

GEO TECHNICAL ASSESSMENTS FOR DEPILLARING IN PANELS

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Abstract:

The geotechnical assessment and strata monitoring analysis for the depillaring of panels CM-15 and CM-16, and the depillared panel CM-10 of the L-1B seam at Vindhya Underground Mine, South Eastern Coalfields Limited (SECL). The study evaluates the geotechnical properties of the coal seam and surrounding rocks, focusing on the physical and mechanical characteristics that impact mining operations. It assesses the stability of the panels CM-15 and CM-16 for safe depillaring and monitors the strata behavior of the depillared panel CM-10 to predict and manage risks associated with underground mining. Additionally, the study aims to identify potential geotechnical hazards and provide suitable mitigation measures for enhancing mine safety and efficiency. This report serves as a foundation for improving mining operations in similar geotechnical conditions, ensuring the safe and optimal extraction of coal resources.

Keywords: Geotechnical Assessment, Strata Monitoring, Depillaring, Coal Seam, Panel Stability, Mining Safety, SECL, Mitigation Measures.

1.Introduction

The mining industry, particularly underground mining, involves significant risks due to the nature of the environment and the geotechnical challenges it presents. In the context of depillaring operations, the safety and stability of mining panels are critical factors that directly impact both productivity and the well-being of the miners. Depillaring refers to the process of extracting coal from pillars left for support during mining, a method that requires precise planning and monitoring to avoid accidents such as ground subsidence, cave-ins, or gas leaks. The L-1B seam at Vindhya Underground Mine, operated by South Eastern Coalfields Limited (SECL), presents unique geotechnical challenges that require in-depth analysis and careful management. This study aims to evaluate the geotechnical properties of the coal seam and surrounding rocks, which influence the stability of the mining panels. By focusing on panels CM-15 and CM-16, and examining the behavior of the depillared panel CM-10, this research assesses the structural integrity of these panels and their suitability for safe mining. Furthermore, the study emphasizes the importance of strata monitoring to track and predict the behavior of underground conditions during the mining process. The findings of this study will contribute to the optimization of mining operations, ensuring both safety and efficiency by identifying and addressing potential geotechnical hazards and proposing mitigation strategies.

Scope of Work:

The scope of this study focuses on conducting a comprehensive geotechnical assessment and strata monitoring analysis for the depillaring of panels CM-15 and CM-16, and the depillared panel CM-10 from the L-1B seam at Vindhya Underground Mine, SECL. The primary objectives include evaluating the geotechnical properties of the coal seam and surrounding rocks, assessing the stability of the mining panels for safe depillaring, and monitoring the strata behavior of the depillared panel. Additionally, the study aims to identify potential geotechnical hazards and provide effective mitigation measures to improve safety and operational efficiency. The findings will contribute to optimizing mining practices in similar geological conditions and ensuring the safe extraction of coal resources.

2.Literature Review

The significance of geotechnical assessments and strata monitoring in underground mining has been extensively discussed in the literature, particularly in the context of depillaring operations. According to Singh et al. (2015), geotechnical properties, such as rock strength and the stress-strain behavior of surrounding rocks, are crucial in assessing the stability of mining panels. The authors emphasize that understanding these properties is vital for designing safe mining operations, particularly in depillaring, where the risk of collapse is high. In a study by Rao and Saha (2016), the authors explored the importance of monitoring strata behavior during mining operations to predict potential hazards such as subsidence and rockbursts. They argue that advanced monitoring technologies, including ground penetrating radar (GPR) and seismic sensors, are essential for real-time data collection and analysis. Kumar and Patel (2017) also highlight the role of geotechnical hazards in mining operations, stressing that careful monitoring of the rock mass behavior can prevent catastrophic events. The use of advanced simulation models to predict the impact of mining activities on surrounding strata is essential for optimizing mining strategies and minimizing risks. The effectiveness of drainage systems in depillaring operations was studied by Ghosh et al. (2018), who found that efficient drainage could alleviate pore water pressure, improving the stability of the mined-out areas. They suggested that the installation of proper ventilation and drainage systems should be considered as part of the geotechnical assessment. Jha and Sharma (2019) further reinforced the importance of geotechnical data analysis in mining operations, stating that the collection of data on coal seam properties and mining-induced stress is crucial for determining the appropriate depillaring method. They also suggest using geospatial techniques to map subsurface conditions accurately. Mishra et al. (2020) examined the failure modes associated with depillaring operations and found that rock mass classification systems, such as RMR (Rock Mass Rating) and Q-system, are effective tools in assessing the stability of mining panels. Their study concluded that these systems provide valuable insights for panel design and operational safety. Saini and Sharma (2021) reviewed the advances in mining technologies, particularly focusing on automated strata monitoring systems. They argue that technologies such as drones and wireless sensor networks enable continuous and real-time monitoring of strata conditions, improving the overall safety of depillaring operations. In a comprehensive study by Verma et al. (2022), it was found that integrating advanced geotechnical tools with predictive analytics can greatly enhance the risk assessment of mining operations. Their research focused on how machine learning algorithms can be used to predict potential geotechnical failures based on historical data and environmental factors. The work of Patel and Verma (2020) further explored data-driven decision-making in mine planning. They proposed the use of simulation software that incorporates real-time monitoring data to predict and manage risks during depillaring, thus reducing operational costs and improving safety. Sharma et al. (2019) in their study on long-term mining safety highlighted the role of integrated monitoring systems in enhancing operational efficiency and safety. They concluded that the integration of geotechnical assessments with real-time monitoring systems ensures better management of mining hazards and enhances the overall productivity of mining operations.

