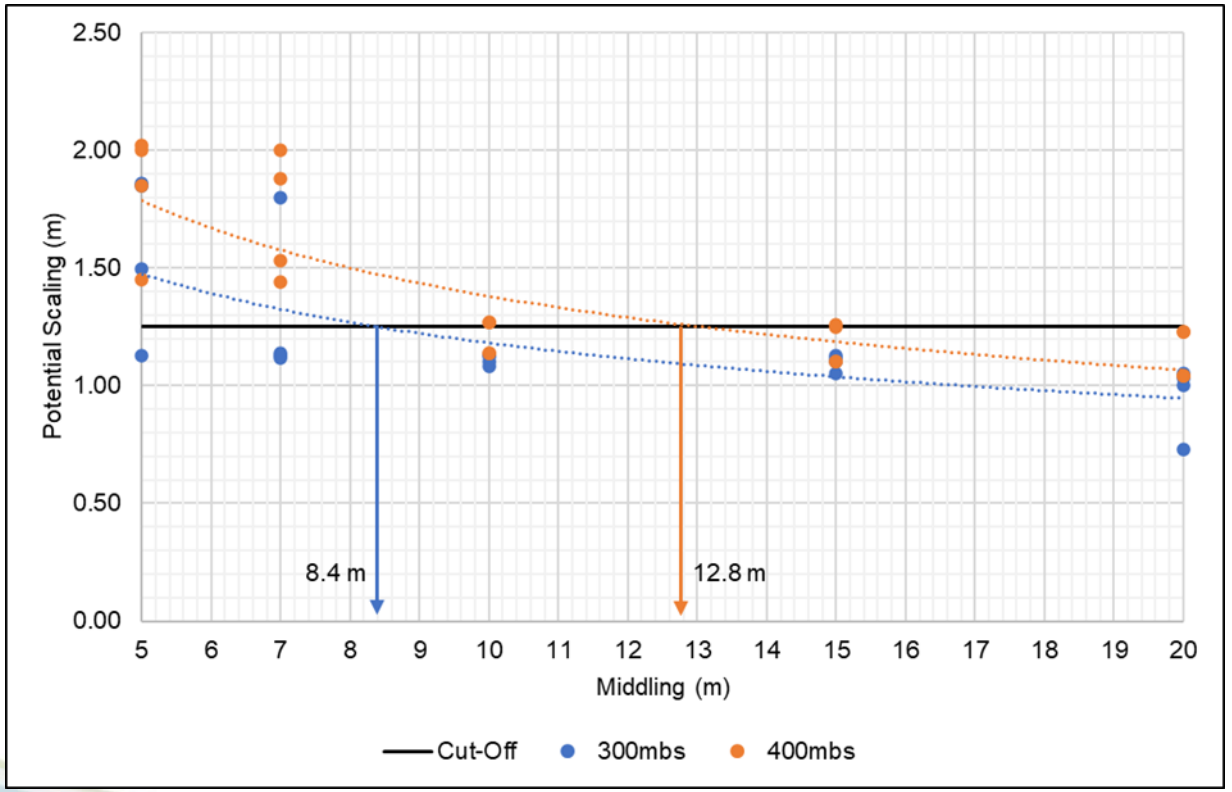
Pillar Scaling

- The extent of pillar scaling in the upper and lower seam pillars was also used to determine a suitable middling thickness



