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Determination of the rock mass displacement zone by numerical modeling method when exploiting the longwall at the Nui Beo Coal Mine, Vietnam

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Abstract

Purpose. It is important to conduct a study to identify the displacement zone caused by mining operations. By numerical modeling the process of mining the longwall 31104 in Seam 11 at the Nui Beo Coal Mine, Vietnam, the authors have determined the total height of the rock mass displacement zone and the boundary of the affected area on the topographic surface.

Methods. In this study, the authors use a numerical modeling method. The models are developed based on the UDEC (Universal Distinct Element Code) software. In addition, field survey methods and statistical analysis methods are used.

Findings. Based on the analysis of the numerical modeling results, it has been determined that the total height of the displacement zone, when exploiting the longwall 31104 in Seam 11, is about 63 m. The analysis of the numerical modeling results also shows that the roof collapse angle is 52°, which determines the area of influence on the topographic surface in the range of 160 m.

Originality. Based on the UDEC software, the authors have developed a simulation model for the mining process of the longwall 31104 in Seam 11. Analysis of the model results has shown the state of the displacement zone of the surrounding rock mass. In this study, the numerical modeling method is applied to simulate the longwall displacement zone, which is consistent with the actual production of the underground mine.

Practical implications. Based on the analysis of the surrounding rock mass displacements zone, when exploiting the longwall 31104 in Seam 11 at the Nui Beo Coal Mine, the affected boundary on the topographic surface has been determined. At the same time, the height of the rock mass displacement zone has also been calculated. Thus, the research results can be used as a basis for implementation in actual production at the Nui Beo Coal Mine.

Keywords: *mining, displacement, longwall, rock mass, numerical modeling*

1. Introduction

Underground mining of minerals has a negative impact on the rock mass and earth surface, as well as on the objects located on it [1]-[6]. One of the forms of such impact is discontinuous displacements, which are now increasingly accompanied by underground mining in the conditions of the Quang Ninh coalfield, Vietnam. Because of the increase in the number of coal mining activities and the depth of mining, geological conditions are gradually becoming more difficult in the Quang Ninh coalfield, Vietnam. Therefore, the study and calculation of the displacement area caused by mining activities are also difficult, but extremely necessary.

The Nui Beo Coal Mine is one of the underground mines in the Quang Ninh coalfield, Vietnam. Each year, the Nui Beo Mine maintains a mining output of about 1.45 million tons [7]. Due to the expanding production area, the Nui Beo Coal Mine has many difficulties. One of the problems is to calculate and forecast the rock mass displacement zone when exploiting the longwalls. The Nui Beo Mine has applied a number of methods, such as dynamic monitoring, theoretical calculation and longwall pressure measurement, but they have not yielded more positive results.

To solve the above problem of the Nui Beo Coal Mine, many methods have been and are currently being used. However, with the intense development of science and information technology applications, it is increasingly widely used in many different fields to solve more complex problems, create fast results and be more effective [5], [8]-[12], [13]. In recent years, information technology has been applied in the mining sector and has solved many important problems and brought more positive results. In particular, the numerical modeling method is used as an effective tool to simulate processes in mining. Hence, numerical simulation is an effective method to solve the complex problem observed in underground mines. There is a lot of software that is applied in mining. Specifically, UDEC (Universal Distinct Element Code) software is used to simulate and predict pressure in longwall [13]-[16]; to monitor and forecast areas of collapse and deformation of roof [17], [18]; for predicting the influence of underground mining on the topographic surface [19], [20]; for predicting the

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influence of faults on mining [21], [22]. FLAC3D software is applied to monitor the pressure around the tunnel [23]-[25]; to predict the influence of tunnel excavation on the topographic surface works [26], [27], and to predict the influence of tunneling through soft rock areas and difficult geological conditions [28], [29]. In addition, some other software programs, such as PHASE2, Unwedge, RocSupport, are used to solve mining problems.

