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Reasonable exploitation solution for longwall in Seam L7 at East Side to ensure the stability of G9 surface works of Mong Duong Coal Mine

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ABSTRACT

When exploiting the working face located under the surface works need to be protected, it may lead to potential risks that cause unsafety and effect for the stability of those works. The degree of influence on the surface works depends on many factors, including the exploitation technology factor. It is always necessary to study and evaluate the impact of mining on the surface works to propose appropriate technical solutions and mining technology to ensure the safety during mining process. Through the field study at Mong Duong Coal Mine, finding a reasonable mining solution for the longwall in Seam L7 at East Side is important to ensure the stability of the G9 surface works. These works include a coal storage, and some construction works of level 4 houses, equipment and machinery for coal transportation and their total weight is estimated about 200,000 tons. Research methods used include numerical modeling method combined with comparative data analysis method. The authors have determined the heights of the collapse zone and fracture zone corresponding to the face advance of the longwall and the degree of influence on the surface works. These are considered as a basis for choosing a reasonable mining solution for the condition of the longwall to ensure the stability of the surface works. The above methods are applied to the condition of the longwall in Seam L7 at East Side of Mong Duong Coal Mine and find a reasonable exploitation for the longwall in Seam L7 with a cutting height of 2.2 m and recovering 100% of top coal (corresponding to 0.8 m). When the longwall is exploited in the strike direction to 140 m, the G9 surface works remain unaffected. When the longwall is exploited in the strike direction of 160 m onward, those works will be affected. The paper's results are used as a basis for Mong Duong Coal Mine to choose a mining solution and to timely adjust the mining solution of the longwall in Seam L7, ensuring efficiency and stability for G9 surface works.

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1. Introduction

The G9 surface works are located in the field site of Mong Duong Coal Mine which includes important works that need to be protected. The Seam L7 at East Side is located under the G9 surface works area. According to the initial assessment, the exploitation of the longwall in Seam L7 may affect the G9 surface works. The Seam L7 has an average thickness of 3 m, an average slope angle of 30^0. The choice of the exploitation solution for Seam L7 to ensure safety, resources saving and the stability of G9 surface works of Mong Duong Coal Mine is therefore very necessary.

Exploiting the longwall or coal seams located under surface works to be protected is a complicated problem because it involves many influencing factors (Tran, 2007; Li, 2011). The mining process will cause collapse and fracturing zones of the roof, and these zones will negatively affect the works on the surface (Do and Vu, 2008; Qian and Shi, 2003a; Qian and Shi, 2003b). International scientists have used many methods as a basis for the selection of mining solutions for coal seams located under works to be protected such as: numerical modeling method, equivalent material modeling method, comparative method and field observation method. In the world and in Vietnam, there has been many research works to ensure the safety when exploiting the coal seams under works to be protected. Typical studies are based on numerical modeling methods to calculate mine pressure (Singh & Singh, 2009; Le et al., 2018), protective coal pillar (Pham et al., 2020), and the recovery rate of top coal (Bui et al., 2020). In the Mong Duong area, there have been a number of studies to calculate the effects of underground mining on surface works (Pham and Mac, 2021), and to calculate the safe mining depth for the coal seams located under rivers and streams (Pham et al., 2021; Tran and Le, 2021). Some other studies are mainly based on observational data to determine surface deformation values (Nguyen et al., 2019; Kowalski et al., 2021).

It can be seen that these studies have not proposed mining solutions for the longwall, and the influence area of the mining process of each mining solution has not been determined. Therefore, in this study, the authors have proposed mining solutions for the longwall, monitoring and determining the height of the collapsed and fractured areas when the longwall is exploited in the corresponding strike direction. This is also the basis for evaluating, analyzing and choosing a reasonable mining solution for the longwall in the condition of Seam L7 of Mong Duong Coal Mine.

2. Data and research methods

2.1. Research method

In this study, the authors use the numerical modeling method combined with comparison and data analysis methods to choose a reasonable mining solution for the longwall in Seam L7 condition. Using UDEC software to build a numerical model that simulates the collapse of roof corresponding to face advance when exploiting the longwall. The analysis results from the numerical model will determine the total height of the collapsed and fractured zones of the roof, as well as the depth of surface subsidence.

The specific steps to implement the method are as follows:

Collect input data for numerical modeling simulation;

Build a numerical model corresponding to different mining solutions of the longwall, specifically as follows:

- Solution 1: the mining height of the longwall is 2.2 m, the recovery rate of top coal is 0%;
- Solution 2: the mining height of the longwall is 2.2 m, the recovery rate of top coal 100%.

Run the numerical model, calculate the results;

Analyze results from the model to determine the mining influence area;

Compare, analyze data and choose a reasonable mining solution for the longwall.

2.2. Research site

The longwall in Seam L7 at East Side is located in the coal seams of Mong Duong Coal Mine, Mong Duong ward, Cam Pha city, Quang Ninh province. The longwall is bounded by coordinates X = 2328.751÷2329.237; Y = 455.925÷456.324. The mining area is completely under the G9 surface works of Mong Duong Coal

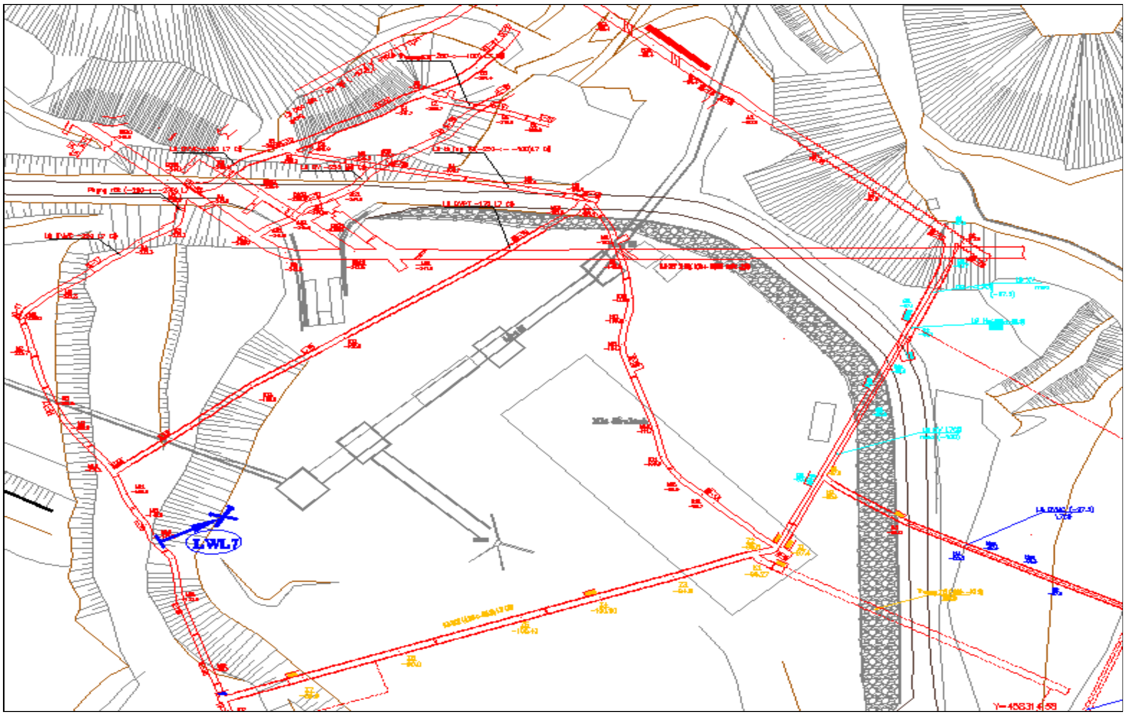


Figure 1. Location of the longwall in Seam L7 (LWL7) at east side of Mong Duong coal mine (Mong Duong Coal Company, 2019).

