

Development of a Novel Mining Method for Coal Extraction at Higher Depth Using Continuous Miner Technology: A Perspective for Indian Coal Mines

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Abstract

The application of continuous miner technology in Indian coalfields has demonstrated satisfactory performance for coal extraction up to depths of approximately 300 m. Its deployment at depths exceeding 300 m in certain mines in India, such as Churcha RO underground mine of Coal India Limited, VK-7, Vakilpalli mine, and Shantikhani of Singareni Collieries Company Limited, has revealed significant strata control challenges, adversely affecting the stability of underground structures and the roof. At higher depths, the increased and redistributed in-situ stresses compromise the effectiveness of the bord and pillar mining method. Notably, Indian coalfields contain an estimated 132.45 billion tonnes of coal reserves within the 300-600 m depth range, necessitating the development of efficient extraction strategies with safety. International experiences, particularly from Australia, indicate the successful utilization of continuous miner technology at depths up to 600 m through an alternative (Wongawilli method) of bord and pillar mining method. In this study, a stability investigation of underground structures of a seam sited at around 315 m depth at Godavarikhani 11 Incline Mine of Singareni Collieries Company Limited was examined through a finite difference-based three-dimensional numerical simulation study. An attempt has been made to address the limitations associated with continuous miner operation at a higher depth of cover. Based on the findings, a novel mining method is proposed for safe and efficient extraction of coal at higher depths using continuous miner technology for the selected mine. The proposed novel method was found to be techno-economically feasible and efficient for safe coal extraction at higher depths.

Keywords: *Underground structure, higher depth, strata control challenges, continuous miner, bord and pillar mining method, novel mining method.*



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GREEN MINING
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Introduction

- Coal reserves of are 400 billion tonnes are estimated up to 1200 m depth (01/04/2025) in India
- Around 132 billion tonnes coal are sited at depth range of 300-600 m
- Coal is primary source of energy in India and U/G mines contribute around 3.04% (2024-25)
- CMT in Indian coalfields found to be satisfactory up to 300 m depth except few structurally controlled instability
- Structurally- and Stress-controlled instability challenges, impacts the performance Bord and Pillar mining

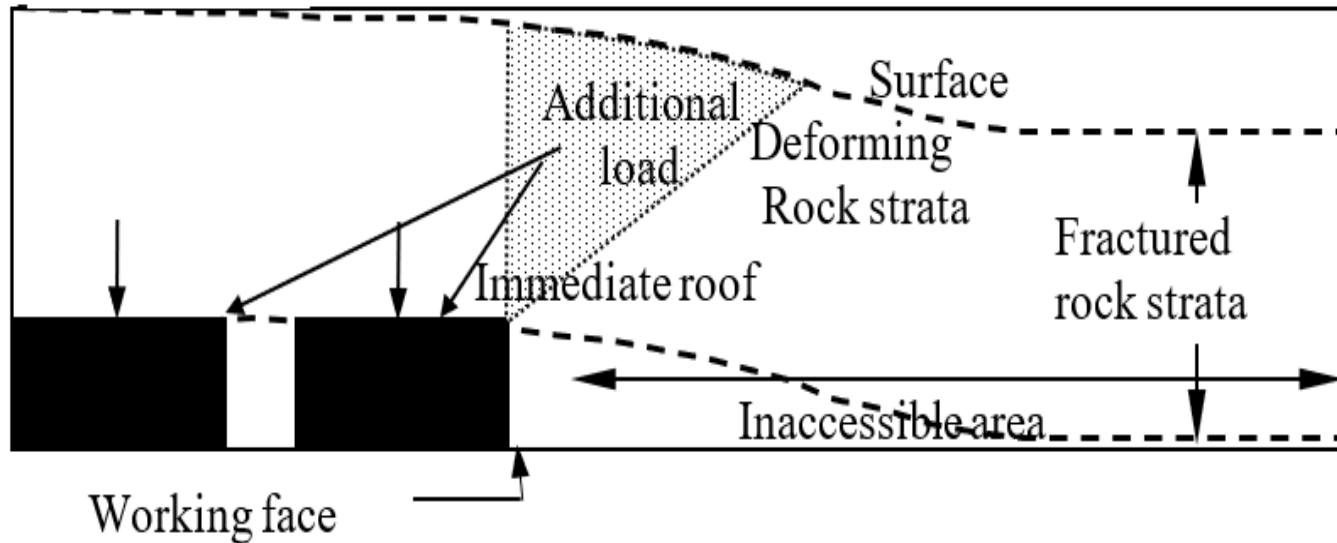


Introduction

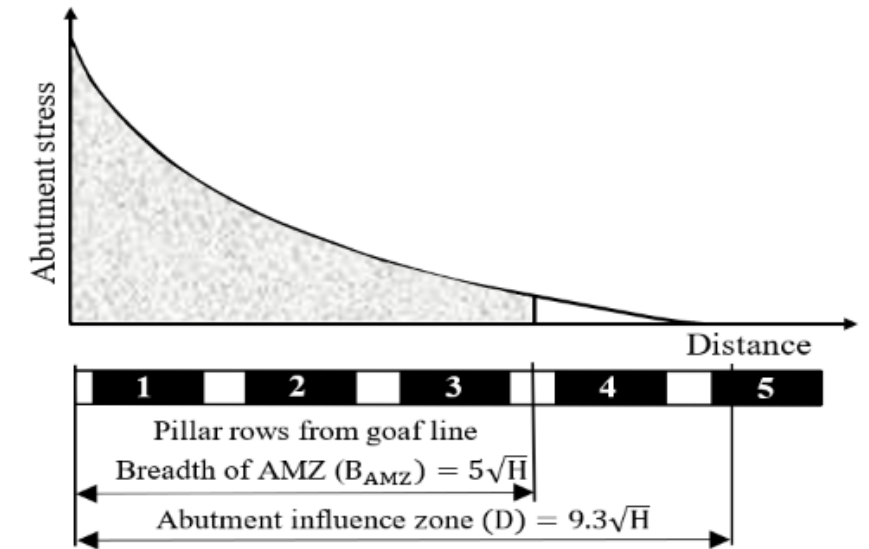
- CMT introduced up to 600 m depth in Australia for **Wongawilli Method**
- An experimental panel located at 315 m depth has been selected for a novel mining method
- Three-dimensional numerical modelling was carried out
- Results of numerical modelling revealed that stability of underground structures improved during secondary mining
- Coal recovery also enhanced
- It can be implemented at Godavarikhani No. 11 Incline Mine, SCCL



Literature Review



(a) Strata mechanics during depillaring ([Singh et al., 1996](#)).