Pillar Scaling

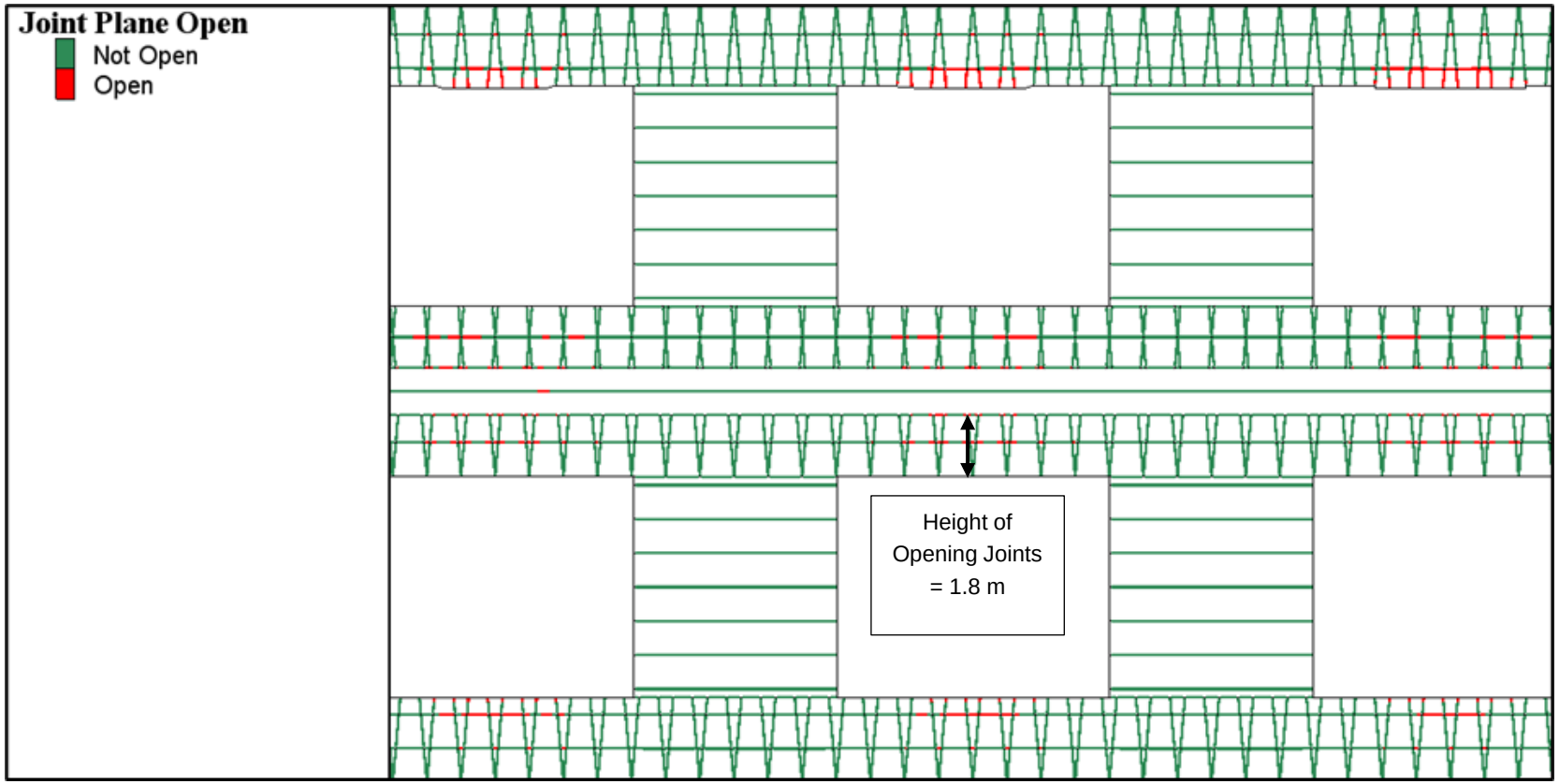
- The cut-off was set to 1.25 m, as this gives an effective pillar width of 3.5 m if the pillar were to scale completely. This will ensure the minimum pillar FOS will remain above 1.5 at 300 mbs and 400 mbs.