In this study, the authors use UDEC software to develop a numerical model to simulate the mining process of longwall 31104 in Seam 11 at the Nui Beo Coal Mine. The UDEC software is a 2-D discrete element calculation program for discontinuous media, which is suitable for simulating a discontinuous block set of joints or structural planes. Thus, it is able to meet the needs of this study. Based on the geological conditions of longwall 31104, a UDEC numerical model is developed for the working face and a rock mass. Based on the results of the model analysis, the results of the research can be determined. The specific steps are as follows:

1) collecting geological documents;
2) developing the models based on UDEC software;
3) analyzing the model results to determine the boundaries of influence on the topographic surface;
4) analyzing the model results to determine the total height of the rock mass displacement zone.

The research results of the paper provide a reliable basis for the Nui Beo Coal Mine that can be considered for deployment and applied in actual production to ensure safety in the mining process.

2. Methods

2.1. Peculiarities of the study site geological conditions

The roof and floor of Seam 11 are usually composed of siltstone, claystone, and sometimes sandstone layers. These rock layers are unstable, thick and thin in some places, sometimes forming lenses.

Sandstone. This type is about 25% of the rocks in the mine and is relatively common; the rock is white to dark gray in color. The main composition is quartz sand and siliceous clay. The rock has a block structure, layers from thick to medium thickness, intensively fractured. It is distributed both over the roof and under the bottom of the coal seam, but not continuously.

Siltstone. This type is about 33% of the rocks in the mine, which are ash-gray, dark gray in color. The main composition is clay, but also mixed with plant humus. It is widely distributed in the mine area, often located near the roof and floor or interspersed in the coal seams.

Claystone. This type is about 9% of the rocks in the mine, with is dark gray color. It is distributed directly over the roof and under the bottom of the coal seams and interspersed in the coal seams, thin layering, sometimes soft. The claystone is often a clod of a coal seam and often collapses when exploiting longwall.

Gravelstone. This type is about 19% of the rocks in the mine. It is white to ash gray in color, mostly distributed away from the walls and pillars of coal seams, mainly composed of silica and quartz sand. The gravelstone has a lenticular structure and is thin to medium in thickness. The gravelstone layers are fractured and intensively weathered.

The results of the mechanical analysis of the samples are shown in Table 1. The stratigraphic column of Seam 11 at the Nui Beo Coal Mine is shown in Figure 1.

The rock mass around the mining area is of unstable type. Thorough analysis and survey of the actual field, as well as the rock mass geological conditions on the surface of the longwall 31104 in Seam 11 show that the geological conditions of the Nui Beo Coal Mine are relatively complex. There are many layers of waste rock on the topographic surface.

2.2. Study site

The longwall 31104 belongs to Seam 11 at the Nui Beo Coal Mine, Ha Long City, Quang Ninh Province, Vietnam. The mining depth of this longwall is from -140 levels. After the Nui Beo Coal Mine was opened with a pair of vertical shafts according to the plan of the Vietnam National Coal – Mineral Industries Holding Corporation Limited, longwall 31104 in Seam 11 was also included in the mining plan of the Nui Beo Coal Mine.

Table 1. Analytical results of the roof and floor rocks of Seam 11 [30]

Rock unit	Value	Compression resistance strength σ_n (kG/cm^2)	Tensile strength σ_k (kG/cm^2)	Internal friction angle (degrees)	Cohesive force C	Specific weight γ (g/cm^3)
Siltstone (immediate roof)	Max	1412.87	121.79	34°50′	449	3.15
	Min	171.00	16.30	31°53′	61	2.68
Gravelstone (main roof)	Max	2652.83	197.34	35°20′	890	2.77
	Min	150.40	11.40	33°06′	139	2.53
Sandstone (main roof)	Max	3132.00	500.00	35°00′	563	2.93
	Min	148.83	6.06	22°30′	117	2.33
Siltstone (main roof)	Max	1385.00	123.00	34°50′	376	2.77
	Min	182.00	16.10	30°15′	66	2.53
Claystone (main roof)	Max	962.80	62.90	32°01′	108	3.15
	Min	150.40	11.40	30°54′	51	2.22
Gravelstone (immediate floor)	Max	1536.91	139.19	35°00′	460	2.65
	Min	800.13	77.71	33°56′	244	2.56
Sandstone (immediate floor)	Max	2811.42	238.00	35°35′	900	2.79
	Min	127.00	42.00	31°45′	138	2.52
Siltstone (immediate floor)	Max	1092.00	78.67	36°15′	324	2.86
	Min	201.60	25.50	32°02′	69	2.54
Claystone (immediate floor)	Max	1987.00	76.50	33°54′	116	2.76
	Min	103.00	22.30	29°30′	43	2.44