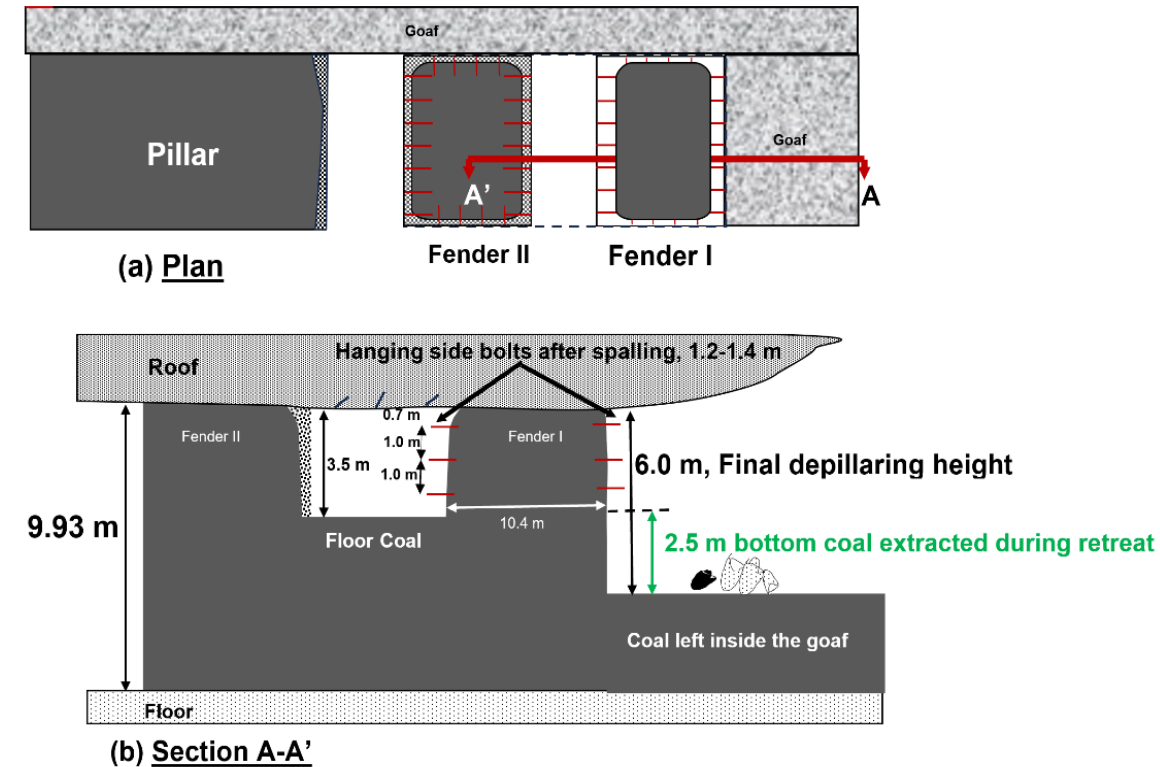
(b) Influence of abutment stress towards working area ([Mark & Chase, 1997](#)).



Literature Review: Findings

• Instability during depillaring at higher depth (Tamilprasanth and Ram, 2025)

- Caveable roof strata
- Thick seam was extracted using CMT at 315-358 m depth.
- Shale/weak layer was found at roof-pillar interface.
- Considerable spalling was observed in the fenders
- Instability at the working face

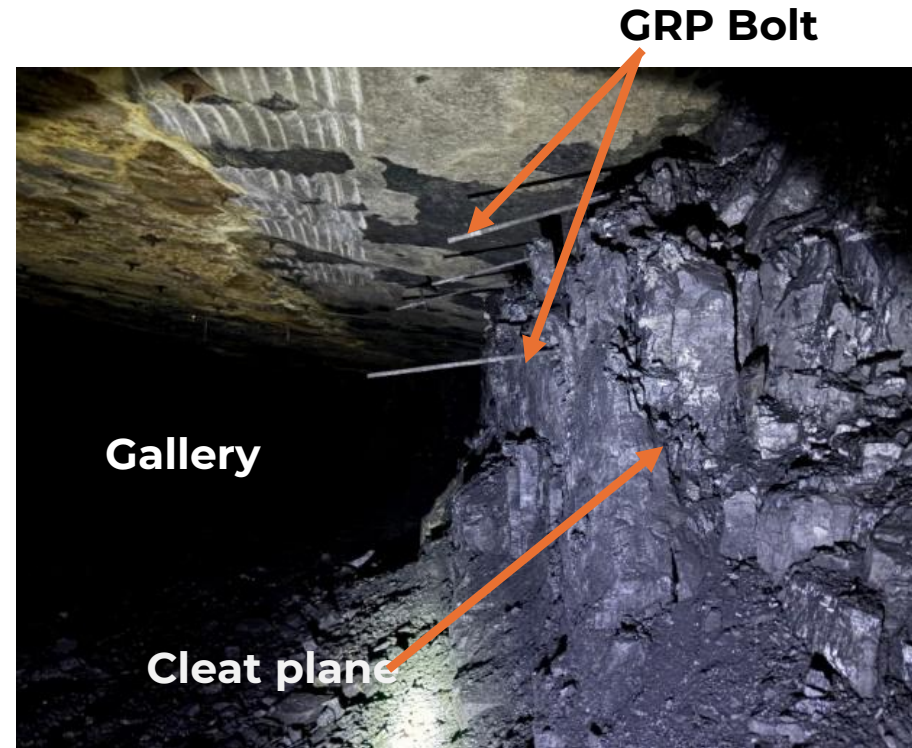




Literature Review: Findings

❑ Instability under higher depth and strong strata (Ram, 2025)

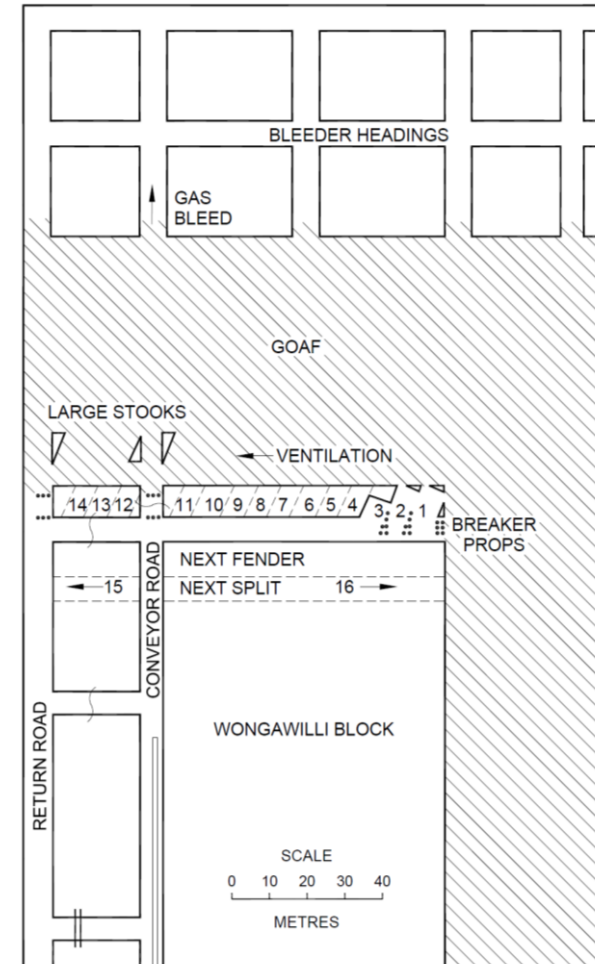
- Structurally and stress-controlled instability





Literature Review: Wongawilli method

- ❑ Suitable for extraction of coal at higher depth (up to 600m)
- ❑ Width of coal block: 60-80 m
- ❑ Fender width is kept 7-9 m,
- ❑ Width to height ratio of a fender ≥ 3
- ❑ Strata control is mainly govern by natural supports