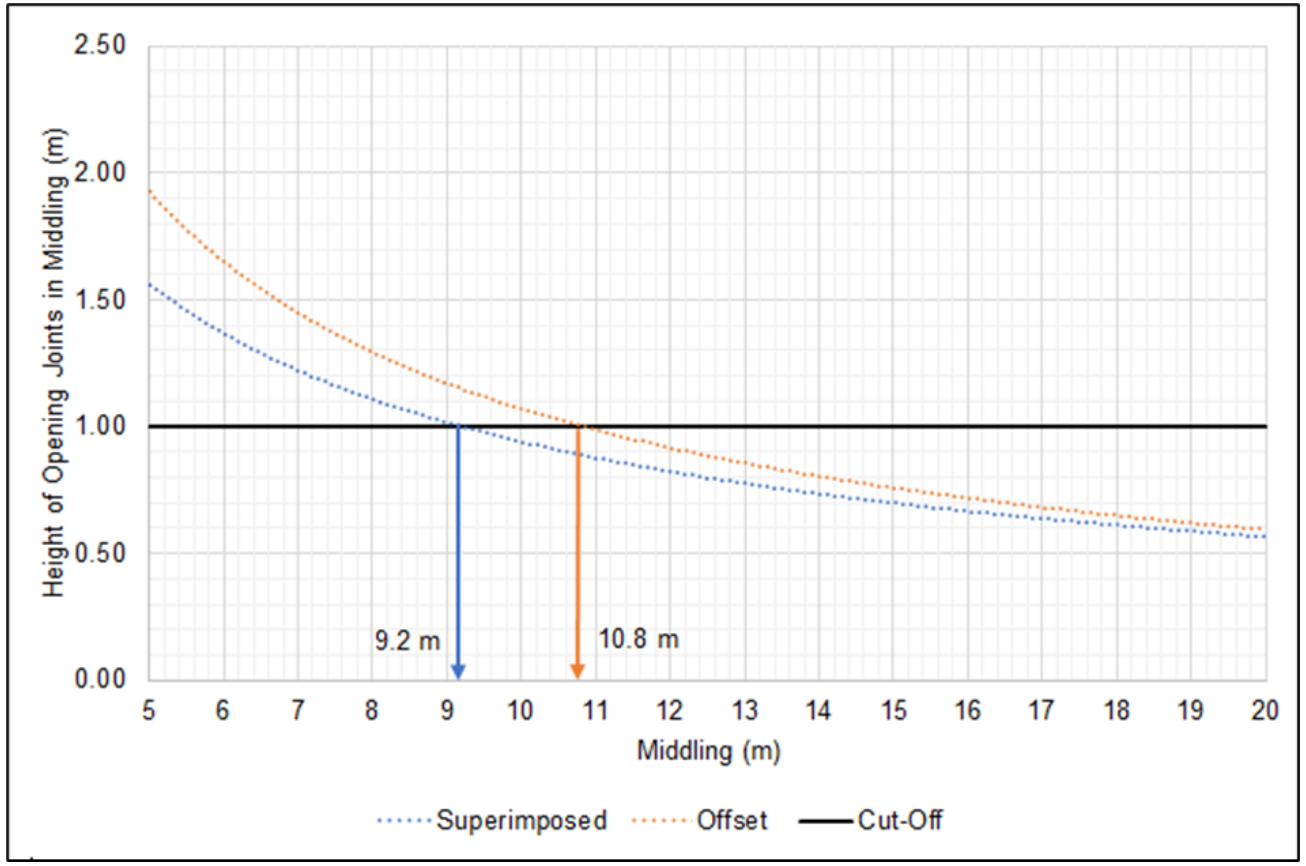
Extent of Opening Joints

- The final aspect used to assess the middling thickness suitability was a plot indicating the extent of opening joints, which is measured from the lower seam hangingwall up to the open joint farthest into the hangingwall.
- The cut-off height was set at 1.0 m as this represents the thickness wherein loose blocks are most prone to dislodging, in line with the 95% fall-out height.