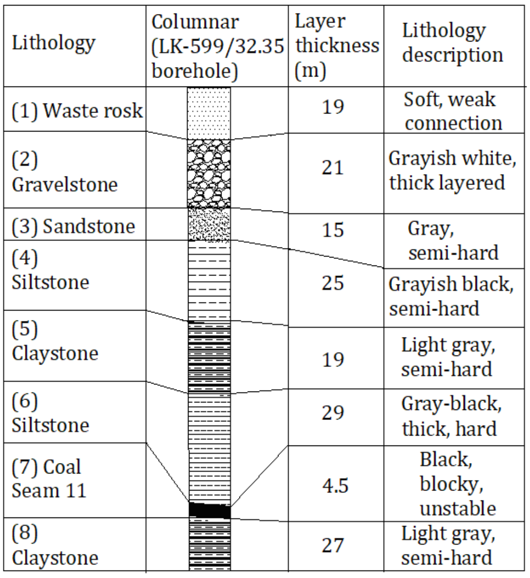

Figure 1. LK-599/32.35 borehole stratigraphic column in Seam 11 at the Nui Beo Coal Mine [30]

This is a longwall belonging to a seam of great thickness, a gentle slope angle. After research and calculations, the Nui Beo Coal Mine has selected and applied manual mining technology (drilling and blasting technology) to exploit this longwall. The waste rock layers are on the topographic surface of this longwall. The mining area is also close to the residential area. Therefore, it is extremely necessary to calculate and predict the influence boundary when exploiting this longwall. This is also the best basis for mining the Nui Beo Coal Mine to develop an effective plan for exploiting longwall 31104 in Seam 11, ensuring safety and saving resources.

The longwall preparation plan is shown in Figure 2.

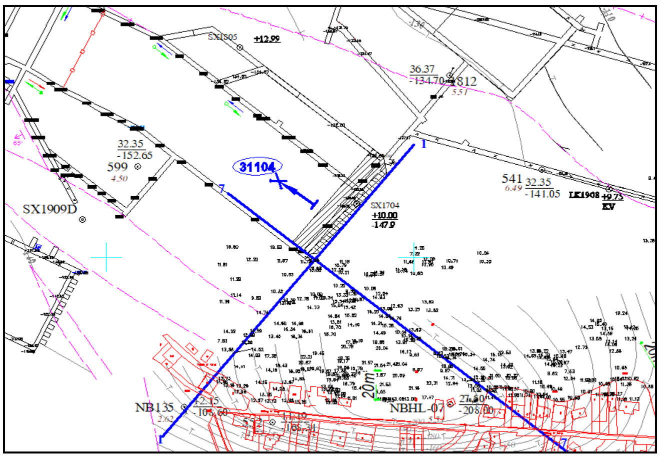

Figure 2. Location of longwall 31104 in Seam 11 at the Nui Beo Coal Mine [30]

2.3. Mining technology of the longwall 31104

The longwall 31104 mining area belongs to the coal Seam 11 with an average thickness of 4.5 m, and an average slope angle of 5 degrees. According to the design of the mining area, the longwall height is 2.2 m, the thickness of top coal recovery is 2.3 m, the longwall length to the dip is 80 m and the longwall length along the strike is 220 m.

The mining technology applied in longwall 31104 is a mining technology of drilling and blasting, recovering top coal, fastening with a moveable hydraulic support ZH1800/16/24ZL and a steel box bar DFB 3600, transportation of coal by scraper conveyors and mine pressure control by caving method. Some of the basic specifications of support and bar used in a specific longwall are shown in Table 2 and Table 3.