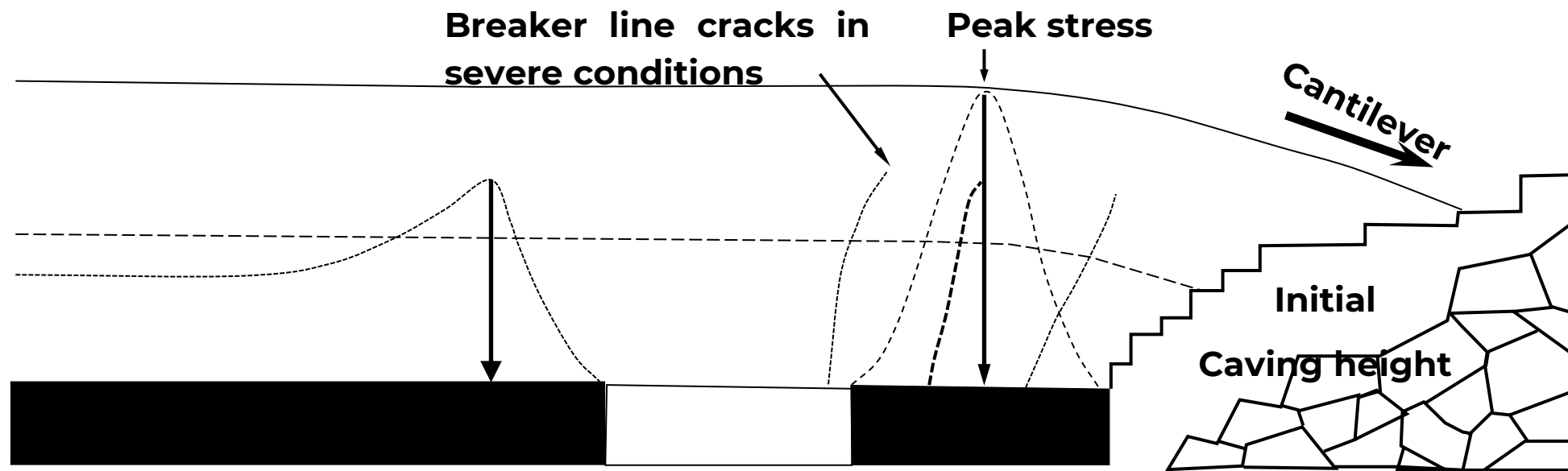




Literature Review: Findings

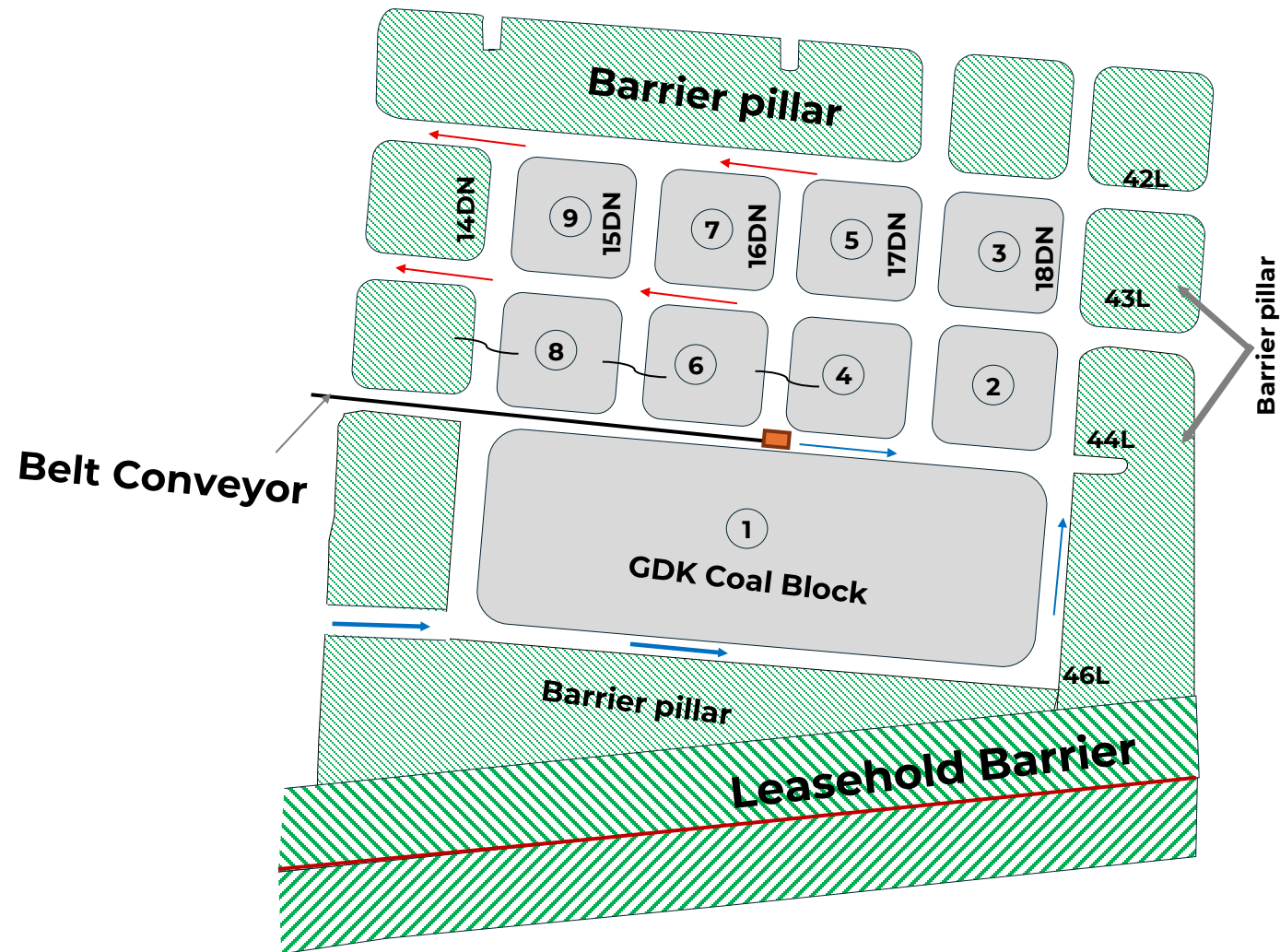
□ Front abutment load (Shepherd & Lewandowski (1998))