Mine with an estimated load of about 200,000 tons. Figure 1 shows the location of the longwall in Seam L7 at East Side of Mong Duong coal mine (Mong Duong Coal Company, 2020).

2.3. Geological conditions and mining technology of the longwall in Seam L7 at East Side

Geological conditions (Mong Duong Coal Company, 2019).

Average thickness of seam: m = 3 m;

Average slope angle: α = 30^0;

The length of the longwall in the dip direction: 267 m;

The length of the longwall in the strike direction: 200 m;

Immediate roof: siltstone, average thickness of 7.3 m, easy to collapse, average hardness of 4.95;

Main roof: sandstone and siltstone, average thickness of 30.8 m, average hardness of 12.67;

Immediate floor: siltstone, average thickness of 7.43 m, average hardness of 4.57.

Figure 2 shows the stratigraphic column and coal seams of the cross-section E-E along line XIX of the Mong Duong Coal Mine (Mong Duong Coal Company, 2019). Table 1 shows the analytical results of the roof and floor rock of Seam L7 (Mong Duong Coal Company, 2019).

Mining technology: In order to exploit the longwall in Seam L7 at East Side, Mong Duong Coal Mine uses mining technology by drilling and blasting supported by ZH frame, transporting coal by scraper conveyors and controlling mine pressure by caving method.

2.4. Building a numerical model

Based on the characteristics and physical and mechanical parameters of the soil and rock in the geological stratigraphic column of the E-E section (Figure 2), as well as the exploitation conditions of the longwall in Seam L7 at East Side, UDEC software is used to build a model with model height of 390 m, model width of 320 m, model length in dip direction of 267 m, average slope angle of 30^0, average seam thickness of 3 m, as shown in Figure 3 (Itasca Consulting Group, 1999). The mining process at the longwall is simulated according to the mining progress of the drilling and blasting technology, supported by ZH frame, with the movement speed of the model extraction is about 2 m/cycle.

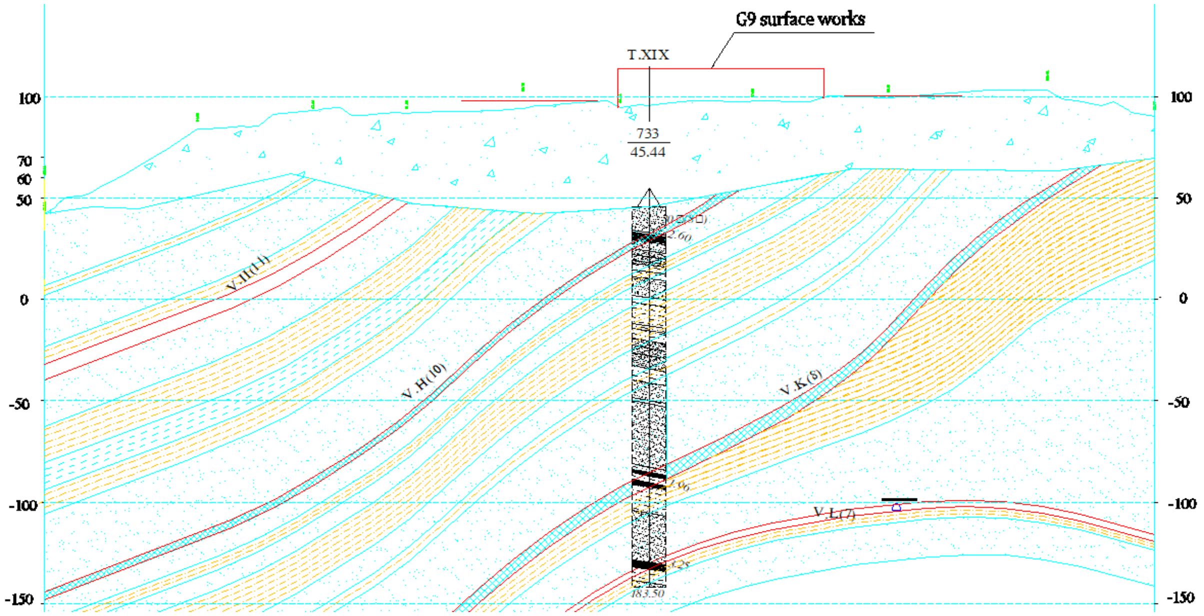


Figure 2. The stratigraphic column and coal seams of the cross-section E-E along line XIX (Mong Duong Coal Company, 2019).

Table 1. Analytical results of the roof and floor rock of Seam L7 (Mong Duong Coal Company, 2019).

Type of rock	Rock unit	Value	Compression resistance strength, σn (kG/cm²)	Tensile strength, σk (kG/cm²)	Internal friction angle (degrees)	Cohesive force, C	Specific weight, γ (g/cm³)
Roof of Seam L7	Sandstone	Max			34.30'	265	
		Min			32.05'	219	
		Medium	898.1	76.33	33.13'	240.67	2.74
	Siltstone	Max	549	49.75	34.00'	179	2.78
		Min	435.6	58.29	32.12'	93	3
		Medium	495.37	47.22	33.13'	134	2.84
Floor of Seam L7	Gravel stone	Max	1877	187.1	34.05'	575	2.71
		Min	968.57	90.26	33.50'	294	2.63
		Medium	1422.79	138.68	33.55'	434.5	2.67
	Sandstone	Max			34.30'	265	
		Min			32.05'	219	
		Medium	898.1	76.33	33.13'	240.67	2.74
	Siltstone	Max	549	49.75	34.00'	179	2.78
		Min	435.6	58.29	32.12'	93	3
		Medium	495.37	47.22	33.13'	134	2.84

3. Results and discussion

3.1. Analysis of model results

When exploiting the longwall in Seam L7 along strike direction, the state of the roof is monitored with two solutions to exploit the height of the longwall at 2.2 m. That is, the recovery rate of top coal is 0% and 100%, as follows:

- Solution 1: the cutting height of the longwall is 2.2 m, the recovery rate of top coal is 0%;
- Solution 2: the cutting height of the longwall is 2.2 m, the recovery rate of top coal is 100%, corresponding to the recovery thickness of 0.8 m.