Table 2. Specifications of moveable hydraulic support ZH1800/16/24ZL [31]

No.	Parameters	Unit	Value
1	Maximum height	mm	2400
2	Minimum height	mm	1600
3	Piston range	mm	800
4	Support width	mm	1200
5	Support length	mm	2760
6	Moving step of telescopic beam	mm	800
7	Number of support legs	leg	4
8	Setting load	KN	1545
9	Yield load	KN	1800
10	Pump pressure	MPa	31,5
11	Prop cylinder diameter	mm	125
12	Strength of support	MPa	0.5
13	Maximum working slope angle	degrees	≤ 45
14	Working slope angle in the strike direction	degrees	15
15	The leg base diameter	mm	400
16	Distance between 2 supports	mm	1250
17	Working time	hours /day	24

Table 3. Specifications of steel box bar DFB 3600 [31]

No.	Parameters	Unit	Value
1	Bar length	mm	3600
2	Hardness index	HB	300-350
3	Minimum load	KN	300
4	Maximum load	KN	400
5	Deformation coefficient when dismantling	mm	0.5
6	Tensile strength σ_b	N/m	500

2.4. Operation scheme, economic and technical indices of longwall 31104

2.4.1. Operation scheme

The production tasks in the longwall face 31104 are organized and performed in cycles. A cycle of two web cuts is completed within two shifts, which is equivalent to moving the face advance by 0.8 m per cycle. A web cut includes the following stages: cutting face and moving supports with an advance rate of 0.8 m, recovering top coal and ventilation drifts. The number of workers in the longwall face is arranged depending on the specific work of each shift. The total number of workers in a day and night is 66 people. The operation scheme and chart of human resource arrangement are shown in Figure 3 and 4.

2.4.2. Economic and technical indices

After establishing an operation scheme for longwall 31104 in Seam 11 at the Nui Beo Coal Mine, which is exploited by drilling and blasting mining technology, with the above combination of equipment, the calculated main economic-technical indices are shown in Table 4.

2.5. The UDEC numerical model development

The UDEC-2D (Universal Disctinct Element Code) software as the main tool is suitable for processing in discontinuous environments of a rock mass, which is represented in 2-D space under the action of static load or motion, in the form of small blocks.

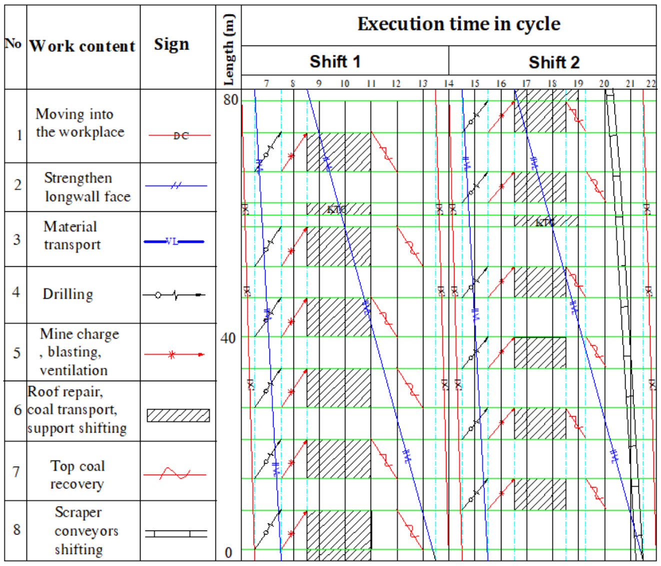

Figure 3. The operation scheme in the longwall 31104 in Seam 11 at the Nui Beo Coal Mine [31]

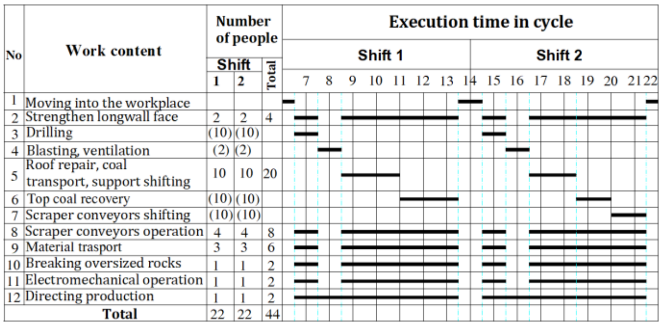

Figure 4. Chart of human resource arrangement in the longwall 31104 in Seam 11 at the Nui Beo Coal Mine [31]