- Fender width: 7-9 m, Depth: 450 m
- Maximum abutment load developed on Fender





Geo-mining Conditions of Experimental Panel





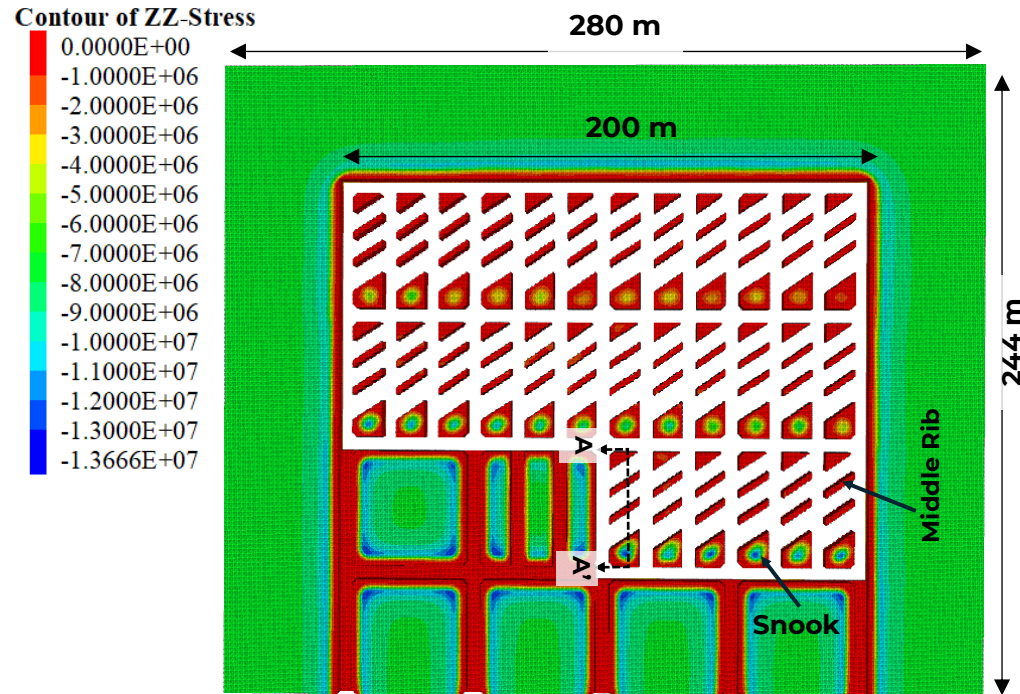
Geo-mining Conditions of Experimental Panel

Parameter	Description
Seam thickness	6-7 m
Depth of cover	315 m
Status of overlying working seam	Goaved-out panels of No. 1 Seam including Barrier pillars. Inter-burden parting is around 80 m. No. 2 Seam is non-vendable
Status of underlying working seam	No. 4 Seam is virgin
Gradient of the seam	1 in 8.5 towards N60°E
Panel Size (Length x Width)	200 m x 191 m
Panel extent	42L-46L and 14DN-18DN
Size of smaller pillar (centre to centre)	50 m x 50 m
Size of coal block	80 m x 194.5 m
Gallery size (Width x Height)	5.5 m x 4 m
Development height	4 m
Proposed depillaring height	6 m
Rock mass rating	50.60
Immediate roof	Medium to coarse-grained sandstone.
Proposed size of Fender of coal block	11 m x 80 m
Width-to-height ratio of big Fender	4.84
Proposed size of Fender of small pillar	11 m x 44.5
Width-to-height ratio of small Fender	4.41
Proposed width of slice	10 m
Proposed size of middle rib	3 m
Proposed size of Snook	89 m ²
Effective width of snook	9 m
Width-to-height ratio of snook	1.5

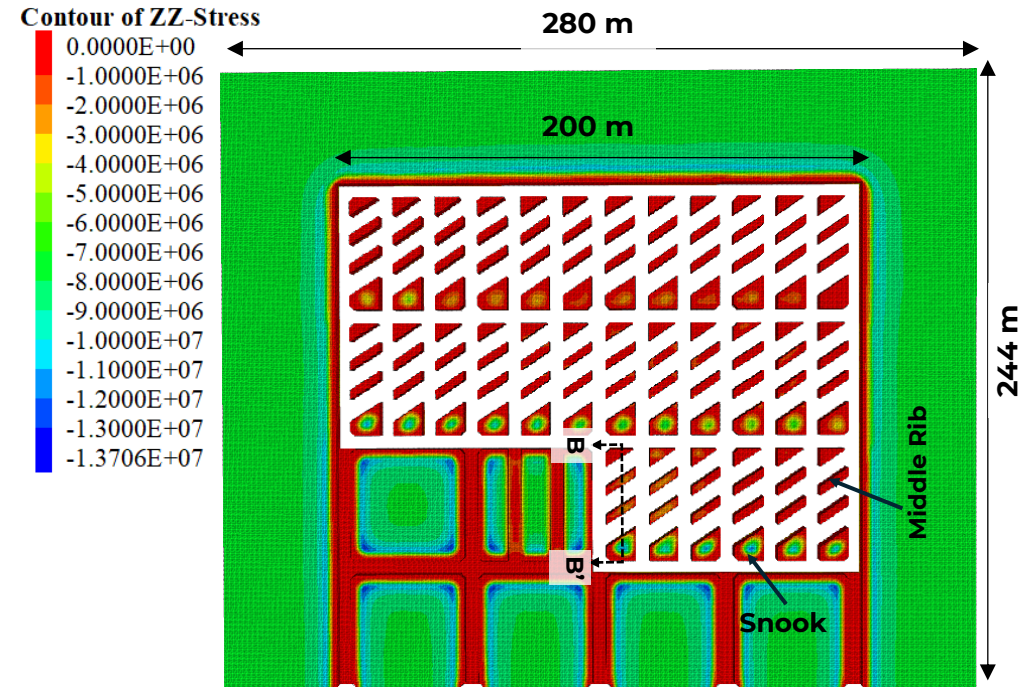


Numerical Modelling

- Fender width 11 m
- Middle Rib: 2 and 3 m thick
- Snook width: 9 m



Depillaring with 2 m width of middle rib



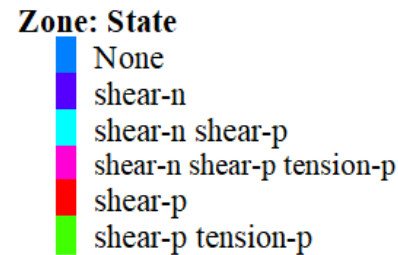
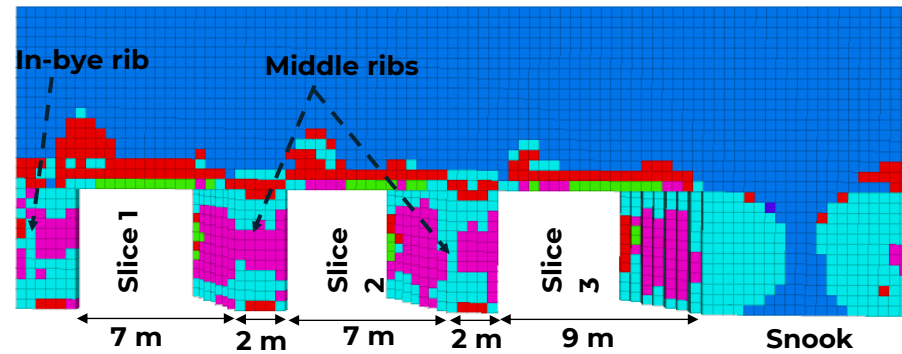
Depillaring with 3 m width of middle rib