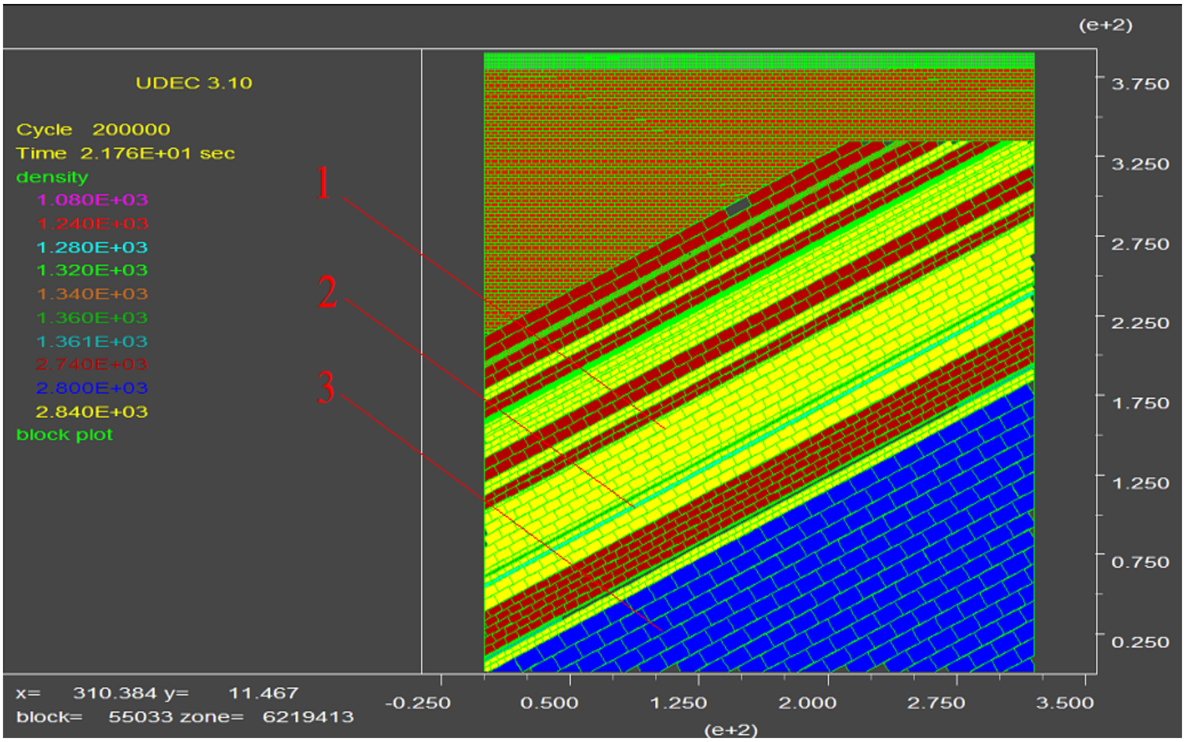


Figure 3. Simulation numerical model by the UDEC 3.10 software of the longwall in Seam L7 at East Side of Mong Duong Coal Mine (1 – roof; 2 – Seam L7; 3 - floor).

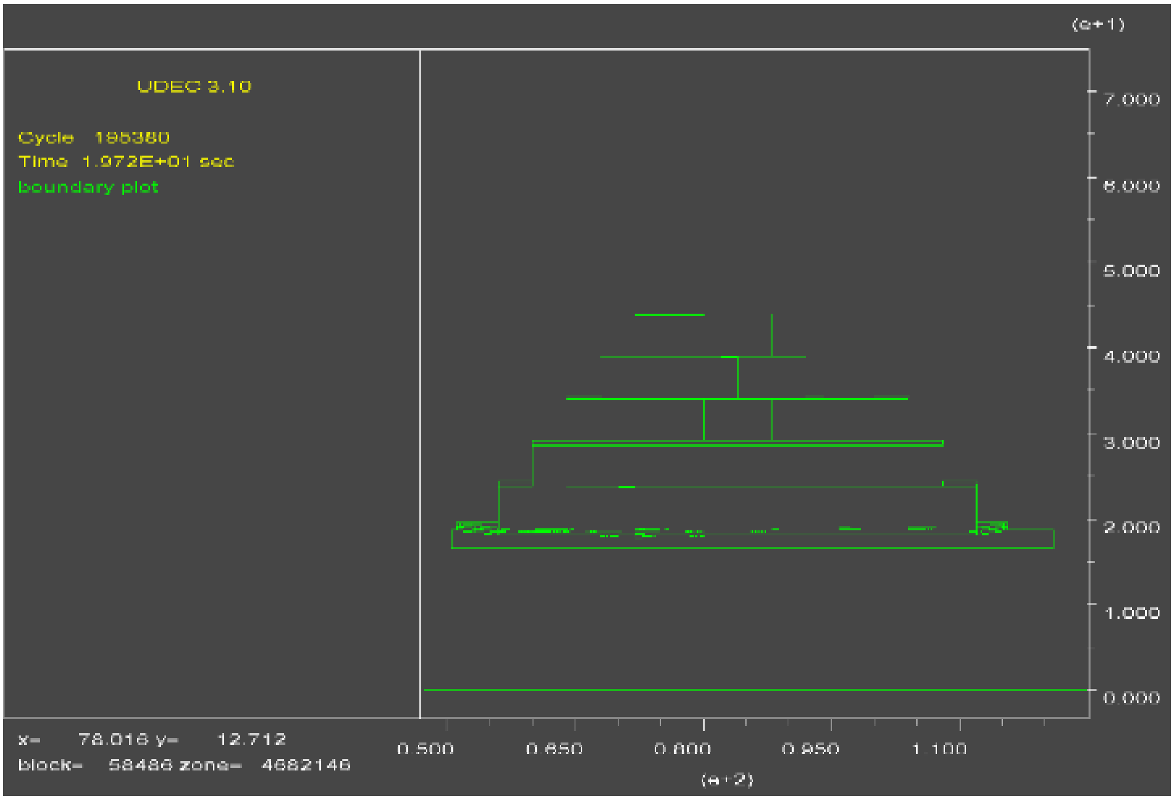
Thus, for each mining solution, when the longwall moves in the strike direction, it will observe the movement of the roof, determine the caving span of the immediate roof, the breaking span of the main roof, the height of the collapsed and fractured zones, and the degree of the crack system development in the roof of longwall. This result proves the extent of the influence of mining on the surrounding rock areas and the G9 surface works. This, thereby, serves as a basis for choosing a reasonable mining solution for the longwall in Seam L7.

Figure 4 (a, b, c and d) shows the results of monitoring the state of the roof of the longwall in the Seam L7 when moving in the strike direction of 70 m.

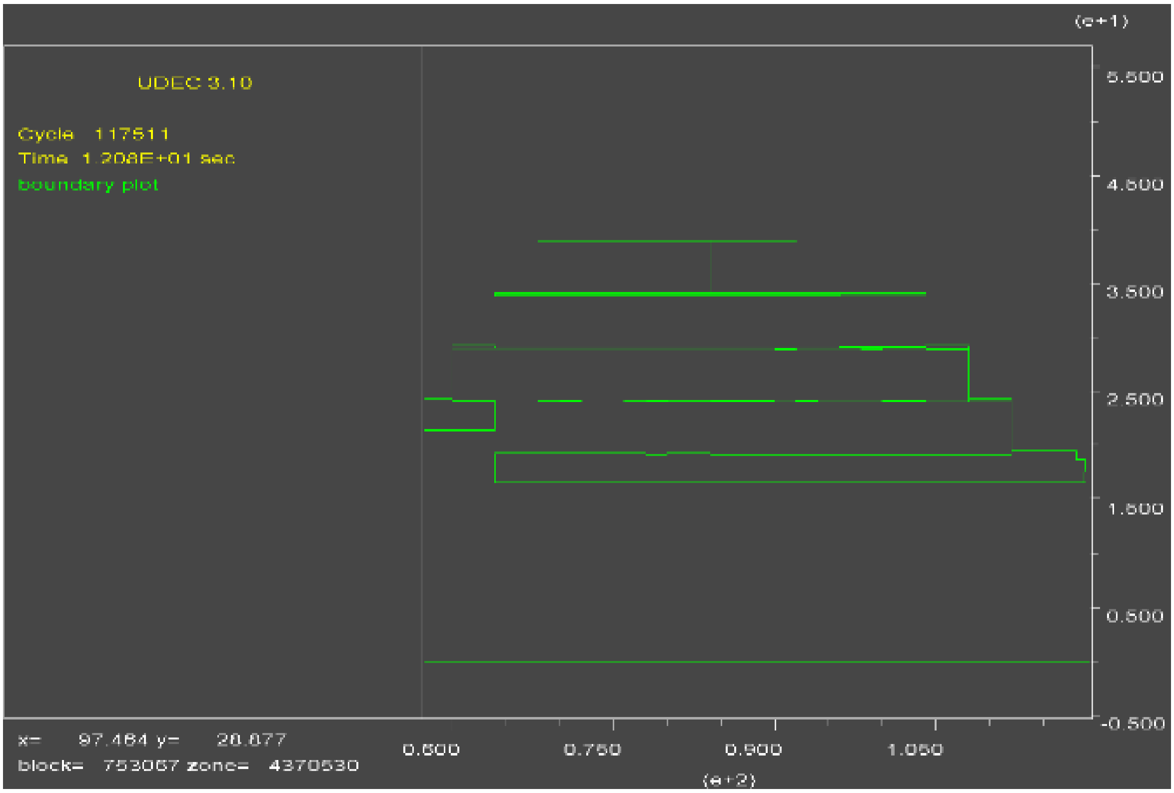
When cutting 70 m in the strike direction, through model observation, it is shown that, in the two mining solutions, the immediate roof collapses very clearly, and the cracks in the roof appeared with more density. In both mining solutions, the immediate roof is destroyed most of its thickness. The pressure in the mining area of the two solutions is similar: the value is 4÷6 MPa, the greatest in the area in front of the longwall face with a value of about 8 MPa. The height of collapse and fracturing of the two mining solutions is not much different, which is about 30÷40 m (Figures 4a and 4b).