Table 4. Economic and technical indices of the longwall 31104 [31]

No.	Parameters	Unit	Value
1	Average thickness of coal seam	m	4.5
2	Average slope angle of coal seam	degrees	5°
3	Average length in dip direction	m	80
4	Average length in strike direction	m	220
5	Cutting height (longwall height)	m	2.2
6	Top coal recovery height	m	2.3
7	Volumetric weight of coal	ton/m^3	1.632
8	Coal strength coefficient	–	$2 < f < 3$
9	Output of one mining cycle	ton/cycle	315
10	Number of shift to complete a cycle	shift	2
11	Number of shifts in a day	shift	3
11	Coal output per a month	ton/month	12400
13	Number of workers in a day	workers	66
14	Direct labor productivit	t/worker	7.9
15	Number of single hydraulic prop DW25	prop	177
16	Number of steel box bar DFB-3600; HDFBC-2800	bar	51

For the mining sector, especially when mining deep faces, the UDEC-2D software is an effective tool for predicting the process of roof collapse during mining. This process is the main cause of the fracture system formation in the roof area, and it also leads to movement and causes surface subsidence when exploiting longwall.

Based on the geological conditions (stratigraphy of the borehole LK599/32.35 in Figure 1 and the results of determined physicochemical rock mass parameters in the area of coal Seam 11 in Table 1) and approved mining design of the longwall 31103 in Seam 11 at the Nui Beo Coal Mine, a simulation model of the studied area has been constructed with dimensions of 400 m in length, 188 m in width, including many rock and coal seams. The longwall height is 2.2 m; the thickness of top coal recovery is 2.3 m. The simulation model is shown in Figure 5.

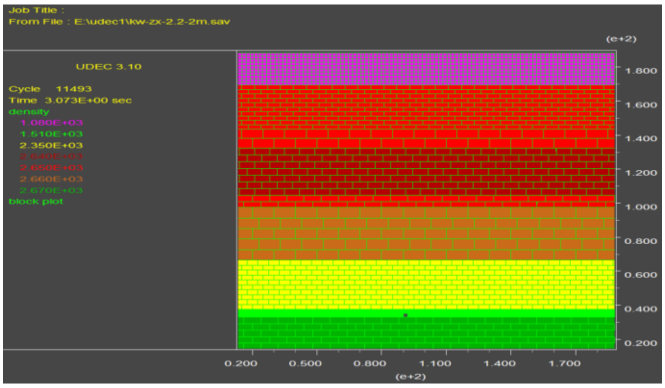

Figure 5. Simulation of the mining area at the longwall 31104 in Seam 11 using the UDEC 2D-3.1 software

Thus, based on the UDEC software, a numerical simulation model has been developed, as indicated above. In order to monitor and predict the state of the longwall 31104 roof in Seam 11 of the Nui Beo Coal Mine, it is necessary to run the model according to each movement step (called a cutting step) of the longwall. From here, the analysis of the results of running the model (called the analysis of model results) will determine the height of collapse and fracture zone of the roof (called the rock mass displacement area). By analyzing the model results, the fracture angle of the roof when exploiting the longwall will also be determined.

3. Results and discussion

3.1. Caving step of the roof and the total height of the displacement zone

This section presents an analysis of numerical modeling results to determine the roof caving step and the displacement zone total height when exploiting the longwall 31104 in Seam 11. In order to determine the caving step and the height of the roof displacement zone, the longwall is exploited along the strike. Thus, the model can simulate the longwall movement for each mining cycle, from which the roof state is observed on the model, specifically below (Figs. 6a-g).

Figure 6a shows that when the longwall starts to cut 2 m along the strike, since the coal cut process does not change the initial stress of the roof, so its state almost does not change. Therefore, the process of the roof displacement in the longwall 31104 does not occur at that time and the roof pressure ranges within 3-4 MPa.

Figure 6b shows a clear change in the longwall 31104 roof, then in the immediate roof, the phenomenon of delamination and fracturing occurs. However, this process is not completed and the roof pressure ranges within 2-5 MPa.

