Numerical Investigation on Gate-entry Stability of Trial Panel in Indonesia Longwall Coal Mine

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Numerical Investigation on Gate-entry Stability of Trial Panel in Indonesia Longwall Coal Mine.

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Abstract. Indonesia is known for its abundant coal reserve. However, weak geological condition of the rock is one of the most common challenges in Indonesia coal mining. The study area of this research is PT Gerbang Daya Mandiri (GDM) mine which is situated in East Kalimantan. Stratigraphy of this area comprises of claystone as dominant rock and the present of multiple coal seams with the thickness ranging from 0.15m to 9.8m. In this mine, longwall mining is adopted for coal seam extraction. Recently, GDM had begun their development of trial panel for depth around 100m to 150m to understand the behavior of the rock for the real longwall operation. Physically, for this trial study depth, claystone is weaker than coal. Thus, by leaving part of coal seam on top and bottom of the excavated entry-gate would help to retain its stability. This paper will use numerical simulation by FLAC3D to investigate the optimum remain coal thickness (RCT) for stability of the entry-gate of trial panel and to identify appropriate roof support. Model simulation is verified using displacement data from extensometer. The outcome results show that the optimum RCT is 1m on roof and 1.5m on the floor. SS540 with 0.5m spacing is appropriated for adopting for this trial panel. The recommended additional support during longwall operation are 5m, 9m, and 25m for 100m, 125m, and 150m coal seam depth respectively.

Keywords: Gate-entry Stability, Longwall Mining, Weak Rock, Remain Coal Thickness, FLAC3D

1 Introduction

Indonesia, host an abundant portion of thick coal deposit, which is usually found in weak geological condition [1]. This weak geological condition has led to the limitation of excavation into a certain height [2]. As a result, some of coal thickness remains on top and bottom of the excavation. This can be beneficial for coal bed that is surrounded by weaker dominant rock as the harder remained coal cans help improve the stability of any opening structure during the mining development and excavation.

Stability of gate-entry is widely considered to be one of the most important aspects in longwall mine design, especially during panel extraction. Gate-entry does not only serve as a way of material transportation but also an important component of ventilation system to get rid of dust and harmful gazes and to provide fresh air to longwall face working area [3]. Lot of research works have been focused on developing mining technique for thick coal seam mine [2, 4, 5]. Some also including weak geological condition [1, 6]. However, few researchers have addressed the effect of remain coal thickness (RCT) on stability of gate-entry for longwall mining in thick coal seam.

This paper is a preliminary attempt to investigate the effect of RCT on gate-entry and incorporated it into longwall mine design in order to obtain a better optimization. To fully understand this effect, a study work is implemented on trial panel study developed in one coal mine in Indonesia using numerical analysis. This research work consists of modelling various case of RCT to investigate the optimum length of RCT on top and bottom of gate-entry, and optimizing gate-entry roof support under influence of RCT. This paper will also seek to address the effect of longwall operation on gate-entry for this trial panel.

2 Characteristic of Study Area

PT Gerbang Daya Mandiri (GDM) is located in East Kalimantan Island, 15km to the north from Samarinda city in the area called Kutai Kertanegara as shown in Fig 1. General geological structure of that area is monocline, which contains many coal seams with the dip and thickness from 3˚ to 13˚ and from 0.15m to 9.8m respectively. The dominant rock in the area is claystone. This mine will adopt longwall mining method for coal extraction. GDM is developing mine in rock that falls into category of very weak or low strength rock [7]. The dominant rock is very weak, especially when it comes to the rock near to the surface. Recently, this mine began to develop a trial panel in the depth around 100m to 150m in order to have a better understanding of rock behavior in that area. Due to the variation of coal thickness, thick coal can be found along this trial panel. As a result, the knowledge of RCT effect is crucial for developing and optimizing this trial panel.