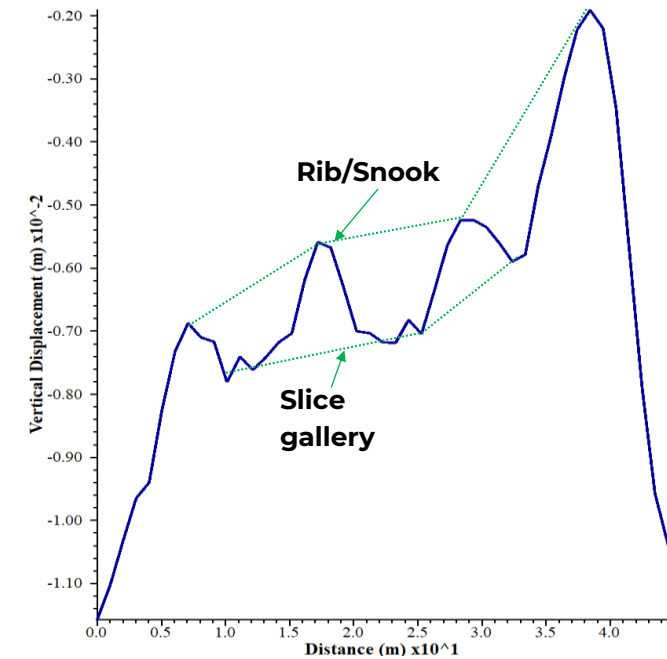
Numerical Modelling

□ Stability Assessment of Structure for 2 m thick middle rib

- Immediate roof found to be unstable
- Roof displacement up to 11.16 mm
- Middle rib found to be unstable



States of ribs/snook and roof along Section A-A'



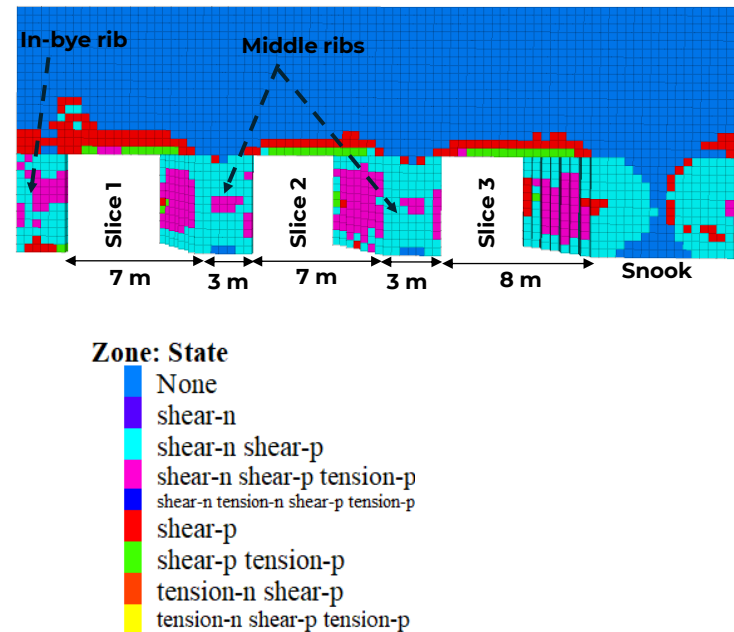
Roof displacement along Section A-A'



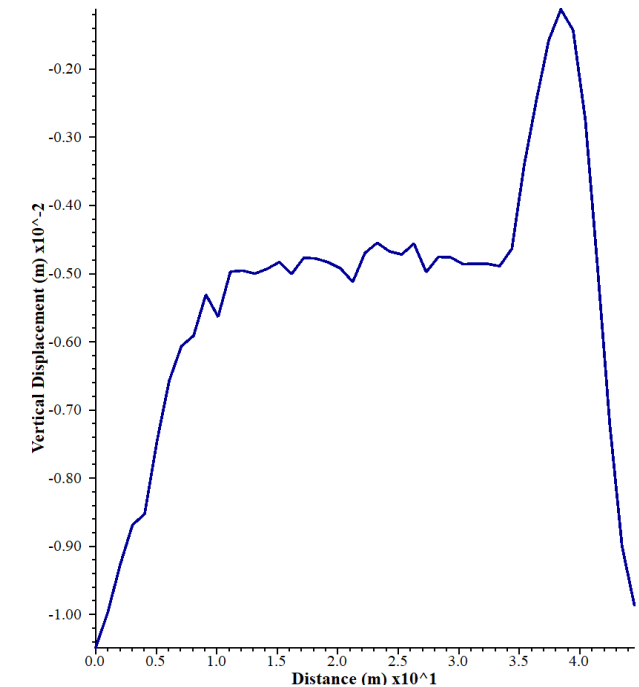
Numerical Modelling

□ Stability Assessment of Structure for 3 m thick middle rib

- Immediate roof found to be unstable
- Roof displacement up to 10 mm
- Middle rib found to be stable



States of ribs/snook and roof along Section B-B'



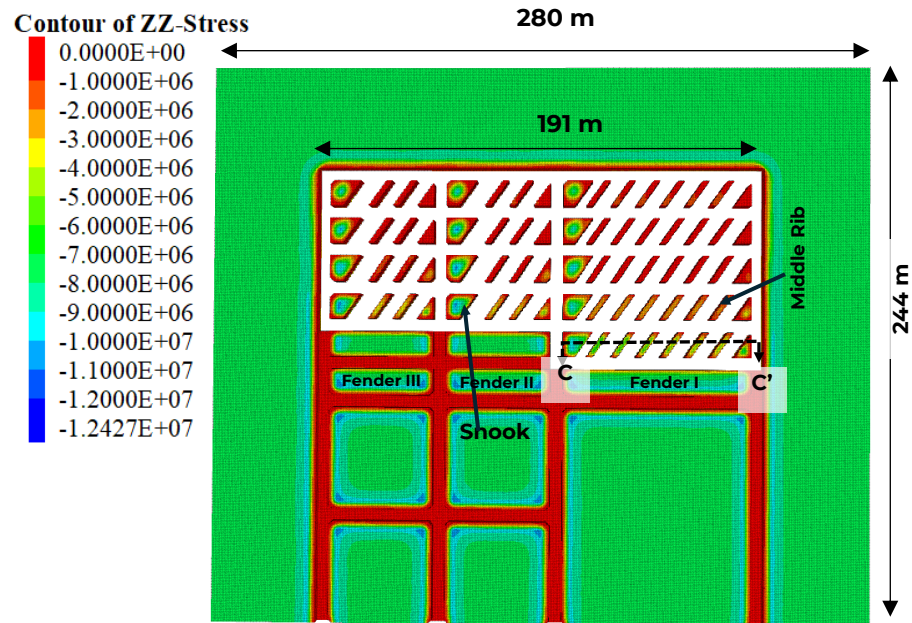
Roof displacement along Section B-B'