3.Methodology

The methodology for this study involves a detailed geotechnical assessment and strata monitoring analysis to ensure the stability and safety of mining panels CM-15 and CM-16, as well as the already depillared panel CM-10, at Vindhya Underground Mine. The following steps outline the approach

Geotechnical Assessment in Panels CM-15 and CM-16

As part of the scientific study for working in upcoming CM Panels 15 and 16, geotechnical assessment was carried out including understanding the caveability of the roof rock inside the goaf, factor of safety of pillars, support system, and instrumentation for verification of the design and efficacy of the support system. These proposed panels were developed earlier with conventional drilling and blasting techniques. The original galleries need to be heightened and widened and subsequently depillared. The geo-mining details for proposed panels are given in Table

Table 1: Geo-mining details of upcoming panels CM-15 and CM-16

S.N	Item	CM-15
1	Target Seam	Seam-L1B
2	Seam Thickness (m)	3.52
3	Depth of Working (m)	30 – 49
4	Length of the Panel (m)	580
5	Width of the Panel (m)	102
6	Number of Pillars proposed in the Panel	140
7	Pillar Dimension (m) (Centre to Centre)	20 x 20
8	Existing Gallery Dimension (w x h)	4.2 x 2.8
9	Proposed Gallery Dimension (w x h)	6.0 x 4.0
10	Immediate Roof of Seam-L1B	Carb Shale, Gritty Sandstone
11	Immediate Floor of Seam-L1B	Shale
12	Parting with overlying Seam-L1A	No overlying seams above the proposed area
13	Parting with underlying Seam-L1C	4 m
14	Rock Mass Rating	45.91 and 46.83
15	Degree of Gassiness	Deg. I
16	Incubation Period	6 months

GEO-MINING DETAILS

- Mine Overview:
 - Vindhya Underground Mine, operated by South Eastern Coalfields Limited (SECL)
 - Located in the state of Madhyapradesh, India
 - Extracts coal from the L-1B seam
- Geology:
 - L-1B seam: 3.5-4.5 meters thick, dip 1 in 10, strikes N 70° E
 - Coal: bituminous, medium-to-high volatile matter
 - Roof and floor: sandstone, shale, and claystone
- Mining Method:
 - Room and pillar mining
 - Depillaring: extracting coal pillars, leaving behind a roof support
- Panels:
 - CM-15 and CM-16: scheduled for depillaring
 - CM-10: already depillared, used for strata monitoring analysis

- Geo-technical Parameters:
 - Rock mass rating (RMR): 45-55 (fair-to-good)
 - Quality designation (Q): 1.5-2.5 (poor-to-fair)
 - Uniaxial compressive strength (UCS): 10-15 MPa
 - Triaxial shear strength (TLS): 1.5-2.5 MPa
- Strata Monitoring:
 - Convergence measurements
 - Extensometer readings
 - Seismic monitoring
- Support Design:
 - Roof support: hydraulic props, beams, and mats
 - Side support: cable bolts and meshes