When cuttting 100 m in the strike direction, the state of the roof of the longwall in the Seam L7 is shown in Figure 5 (a, b, c and d).

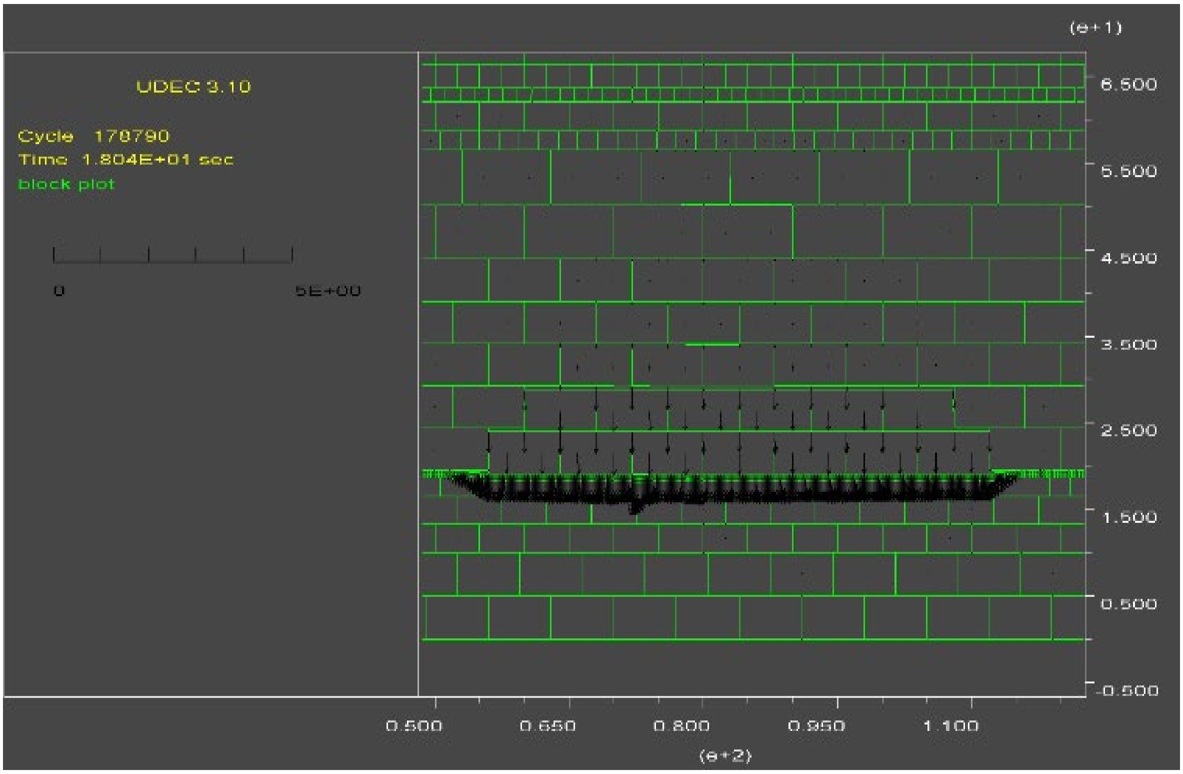
The numerical model observation shows that the roof pressure is similar to when cutting to 70 m. In both mining solutions, the roof behind the longwall gradually stabilized. The pressure of the roof in this area of the mining solutions is slightly changed, the value of the pressure is still 4÷6 MPa, the height of collapse and fracturing of the mining solutions do not change much, which is from 70÷90 m (Figures 5a and 5b). The analysis results from the model showed that the main roof was completely affected by the coal mining process at the longwall. The density of rock movement into the mining area is increasing day by day, as shown by the movement vectors of rock in Figures 5c and 5d. The system of fractures continued to form and develop from the main roof area to the alluvia area near the G9 surface works of Mong Duong coal mine.



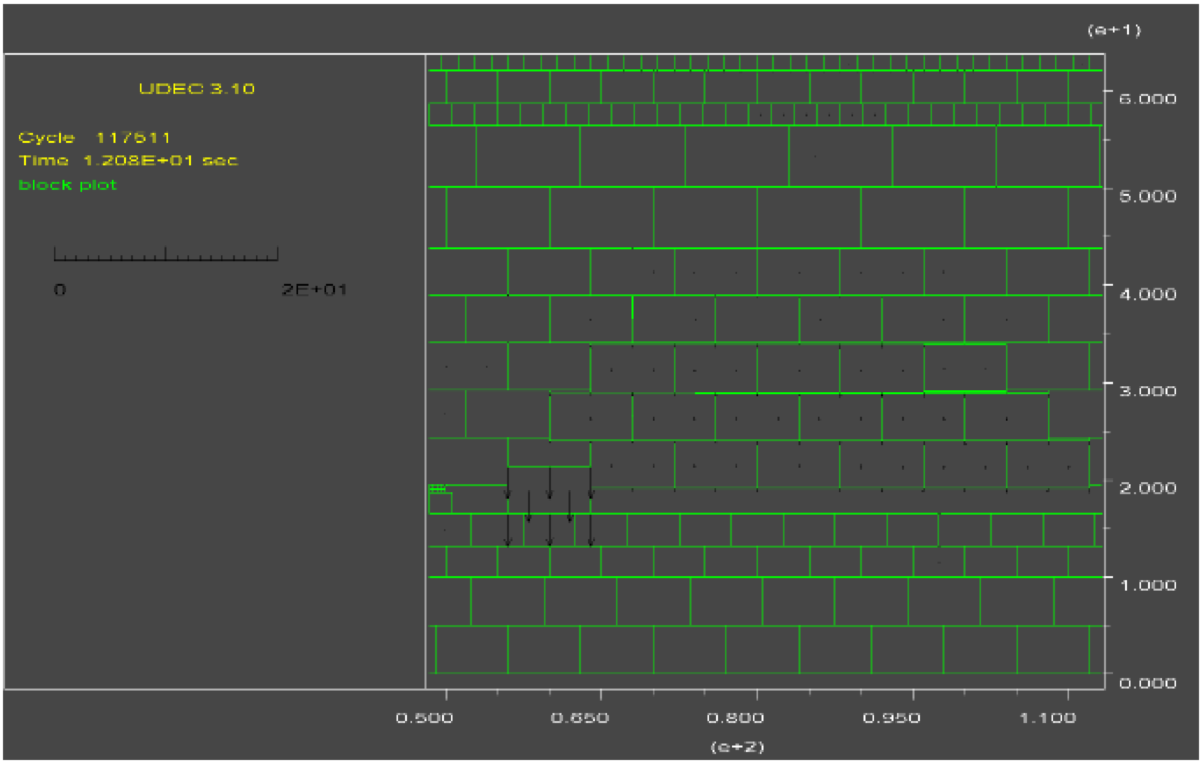
(a) - Height of collapse and fracture zones (solution 1).