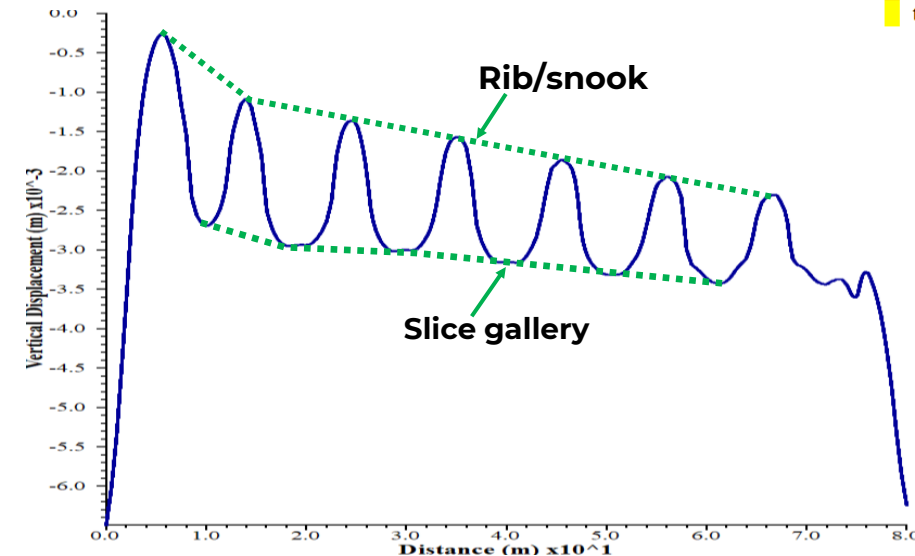
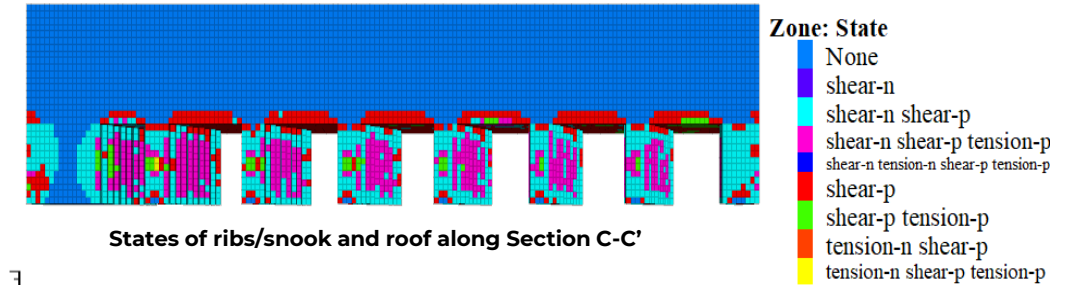
Numerical Modelling

□ Depillaring with Proposed Novel Method: 2 m thick middle rib

- Roof displacement in slices: 2.60-3.20 mm
- Shearing at the rib-roof interface was noticed



Depillaring with 7 m and 2 m width of slices and middle ribs respectively.



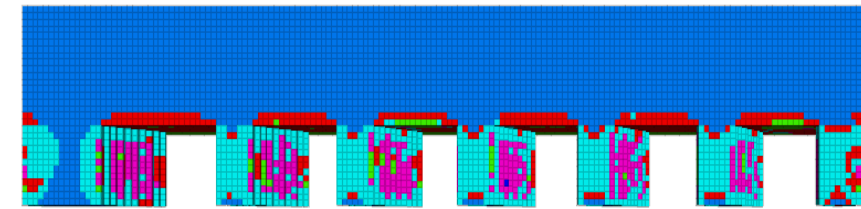
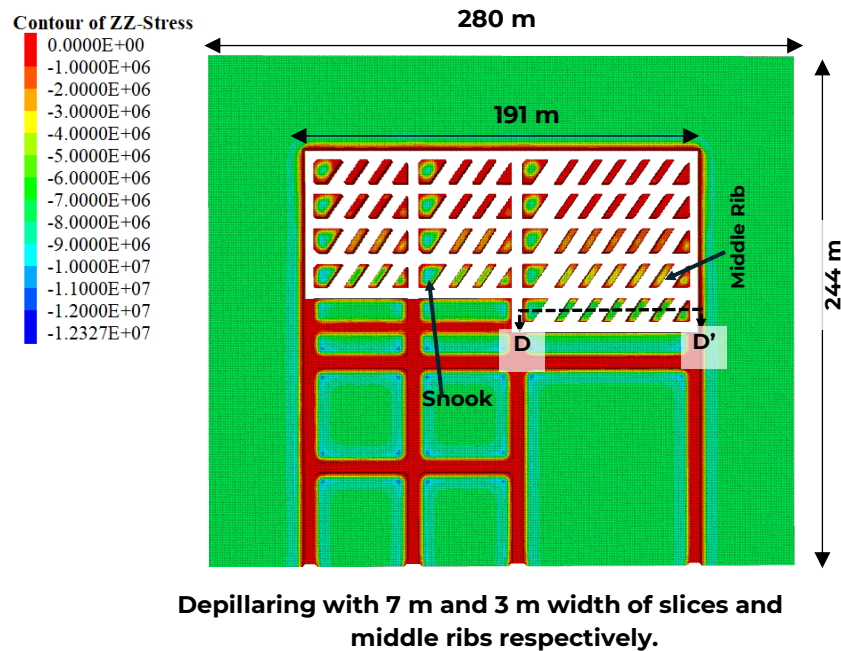
(b) Roof displacement along Section C-C'



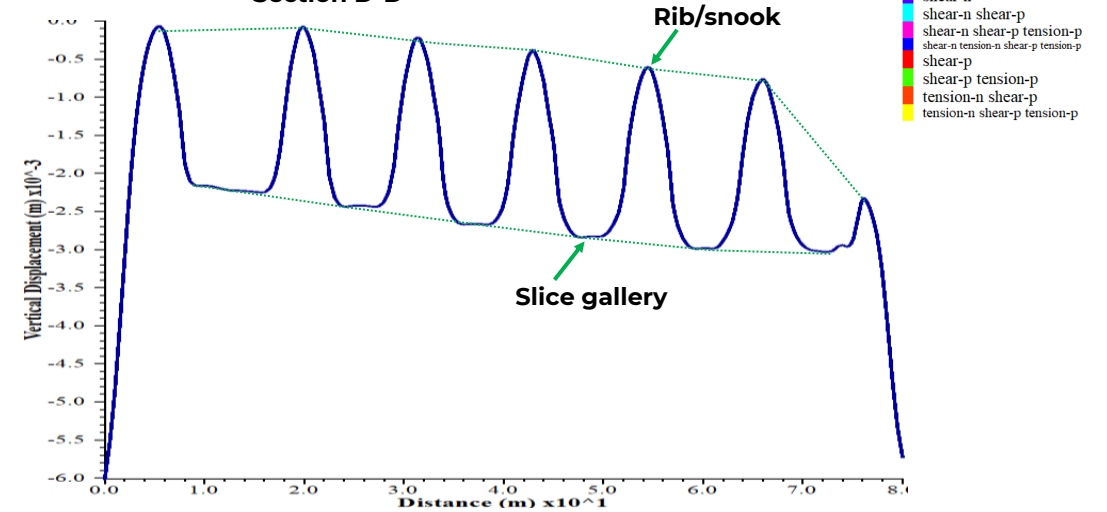
Numerical Modelling

□ Depillaring with Proposed Novel Method: 3 m thick middle rib

- Roof displacement in slices: 2.20-2.80 mm mm
- Shearing at the rib-roof interface was less



States of ribs/snook and roof along
Section D-D'