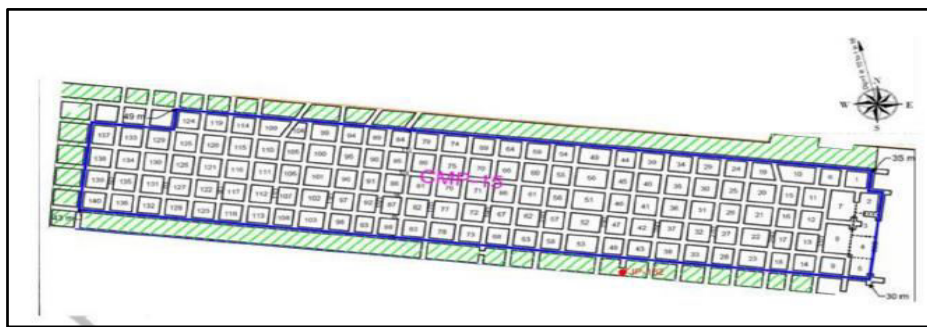


Figure 2: Plan showed proposed panel CM-15

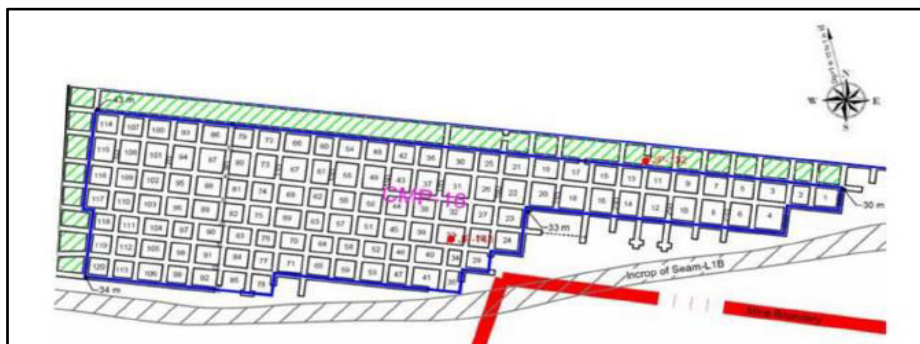


Figure 3: Plan showed proposed panel CM-16

Borehole Section

Two boreholes, namely JP-132 and JP-134, fall within the area of the proposed CM panels. It is evident from the boreholes that the proposed panels have no presence of overlying Seam L1A. The thickness of target seam L1B varies from 3.52 m to 4.76 m. The underlying seam L1C occurs at a depth of 4 m. The absence of any igneous rocks is also obvious from these borehole sections. The overlying strata is dominantly composed of medium and fine-grained sandstone. The immediate roof is composed of carbonaceous shale, and the floor varies from shale to very fine-grained sandstone.

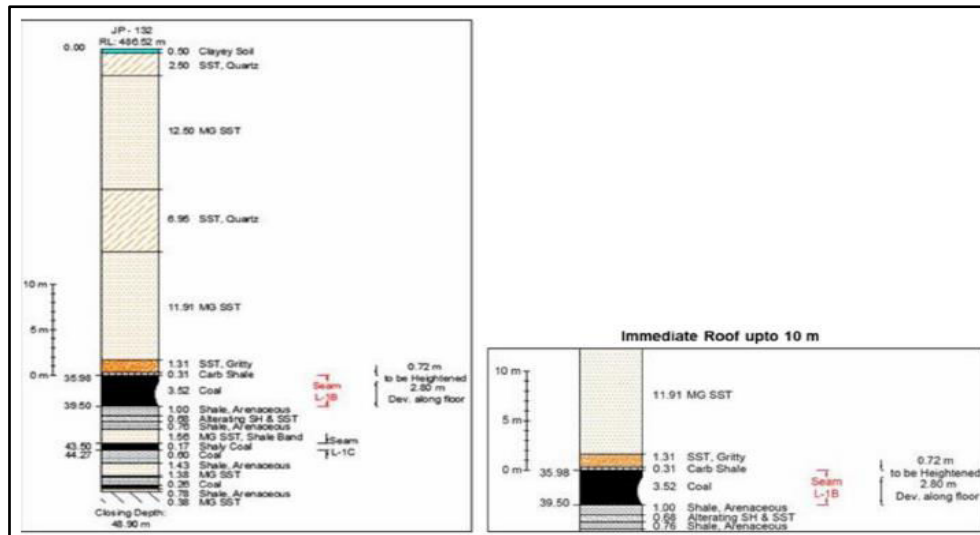


Figure 4: Bore hole selection JP 132

4. Pillar Design

Stability of a coal pillar is usually assessed by the factor of safety (FOS) using pillar strength and load on the pillar. The failure mode of a pillar is generally governed by its width-to-height (w/h) ratio, and its influence on strength is usually explained by the confined core concept. Thus, FOS and w/h ratio are generally used to design coal pillars. Das (1986) tested coal samples in the laboratory to assess post-failure stiffness of coal pillars.