(b) - Height of collapse and fracture zones (solution 2).

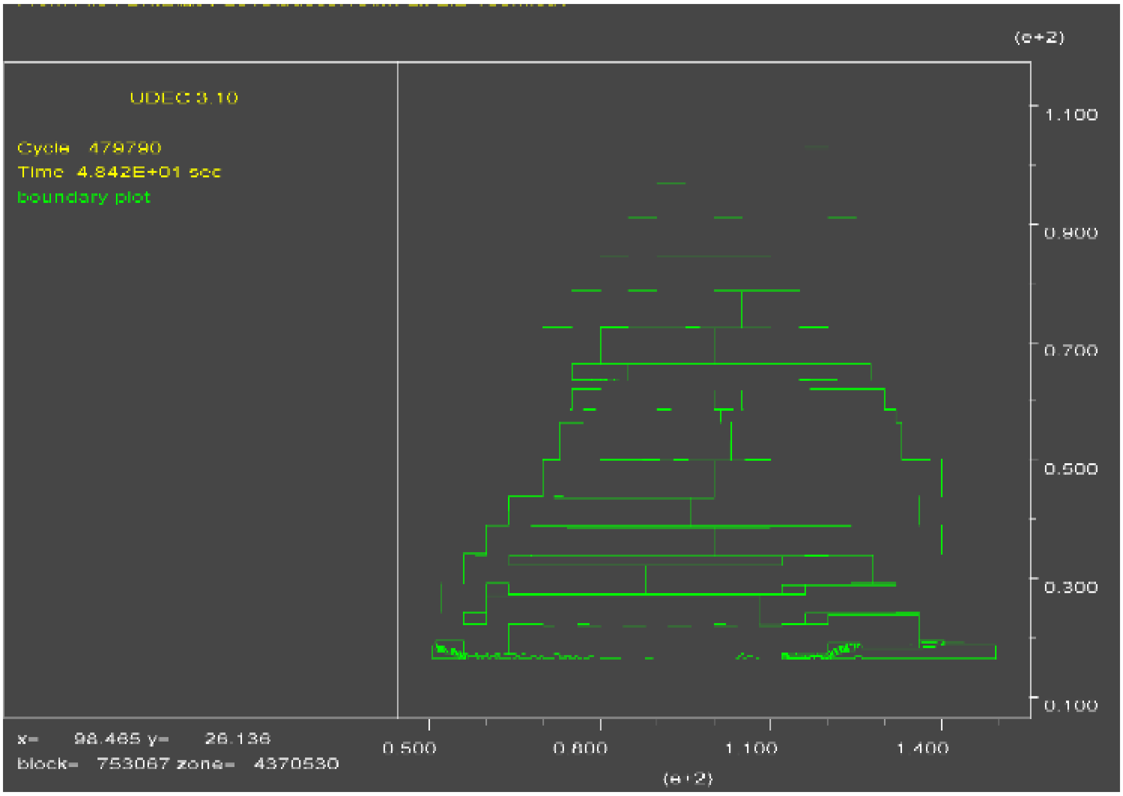


(c) - The process of moving of roof (solution 1).

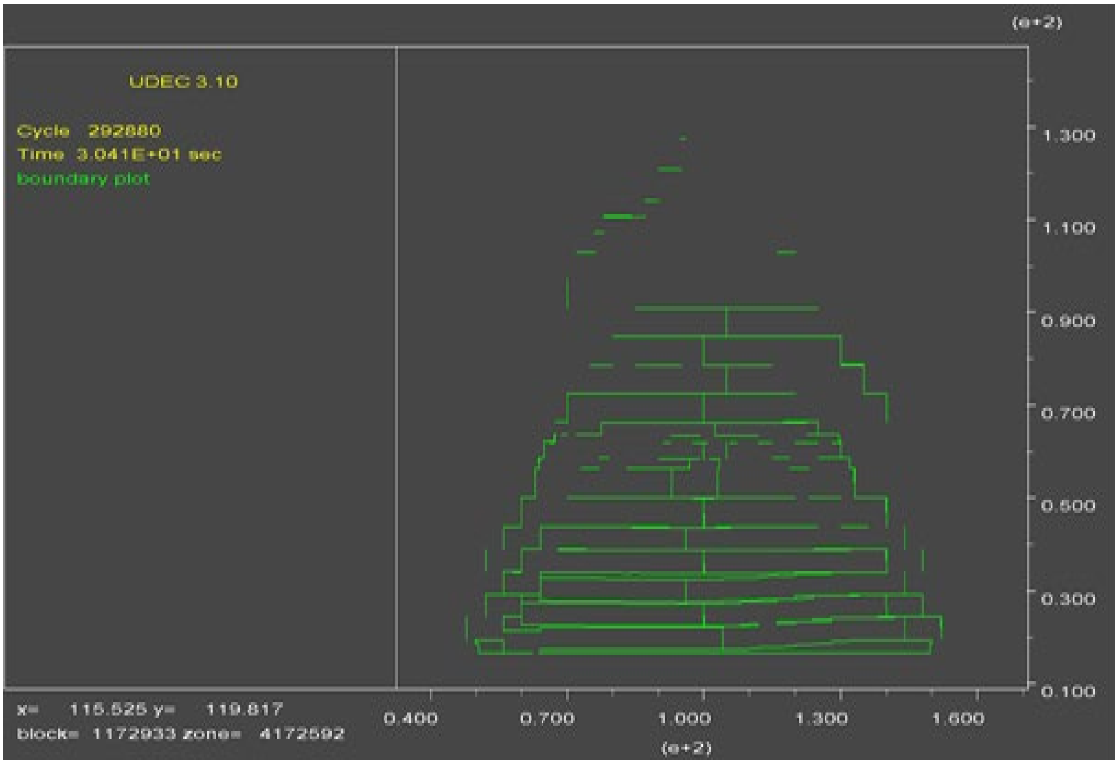


(d) - The process of moving of roof (solution 2).