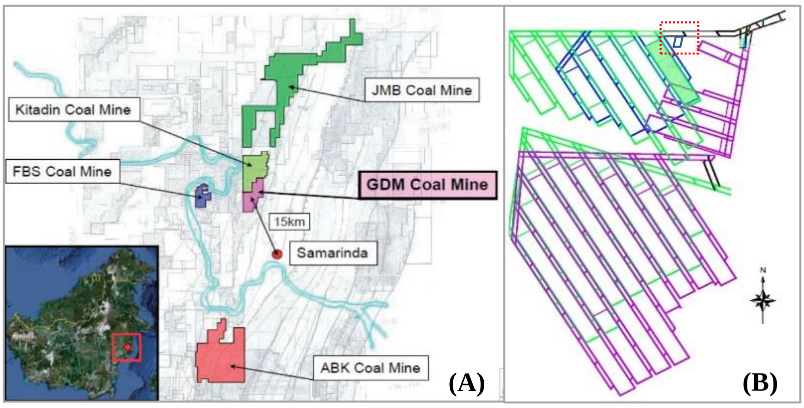

Fig. 1. Study Area (A: Location Map of GDM, B: Mine Layout)[7]

3 Numerical Analysis

In order to investigate the behavior of the rock for this research, all numerical analysis was carried out using FLAC3D. The modeling is constructed based on the actual condition in the mine site and specific case study. Model validation is performed at the beginning of the numerical analysis to ensure the accuracy of the model by comparing the result form simulation to the actual result of field measurement. This trial panel is 70m by 200m with 3m of mining height. Steel arch sets will be used to support gate-entry roof.

3.1 Model Description

Simulation models were constructed based on specific case studies. General model dimension is illustrated in Fig. 2, which can be described as 90m width and 300m length with the under-burden of 50m. Over-burden and coal thickness are varied based on each individual case study. The panel dimension is 70m by 200m with 3m height. Symmetrical model running is adopted for all simulations in order to reduce running time, which means only half of the panel is modelled in FLAC3D. In the model, RCT on the roof and floor of the excavation area range from 0m to 2.5m. There are two types of steel namely ss400 and ss540 for roof support with two different spacing: 1m and 0.5m.

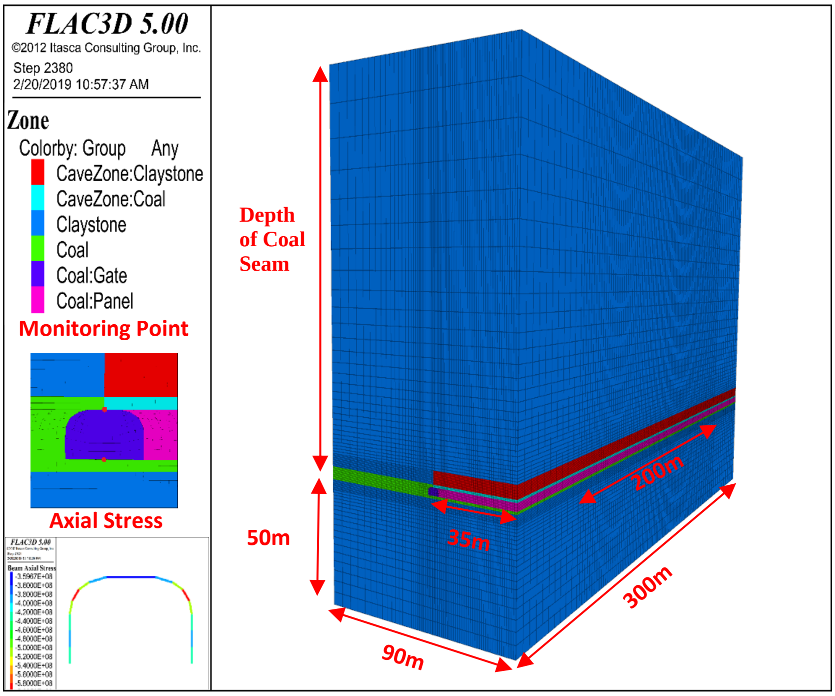

Fig. 2. General model dimensions

Because there will be three main objectives to be covered in this paper, for each individual topic, simulation model configuration will adjust accordingly. For the first topic, which will cover the optimum RCT in order to maximize the stability of gate-entry, seam depth is fixed to 150m depth, stress ratio are 1, 1.5 and 2 and gate-entry is unsupported. Monitoring points will be on the roof and floor of the gate in the middle of the model. For second topic, which will cover the optimization of gate-entry roof support, depth of the overburden are 100m 125m and 150m, two types of roof support with 1m and 0.5m spacing, stress ratio is fixed to 1. For this case, the result will be obtained by monitoring the maximum axial stress act on steel arch support along the gate. The last topic, which covers the impact of panel extraction operation to gate-entry, also utilize the same model configuration as the second topic. The coal panel is extracted 100m. The height of the caved roof for goaf modelling is calculated to be 5.93 [7]. However, only ss540 is adopted as roof support with 1m and 0.5m spacing for this case. The worst-case scenario, where there is no RCT above or below the gate excavation, is selected. Mechanical properties of the rock and support are listed down in Table 1 and Table 2 respectively.