Proposed Manner of Pillar Extraction

Depillaring in proposed Panels CM-15 and CM-16 shall be carried out in a similar fashion as it was done in the previous panels worked by JMS and is currently being continued in Panel CM-11. The Non-Split method was originally developed in South Africa in the 1990s to overcome issues of overrun of goaf, early caving resulting in burial of CM, and injuries due to the fall of ground. JMS has successfully introduced this method at Kapildhara Mine (SECL), Churi Mine (CCL), Bangwar Mine (SECL), Kumardih-B Mine (ECL), Vindhya Mine (SECL), and recently at Kurja-Sheetaldhara Mine (SECL). The method involves taking slices at 45° to 60° along three sides of the pillar from the dip and level galleries. Due to the size of the pillar and the cut-out distance of the CM, the pillar can be extracted without a split gallery. This method is applied to comparatively smaller sizes of pillars.

The principal reasons for the success of this method are as follows:

- The lengths of slices into the pillar are significantly reduced compared to split and fender methods.
- All slices are nominally at 45° to 60° to the dips and levels.
- All slices are pre-marked using survey pegs and direction lines.

The pillar's remnants (snooks) are pre-designed in terms of width-to-height ratio to be of sufficient size to control the rate at which the roof caves in a more manageable manner. Although the Non-Split system was developed for difficult mining conditions beneath overlying dolerite sills, the system was applied to reduce the risk of goaf overruns due to the unpredictable behavior of the immediate roof. Taking advantage of the 14.0 m square and smaller pillar, the Non-Split method of pillar extraction is recommended. This system has previously been successfully adopted in Vindhya Underground Mine

and other mines. This method negates the necessity of having long-term split galleries and increases the safety and recovery of minerals.

Breaker Line Roof Support

Roof bolt-based breaker line supports (RBBLs) are to be installed at the active goaf edge to control goaf encroachment into the working area. It acts as a pivotal point between the goaf and working area and provides a degree of local immediate roof support to prevent slabbing of the roof at the goaf edge during caving inside the goaf. It is proposed here to install two rows of roof bolts of 2.40 m length at 1 m x 1 m grid pattern located 1 m out-by from the goaf edge (corner of the pillar facing the goaf line) along the middle position of the rib/snook for safe MD operation of the panels CM-15 and CM-16. The spacing between last bolts in the row from the side shall not be more than 0.5 m. These are to be installed between and in addition to the development support. It is also recommended that the RBBLs are installed in the roadways for at least two rows of pillars before pillar extraction commences to optimise the speed of retreat. In addition to the rock bolts of breaker lines, it is recommended that at least one timber “policeman” pole is installed within the breaker line at the active goaf edge to provide a visual warning of the onset of loading both within and along the goaf edge.