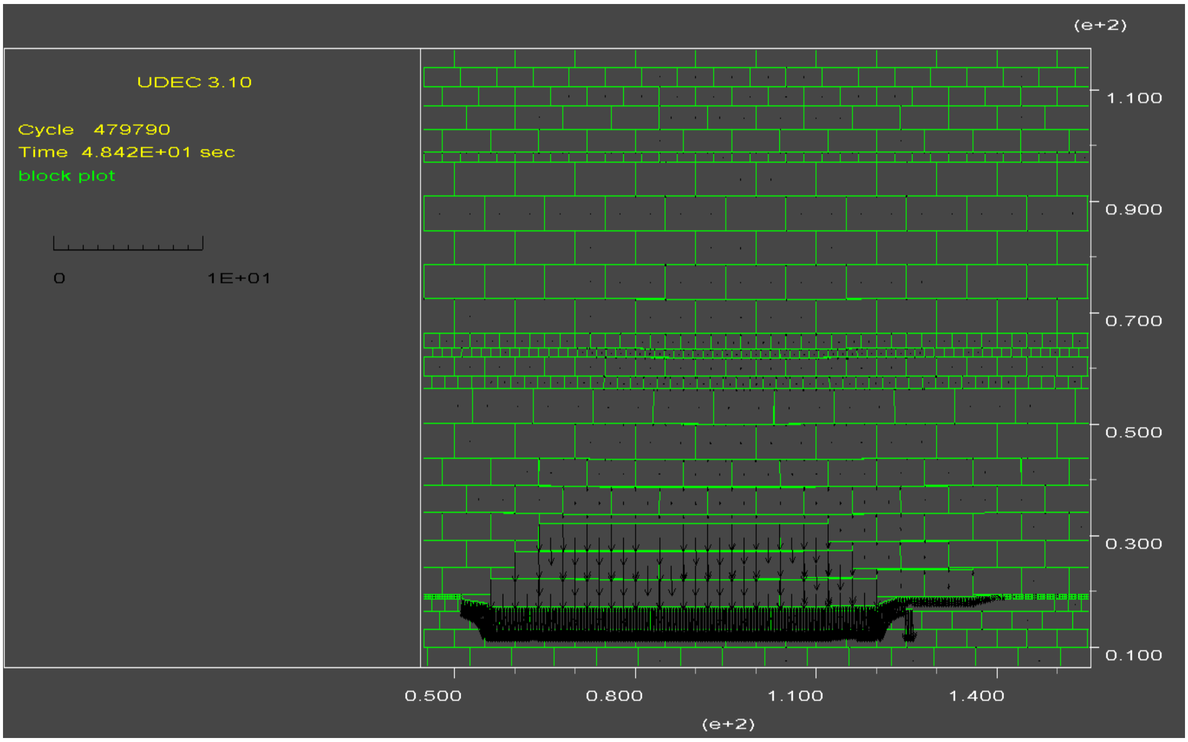
Figure 4. State of the roof of the longwall in the Seam L7 at the East Side of Mong Duong mine when cutting 70 m in the strike direction.



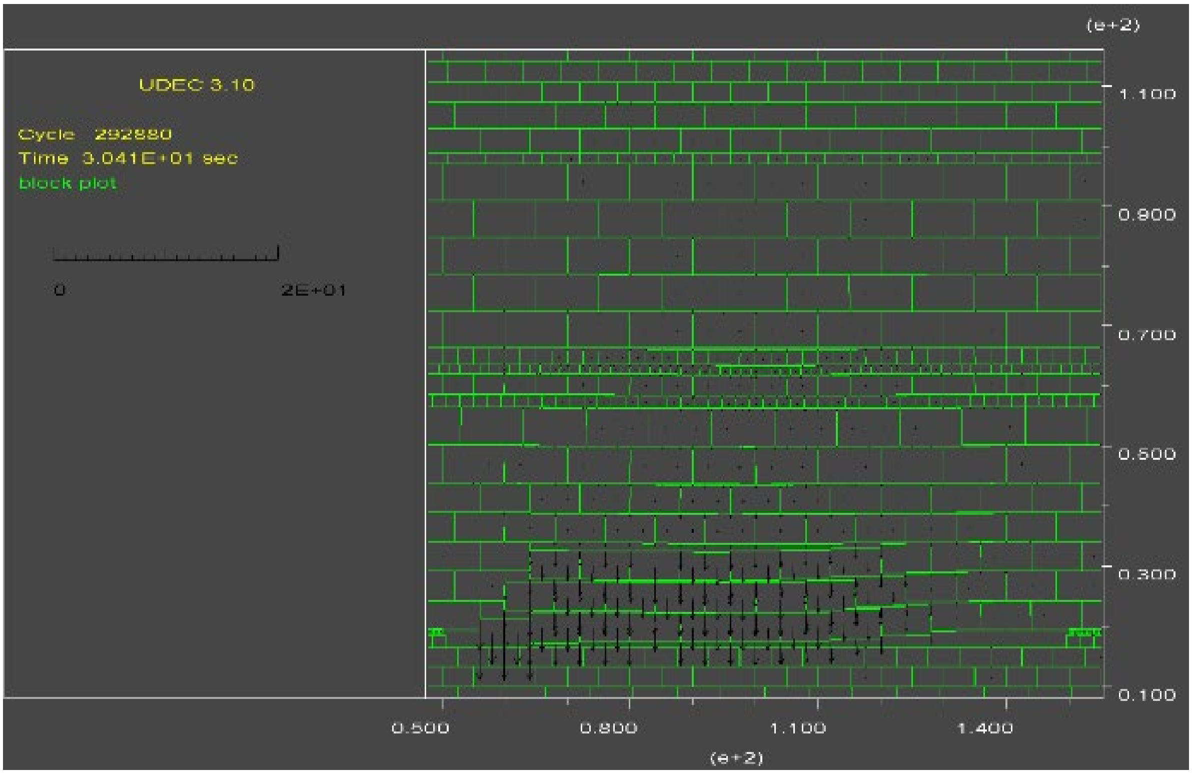
(a) - Height of collapse and fracture zones (solution 1).



(b) - Height of collapse and fracture zones (solution 2).

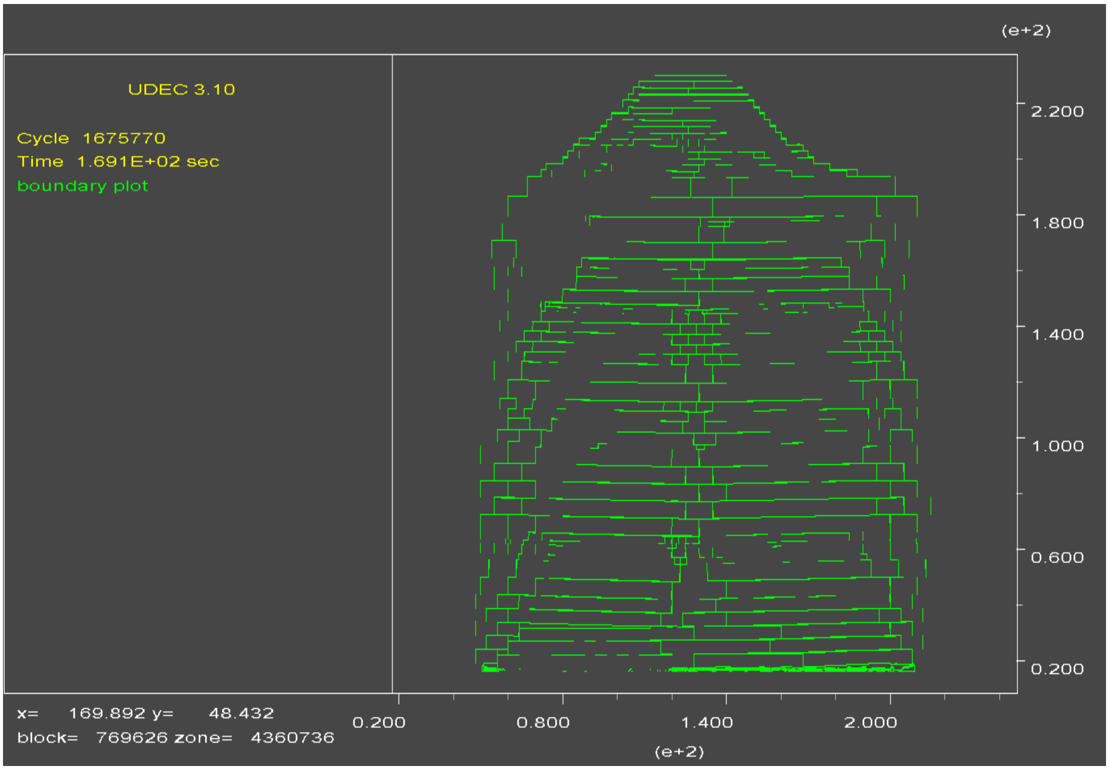


(c) - The process of moving of roof (solution 1).