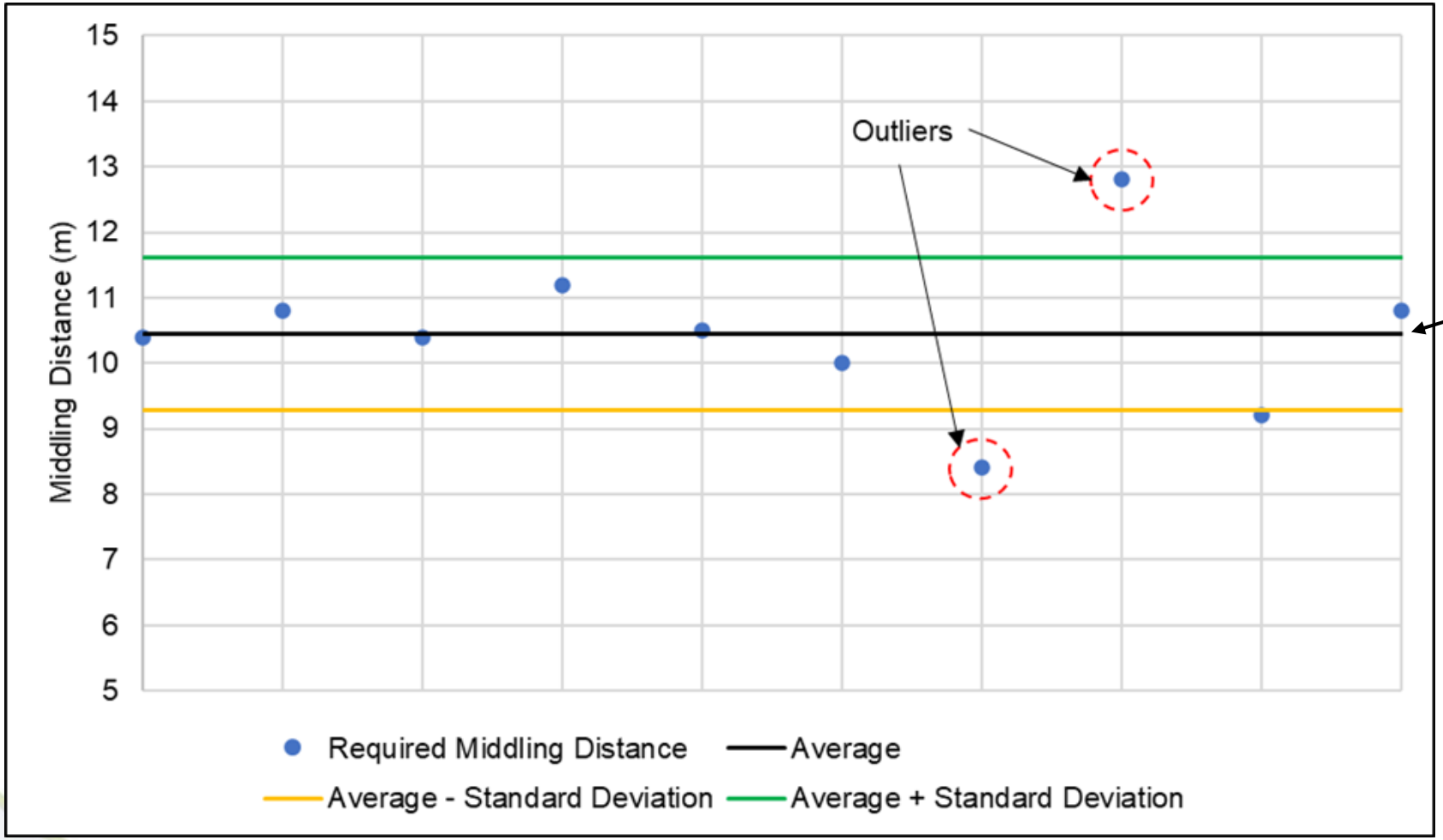
Extent of Opening Joints



Extent of Opening Joints



Summary of Results



10.45m

Future Work

- Future work being done to gather practically implemented data and add to the numerical simulation database.
- Potential for the derivation of empirical charts / formulae for use in shallow meta-sedimentary hard rock mining environments.

Thank You