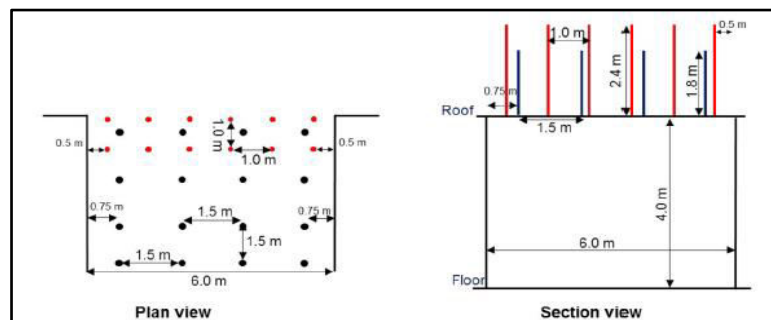


Figure 5: Proposed breaker Line Support for Goaf Edge

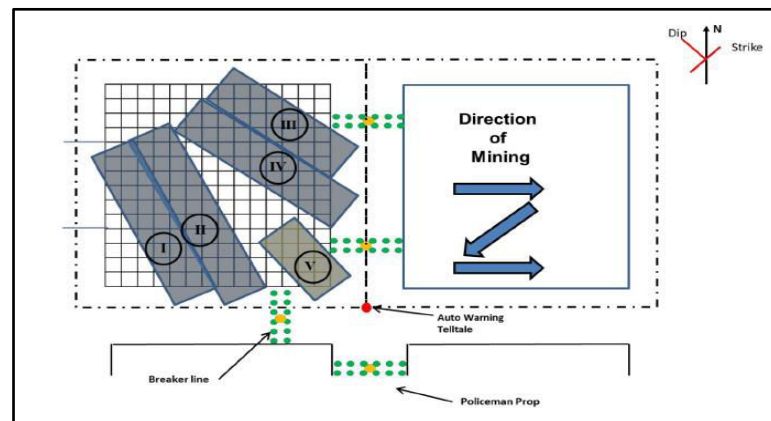


Figure 6: Position of Breaker Line Support around the workings for 14 m x 14 m solid pillars.

After the development of roadways, the model was run for depillaring operations with five pillars in a row. The design and sequence of pillar extraction considered for numerical modelling is shown in Figure. The average vertical stresses over the snook after extraction of slices in Pillar 1 (solid 14 m x 14 m) increased up to 2.8 MPa, The vertical stresses and Factor of Safety (FoS) for the snook as estimated using empirical relation is also indicating FoS for the snook around 1.03, this allows safe extraction for the neighbouring pillars at the same time do not offer much resistance to natural caving. The rib/snook

should be reduced judiciously during extraction of pillars in first row as FOS of the rib/snook should be in a range of 0.3 to 0.5.

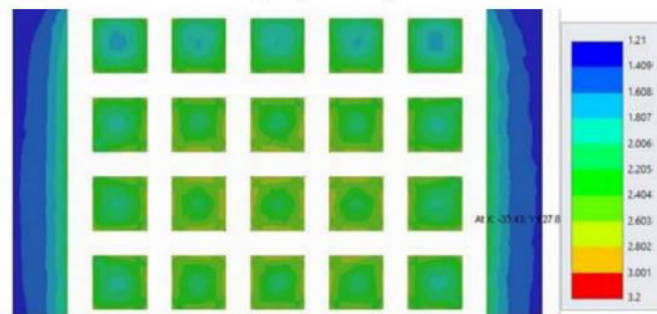


Figure 7: Vertical Stresses over the Solid Pillars (14 m x 14 m) After Development in Model

The numerical model was run accordingly for estimating the vertical stress during and after pillar extraction. The average vertical stresses from the numerical model after development of solid pillars of 14 m x 14 m is found to be 2.40 MPa, which is close to the empirical estimation. The vertical stresses built up over the pillar after development through numerical modeling are given in Table.

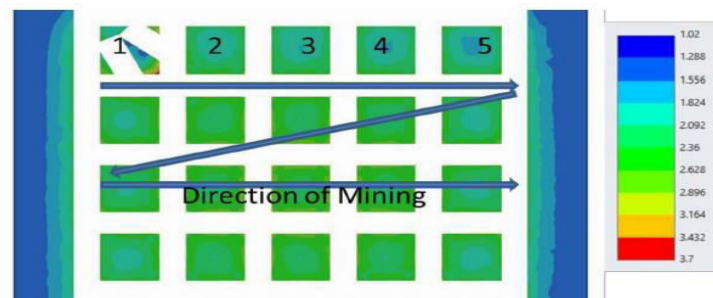


Figure 8: Vertical Stresses Solid Pillars (14 m x 14 m) After Extraction of Pillar 1 in Model.

The vertical deformation of the roof rock after extraction of solid Pillar 1 (14 m x 14 m) in the numerical model. The maximum roof deformation is around 7.2 mm inside the goaved-out area, indicating load over the left-out ribs and adjacent pillars.

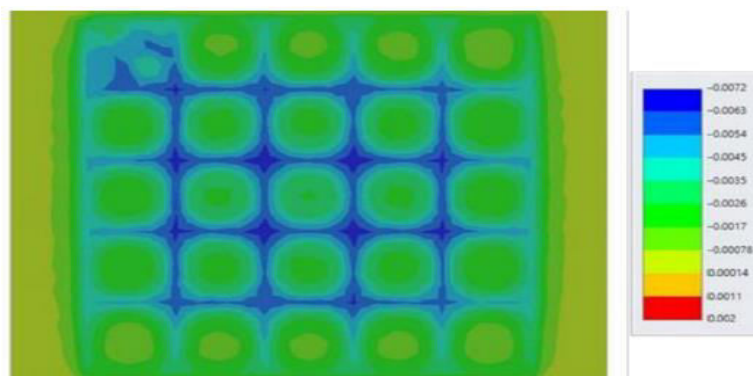


Figure 9: Vertical Deformation After Extraction of Pillar 1 in Model.