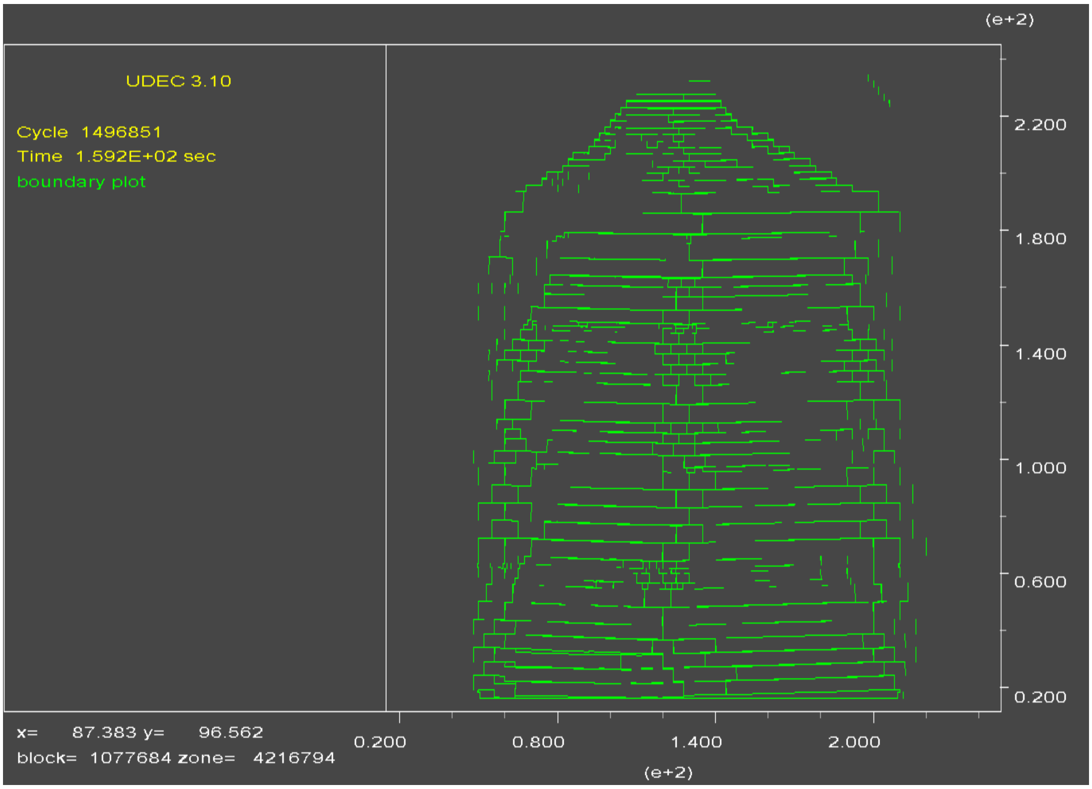


(d) - The process of moving of roof (solution 2).

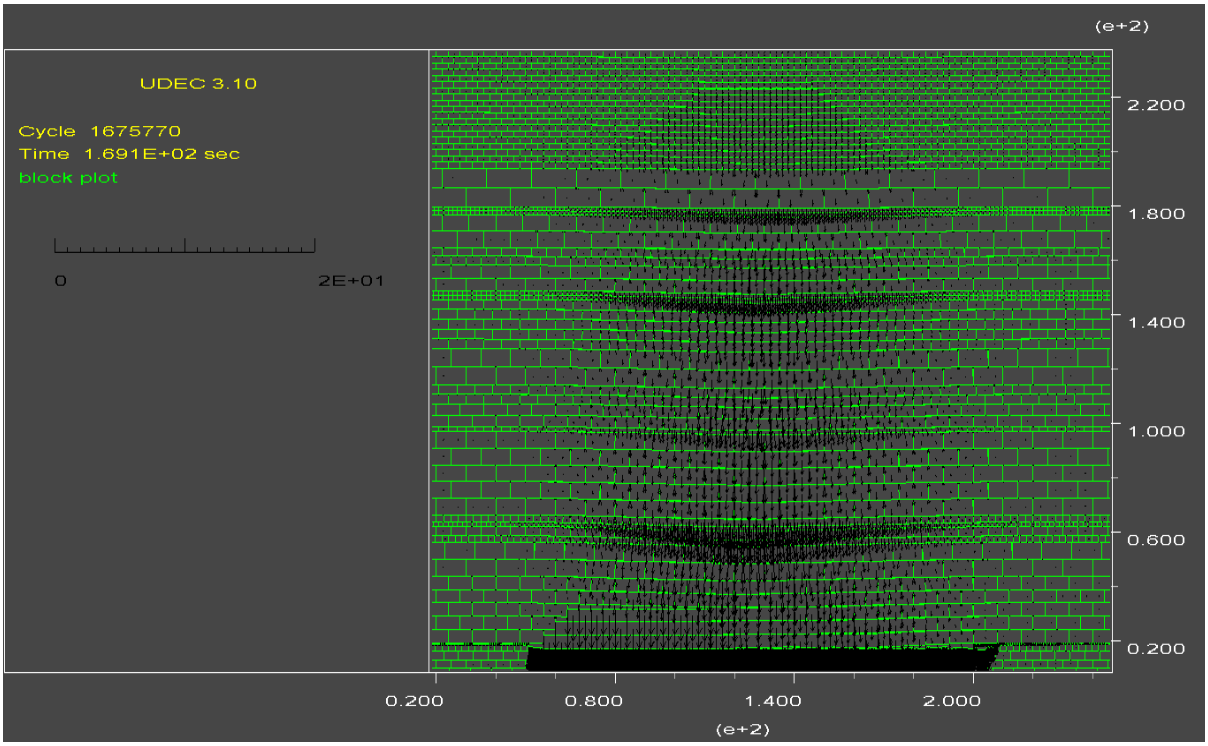
Figure 5. State of the roof of the longwall in the Seam L7 at the East Side of Mong Duong mine when cutting 100 m in the strike direction.