Table 1. Rock mechanical properties

Rock	UCS (MPa)	Density (Kg/m^3)	E (MPa)	υ	C (MPa)	φ (°)	σ_T (Mpa)
Claystone	4.84	2108.10	805.86	0.28	0.6	37.45	0.52
Coal	8.16	1380	1300	0.32	2.63	45.6	0.58
Goaf	-	1700	15	0.25	0.001	25	-

Table 2. Roof support mechanical properties

Density Kg/m^3	E (GPa)	υ	Cross Area (Cm^2)	Yield Strength (MPa)	Yield Strength (MPa)	I_y (m4) $.10^{-8}$	I_z (m4) $.10^{-8}$	J (m4) $.10^{-8}$
7800	200	0.3	36.51	400	540	732	154	22

3.2 Model Validation

Model validation is very essential for numerical study. The result form monitoring displacement using extensometer on top roof of gate allows us to validate the simulated results. Due to the limitation of field measurement, extensometer 32, which is located in the depth around 50m, is selected for model validation. Simulation model was constructed according to the rock condition that extensometer 32 is situated with the depth of the modelled gate is 50m with 1m spacing of horseshoe-shaped steel arch as support system.

The result of gate roof displacement is monitoring until 5m above the roof. Fig. 3 shows the comparison between model simulations result and extensometer 32 result.

The **conspicuous observation** from these results comparison shows great agreement. This evidence implies that **this m**odelling configuration cans be used effectively to predict the behavior of the rock during mining excavation.

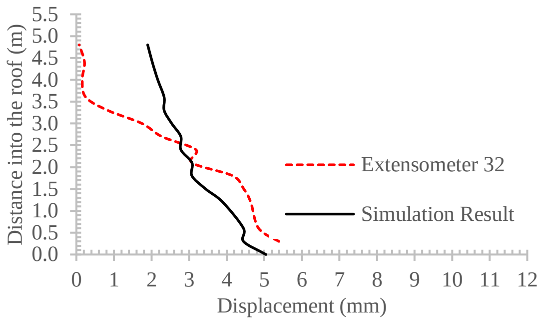

Fig. 3. Comparison between extensometer result and simulation result

4 Results and Discussion

4.1 Gate-Entry Stability Control by Leaving Remain Coal Thickness

The first set of model simulation is to highlight the effect of RCT on maximizing the stability of gate-entry. This correlation can be revealed in Fig. 4 which is the result of monitoring roof displacement in the case of stress ratio equal to 2. This result shows that the improvement of displacement is occurred in a certain range of RCT. Above that value even thicker RTC is remain, there is not much improvement can be seen. A similar trend can also be found in all the results from others case studies. For better illustration, each result from all cases are sectioned based on a range of RCT of 0.5m. In each section, the value of percentage improvement of displacement is calculated by compare with the displacement value without any RCT. The outcomes are plotted in Fig.5 for roof and floor. As expected, the value of percentage improvement is converged into a smaller value for the thicker RCT. For all stress ratio, Fig.5A shows that there is a noticeable improvement from 0 to 0.5m of RCT. Thicker than 0,5m thickness the improvement is rather minor.

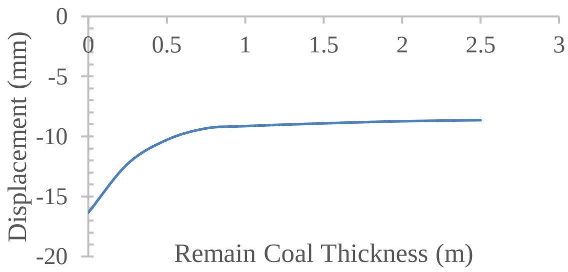

Fig. 4. Relationship between roof displacement and RCT (K=2)

This statement is also true for the floor in Fig.5B where the optimum RCT is 1.5m. A pronounced statement can be drawn out from the observation of this result is that the improvement of displacement is significant in a certain RCT. From this thickness, even a thicker RCT is left above or below gate excavation; only minor improvements can be seen.