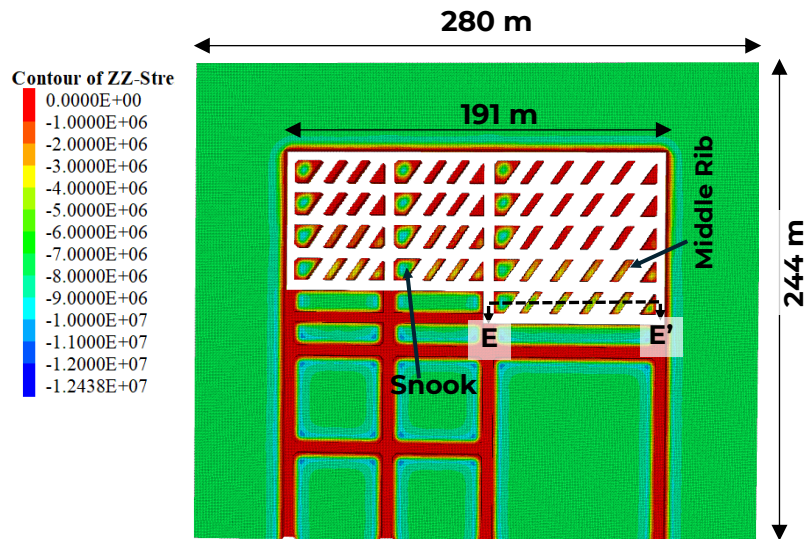
(b) Roof displacement along
Section D-D'



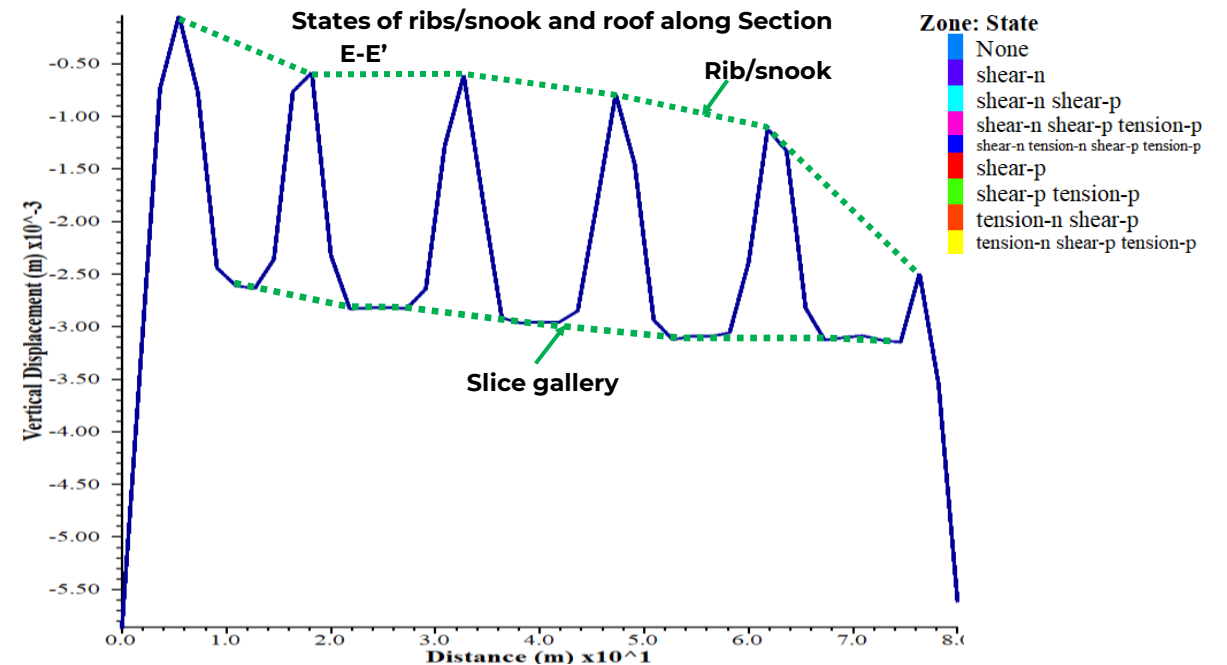
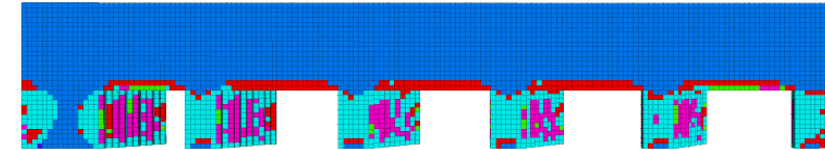
Numerical Modelling

□ Depillaring with Proposed Novel Method: 3 m thick middle rib and 10 m slice

- Roof displacement in slices: 2.60-3.00 mm
- Shearing at the rib-roof interface was less



Depillaring with 10 m and 3 m width of slices and middle ribs respectively.



Roof displacement along Section E-E'



Analysis And Discussion

Stability of the underground structures is, generally, examined through factor of safety- and width-to-height (w/h)

Sheorey's (1992), Salamon and Munro (1967) and van der Merwe (2005) formulae used for strength estimation.

$$\text{Pillar Strength} = 0.27 \sigma_c h^{-0.36} + \left(\frac{H}{250} + 1 \right) \left(\frac{w_e}{h} - 1 \right) \text{ MPa} \quad (1)$$

$$\text{Pillar Strength} = \frac{7.12 w_e^{0.46}}{h^{0.66}} \quad \text{MPa} \quad (2)$$

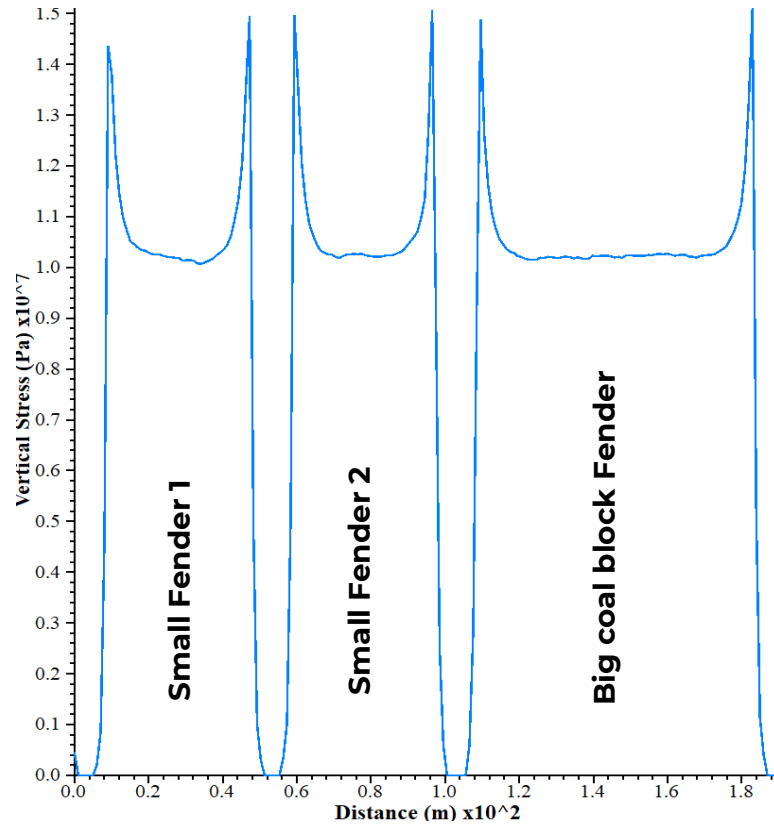
$$\text{Snook strength} = 3.5 \frac{w_e^3}{h} \quad \text{MN} \quad (3)$$

where, w_e = effective width of snook (m), h = height of snook (m), F_{xm} = strength of snook (MN).