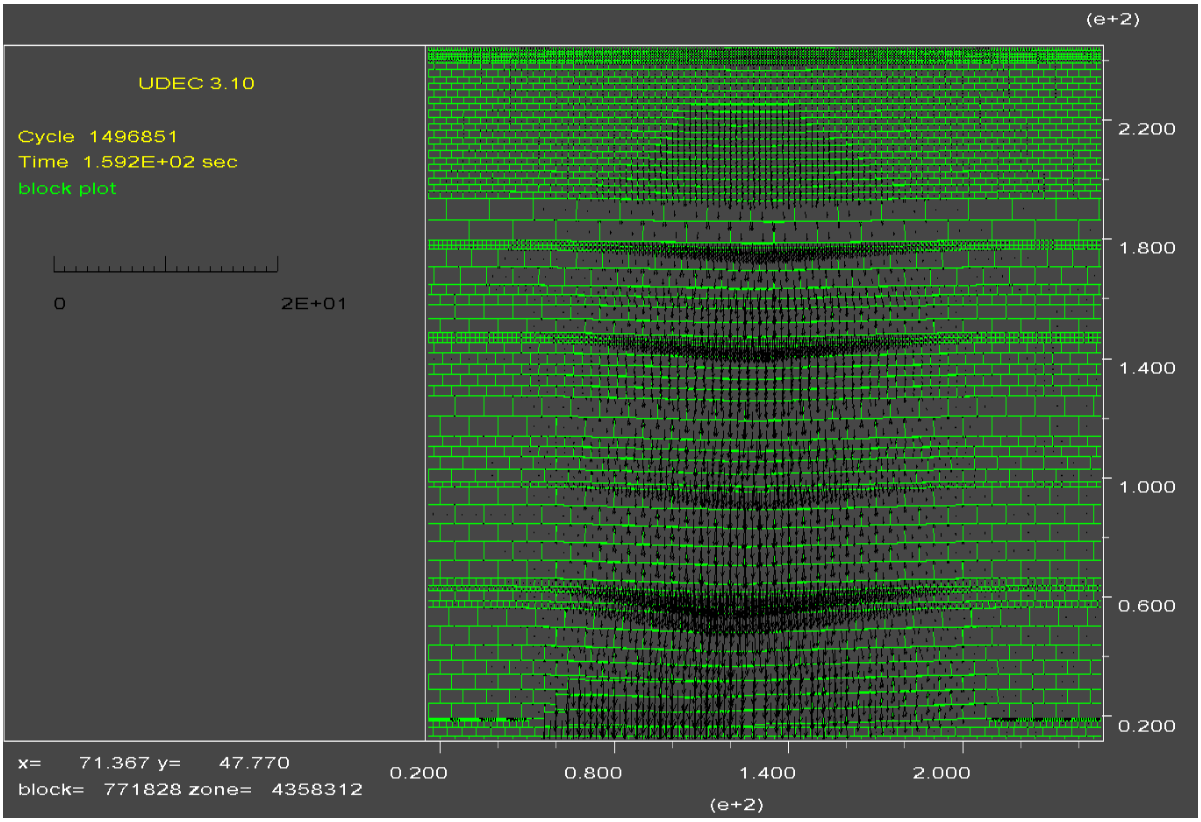
(a) - Height of collapse and fracture zones (solution 1).



(b) - Height of collapse and fracture zones (solution 2).



(c) - The process of moving of roof (solution 1).



(d) - The process of moving of roof (solution 2).

Figure 6. State of the roof of the longwall in the Seam L7 at the East Side of Mong Duong mine when cutting 140 m in the strike direction.

When cutting 140 m in the strike direction, the state of the roof of the longwall in the Seam L7 is shown in Figure 6 (a, b, c and d)

The numerical model observation shows that the roof continues to form more systems of fractures, which gradually expand up to the surface. At the same time, the height of collapse and fracturing zones of the two mining solutions also gradually increased, which is 80÷100 m (Figures 6a and 6b). The density of rock movement into the mining area is increasing day by day, as shown by the movement vectors of rock in Figures 6c and 6d. In the alluvia area near the G9 surface works, the density of fractures developed with a length of 0.4÷0.6 m, which is relatively clear. Through monitoring images, the pressure in the mining area is 4÷6 MPa. Observations on the model show that the movement of roof can reach values 0.06÷0.1 m in alluvia area near the G9 surface works.

As longwall cutting to 160 m and 200 m in the strike direction, the results of the model analysis show that, in the two solutions of exploiting, there is a strongly developed system of factures, which is reasonable because the longwall has been exploited for about 6 months, behind the mining area which has gradually stabilized. It can be seen that, in both mining solutions, the formation and location of the fracture systems are almost the same. The total height of collapse and fracture zones of both mining solutions are 150÷170 m. Model observations show that when the longwall falls in the strike direction of 140 m onwards, the level of subsidence develops according to the reduction progress. When the longwall is 160÷200 m, the surface subsidence level reaches 0.2÷1.0 m.

3.2. Analysis and selection of solutions

The monitoring in numerical models shows that the roof state of the two mining solutions is not much different. Thus, it can be concluded that the influence of underground mining on the G9 surface works in the two mining solutions is almost similar. The key is to clarify the total height of collapse and fracturing zones of the two mining solutions to serve as a basis for determining the impact of underground mining activities on the G9 surface works of Mong Duong coal mine.

From the results of model analysis for the two mining solutions as above, we have the following summary Table 2.

The results from Table 2 show that, when the longwall is exploited in the strike direction to 140 m, the height of the collapsed and fractured area is 80÷100 m, and the level of surface subsidence is 0.06÷0.1 m. However, when the longwall is exploited in the strike direction of 160 m onward, the total height of the collapsed and fractured area develops strongly, ranging 150÷170 m, and the level of surface subsidence is 0.2÷1.0 m. Accordingly, the G9 surface works will be affected when exploiting the longwall from 160 m onwards.

Thus, with the above results, the reasonable exploitation solution for the longwall in Seam L7 at East Side is Solution 2: exploiting with a height of 2.2 m and recovering 100% of the top coal (corresponding to 0.8 m). With this solution, the thickness of the coal seam will be fully exploited, minimizing the impact on the G9 surface works, and this therefore is a suitable solution.

4. Conclusions

The research results show that the numerical modeling method using UDEC software for simulation of the mining process in order to predict and determine the total height of collapsed and fractured areas and the influence of

Table 2. Height of collapse and fracturing zones of two mining solutions 1 and 2.

	The length of the longwall when cutting in the strike direction (m)	The height of collapse and fracturing of the roof of the longwall in Seam L7 (m)	Surface subsidence (m)
Solutions 1 and 2	70	30÷40	-
	100	70÷90	-
	140	80÷100	0.06÷0.1
	160÷200	150÷170	0.2÷1.0

mining process of the longwall is reasonable and necessary. From the results of the model analysis, the authors have selected a reasonable mining solution for the longwall in Seam L7 at the East Side of Mong Duong Coal Mine with a cutting height of 2.2 m and 100% top coal recovery rate (corresponding to 0.8 m). This is also a solution that can exploit the entire thickness of the seam, ensuring no waste of resources. The model monitoring results show that when the longwall is exploited in strike direction up to 140 m, the surface subsidence is 0.06÷0.1 m. When the longwall is exploited in strike direction of 160÷200 m, the height of the collapsed and fractured area is 150÷170 m, and the surface subsidence is 0.2÷1.0 m. The research results of the article can be used as a basis for Mong Duong Coal Mine to determine the affected area of the movement and deformation of the roof when exploiting the longwall in Seam L7. Subsequently, it is possible to evaluate the stability of the G9 surface works, and at the same time apply a comprehensive solution of engineering and technology to ensure safety during the mining process of this longwall.

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Contribution of authors

Tien Trung Vu and Son Anh Do reviewed and wrote the introduction and discussion; Dung Tien Le and Hung Duc Pham collected documents and wrote the conclusions; Kien Trung Tran edited the writing.

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