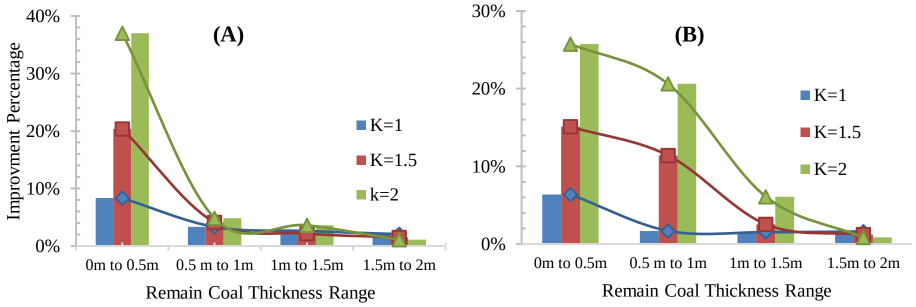

Fig. 5. Relationship between displacement and RCT (A: Gate-roof, B: Gate-floor)

4.2 Optimizing Roof Support During Gate-Entry Excavation

This part of the paper is dealing with the evaluation of steel set capacity, which is suitable for adopting as support system in gate-entry base on the depth of coal seam. This assessment will also consider the effect of remain coal thickness. The result is showed in Fig.6 for 1m and 0.5m spacing. The result of maximums axial stress acting on steel for each case is compared with yield strength of two types of steel support: ss400 and ss540. The basic idea is that, if the maximums axial stress is higher than yield strength of support, steel arch will deform and roof of gate-entry will become unstable.

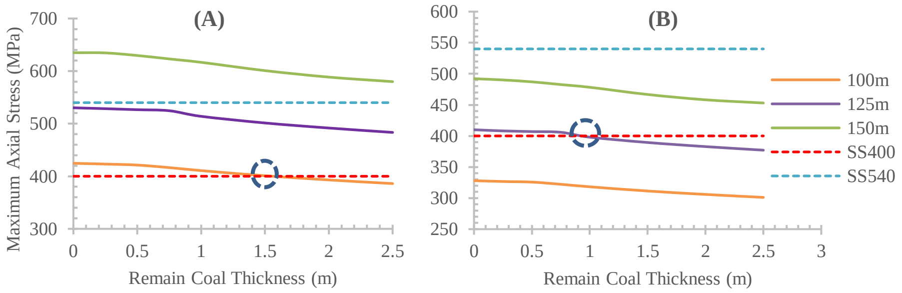

Fig. 6. Maximum axial stress on steel arch (A: 1m spacing, B: 0.5m spacing)

These results highlighted that 1m spacing ss400 can be used to support 100m depth in with 1.5m of RCT. whereas, ss540 is suitable for depth up to 125m. In case of 0.5m spacing, it provides a stronger capacity for both steel types. This narrower spacing increase the capacity of ss400 to be suitable for supporting up to 125m depth with 1m of RCT. The increasing capacity of ss540 on the other hand is able to withstand the load up to 150m depth effectively.

4.3 Impact of Panel Extraction Operation to Gate-Entry

The impact of panel extraction is crucial in longwall mining study especially when it comes to maintaining the stability of gate-entry. Generally, stress will increase significantly in some distance from the longwall face. These distances are important for optimizing additional mobile support during panel extraction operation. To validate this problem, this set of model simulation is generated in the worst-case scenario where the present of RCT is not available. The panel is extracted 100m length. Results of maximum axial stress from longwall face, along gate-entry, are monitoring and plotted in Fig.7 and Fig.8 for 1m and 0.5m spacing respectively. The observation of both figures emphasized that due to panel excavation, stress considerably increases near longwall face. If 1m spacing of ss540 is adopted, for 100m depth of coal seam, the distance of overstress is 10m. While for 150m depth, the distance of overstress 90m, which in this case is not recommended. For 0.5m spacing support, the length of additional support is needed based on the depth of the operation. The required length of additional support of 100m, 125m and 150m coal seam depth are 5m, 9m, and 25m respectively.