The vertical stresses in the panel with solid pillars of 14 m x 14 m also increased gradually after each pillar extraction in the row. The vertical stresses recorded over the Snooks after completion of pillars in the 1st row have increased, and on the adjacent pillars. As the 3rd pillar in the 3rd row is extracted, the vertical stresses over the snooks increased up to 4.3 MPa with 29 mm of bed separation in the goaf

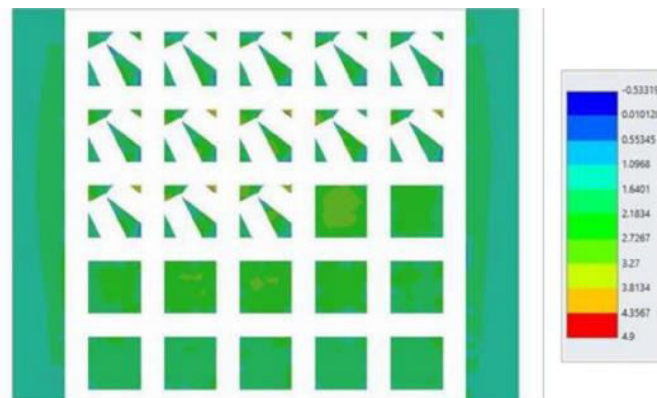


Figure 10: Vertical Stresses Over Pillars During Extraction of Third Row of Pillars in Model

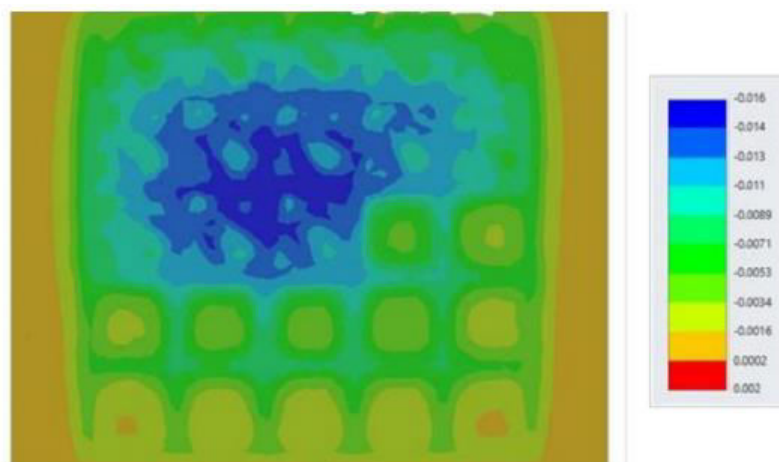


Figure 11: Vertical Deformation After Extraction of Two Rows of Pillars in Model.

It is evident from the results of numerical modeling and analysis that the method of working designed for Panels CM-15 and CM-16 of L-1B Seam at Vindhya Underground Mine shall progress with safe extraction.

Conclusion

An assessment of the underground structures for heightening & widening, including mechanized depillaring in proposed panels, is done using an empirical approach, numerical modelling, and strata monitoring results in the previous panel CM-10. Details of the design aspects of gallery, pillar/snook, safe cut-out distance, support system for the Panels CM-15 and CM-16 of L-1B Seam of the mine are described in this report. Results of simulation study also support the design of underground structures estimated through empirical approaches. A simple strata control and monitoring plan is also suggested to assess the efficacy of the suggested design of underground structures and support system. Results of strata behaviour study during H&H and depillaring of Panel CM-10 revealed that the designed roof bolt support system and underground structures were competent for safe mining operations. The following findings have been made based on the strata monitoring in panel CM-10.

- Heightening and widening followed by depillaring was successfully completed without any strata control problems in Panel CM-10.
- Non-Split method was found to be suitable for extracting coal from the standing on pillar.

c) The first local roof fall occurred in the panel after an area of exposure of 4,000 m² (about 8 pillars), and after this, the falls occurred regularly supporting the impact split results of categorising the immediate roof under “Easy” caving class. The statistical analysis based on the roof falls data generated from the first depillaring panel shows that the average area of exposure prior to the local roof fall was about 3,000 m² (5 - 6 pillars) and the average area of fall was about 1,000 m² (~2 pillars).

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