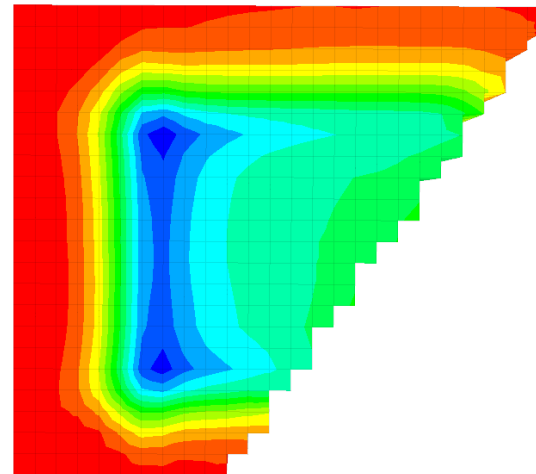
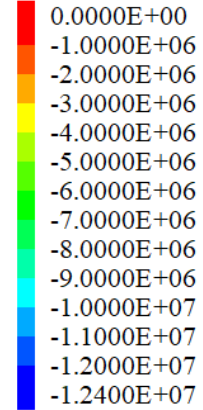
where, S = pillar strength (MPa), σ_c = uniaxial compressive strength of coal (MPa), h = working height (m), H = depth of cover (m) and w_e = effective width of the pillar (m) = $4A/P_c$, where A is area and P_c is perimeter of pillar.



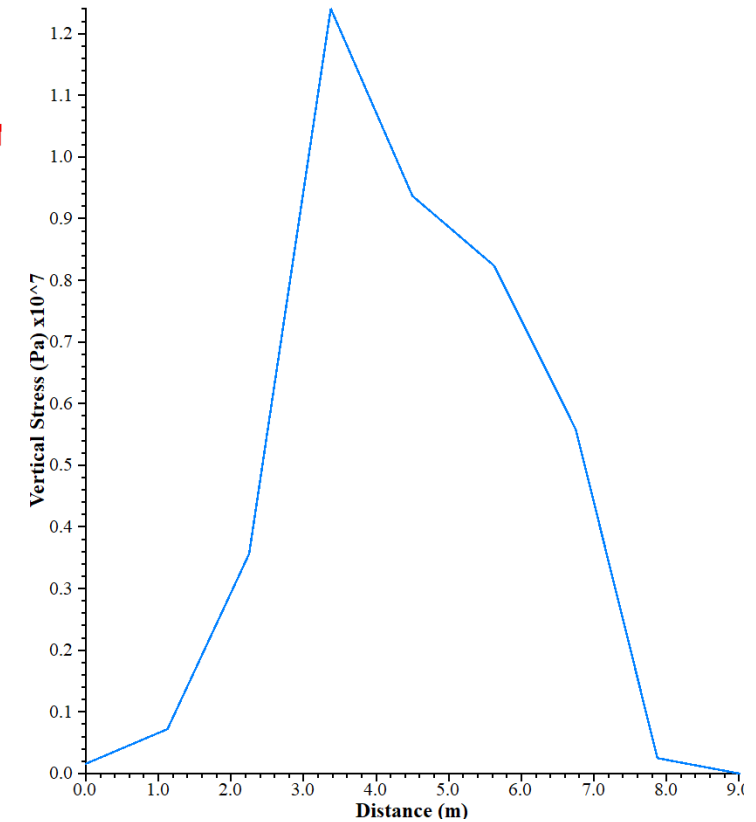
Analysis And Discussion



Contour of ZZ-Stress



Snook





Analysis And Discussion

Estimation of factor of safety (FoS) of fenders and snook using empirical approaches and load measured through numerical modelling

Empirical strength Formulae	Fender/ Snook	Strength (MPa)	Proposed Novel Mining method						Split and Fender method			
			Depillaring with 2 m thick rib and 7 m slice width		Depillaring with 3 m thick rib and 7 m slice width		Depillaring with 3 m thick rib and 10 m slice width		Depillaring with 2 m thick rib and 7 m slice width		Depillaring with 3 m thick rib and 7 m slice width	
			Stress (MPa)	FoS	Stress (MPa)	FoS	Stress (MPa)	FoS	Stress (MPa)	FoS	Stress (MPa)	FoS
Sheorey (1992)	Small Fender	11	6.30	1.75	6.18	1.78	6.29	1.75	7.33	1.50	7.48	1.47
	Big Fender	11.94	5.91	2.02	6.28	1.90	6.17	1.94	--	--	--	--
Salmon & Munaro (1967)	Small Fender	10.68	6.30	1.69	6.18	1.73	6.29	1.70	7.33	1.46	7.48	1.43
	Big Fender	11.14	5.91	1.88	6.28	1.77	6.17	1.81	--	--	--	--
	Snook	5.99	13.94	0.43	13.53	0.44	12.40	0.48	16.23	0.37	15.64	0.38
Merwe (2005)		4.70	13.94	0.34	13.53	0.35	12.40	0.38	16.23	0.29	15.64	0.30
Sheorey (1992)		3.97	13.94	0.28	13.53	0.29	12.40	0.32	16.23	0.24	15.64	0.25



Analysis And Discussion

□ Comparison of coal recovery and safety issues

Method	Manner of fender extraction	Recovery (%)	Remarks
Proposed Novel Method	Extraction of fender with 7 m width of slice and 2 m thick middle rib	78.6	Not suitable due to stability issue
	Extraction of fender with 7 m width of slice and 3 m thick middle rib	76.32	Delay in caving
	Extraction of fender with 10 m width of slice and 3 m thick middle rib	77.55	Found to be suitable, however, may be modified after strata monitoring in experimental panel
Split and Fender Method	Extraction of fender with 7 m width of slice and 2 m thick middle rib	77.83	Not suitable due to stability issue
	Extraction of fender with 7 m width of slice and 3 m thick middle rib	75.22	Instability may be encountered due to double split galleries. In case of single split gallery, recovery will reduce.



Conclusions And Recommendations

- Split and Fender method experiences instability issues during depillaring at a higher depth of cover
- The proposed novel method contains
 - a larger area of natural support and a smaller number of openings, better control the abutment
 - At the time of depillaring, splitting, and slicing, it would be done under the shadow of a bigger coal block
- **The manner of fender extraction with 10 m width of slice and a 3 m thick middle rib has been found to be suitable for the proposed novel method.**



Conclusions And Recommendations

Following recommendations are drawn based on the simulation study

- Width of bigger block can be kept **80 m**
- Width of fender should be kept 11 m
- An oblique slice of 10 m in width and 12 m in length should be extracted
- Thickness of middle rib should be kept 3 m
- The 2 m thick bottom coal can be extracted at the time retreat by making ramp 1 in 6 from the position of the breaker line support.
- Effective width and size of the snook should not be less than 9 m and 89 m², respectively.
- Roof bolt-based breaker line should be installed at the goaf edge to control the goaf encroachment.



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- The views presented in the paper are of the authors and do not necessarily reflect the opinion of the institute to which they belong.





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