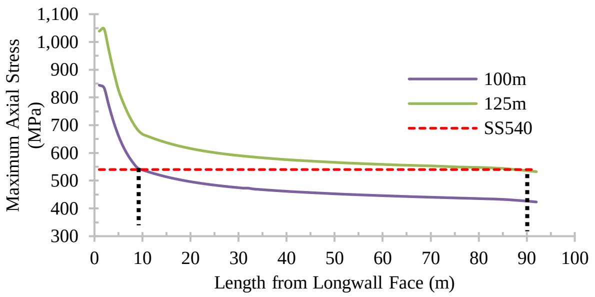

Fig. 7 Maximum Axial stress Along Gate-entry for 1m spacing

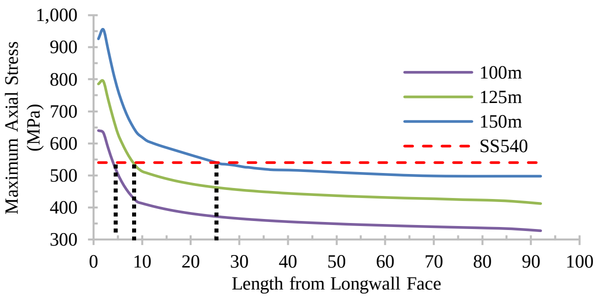

Fig. 8 Maximum Axial stress Along Gate-entry for 0.5m spacing

5 Conclusion

This research work had led us to the conclusion that:

Stability of gate-entry can be maximized by leaving RCT on top and bottom of the excavation area. The optimum thickness of RCT should be around 0.5m on the roof and 1.5m on the floor.

To maintain the stability of the gate, 0.5m spacing of SS400 can be used up to the depth of 125m. One meter spacing can only support up to 100m depth with the condition that there must be at least 1.5m of RCT above and below the excavation area. SS540 can increase 1m spacing capacity to support up to 125m depth with the condition of 1m RCT. The support of 0.5m of SS540 can be effectively used to support 150m depth.

Due to the effect of longwall operation, it is recommended to use SS540 in 1m spacing with 10m of additional support for 100m depth. The ultimate support design for 100m, 125m, 150m coal seam depth should consider using 0.5m spacing of SS540 with the additional support of 5m, 9m, and 25m respectively during longwall face extraction operation.

References

1. Sasaoka, T., Hamanaka, A., Shimada, H., Matsui, K., Lin, N.Z., and Sulistianto, B.: Punch multi-slice longwall mining system for thick coal seam under weak geological conditions. Journal of Geological Resource and Engineering. 1,28-36 (2015)
2. Ozfirat, M., Simsir, F., and Gonen, A.: A brief comparison of Longwall Methods used at mining of thick coal seams. In:The 19th International Mining Congress and Fair of Turkey, pp. 09-12. IMCET, Izmir, Turkey (2005)
3. Brune, J. and Sapko, M.: A modeling study on longwall tailgate ventilation. In:14th United States/North American Mine Ventilation Symposium. . Dept. of Mining Engineering, Salt Lake City, University of Utah (2012)
4. Hebblewhite, B.: Status and prospects of underground thick coal seam mining methods. In:The 19th International Mining Congress and Fair of Turkey. IMCET, Izmir, Turkey (2005)
5. Matsui, K., Sasaoka, T., Shimada, H., Furukawa, H., Takamoto, H., and Ichinose, M.: Some considerations in underground mining systems for extra thick coal seams. Coal International. 259(2),38-43 (2011)
6. Zarlin, N., Sasaoka, T., Shimada, H., and Matsui, K.: Numerical study on an applicable underground mining method for soft extra-thick coal seams in Thailand. Engineering. 4(11),739 (2012)
7. Pongpanya, P., Sasaoka, T., Shimada, H., Hamanaka, A., and Wahyudi, S.: Numerical Study on Effect of Longwall Mining on Stability of Main Roadway under Weak Ground Conditions in Indonesia. Journal of Geological Resource and Engineering. 3,93-104 (2017)