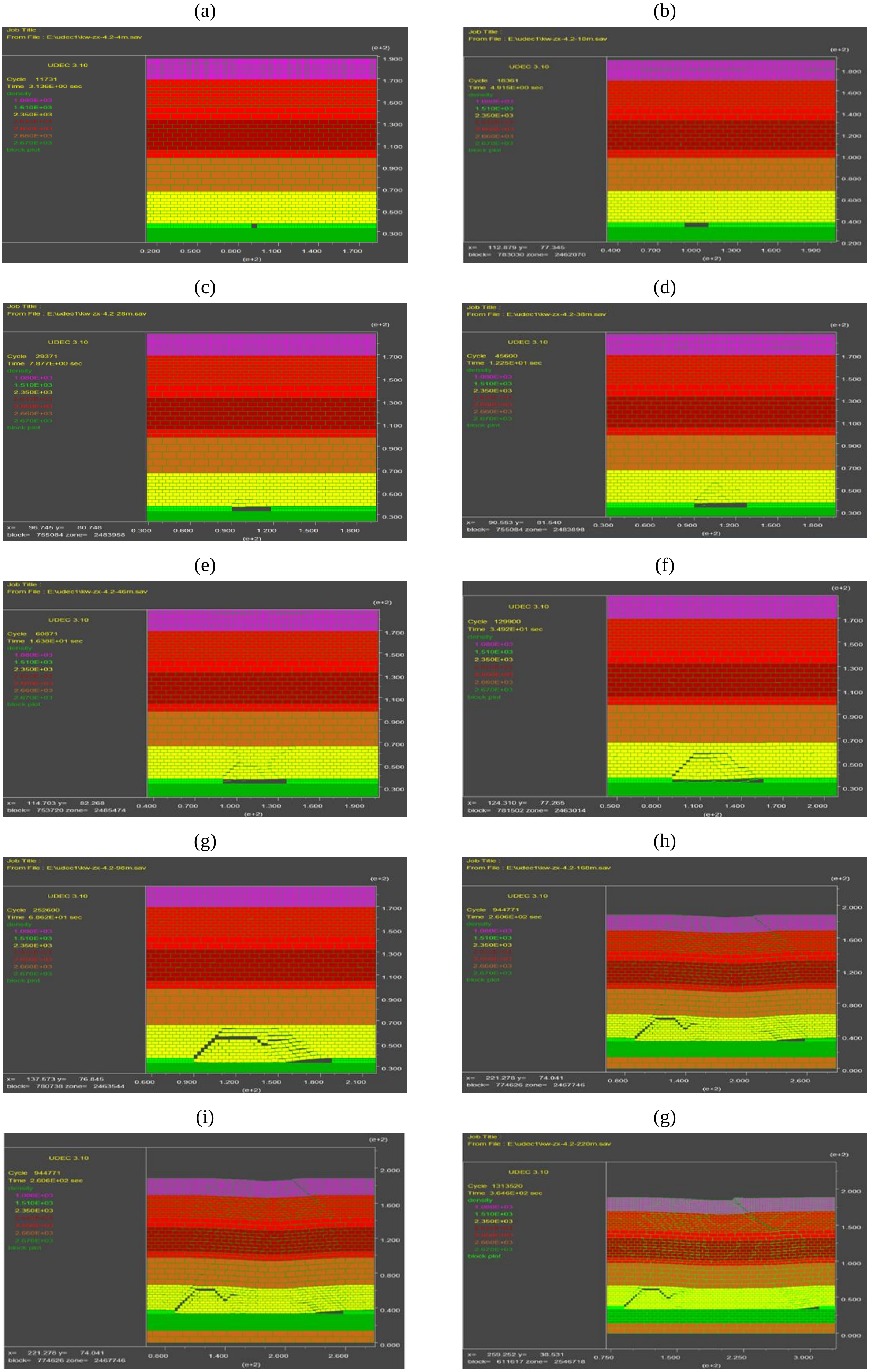

Figure 6. Process of the roof caving along the strike when the longwall cuts: (a) 2 m; (b) 18 m; (c) 28 m; (d) 38 m; (e) 46 m; (f) 66 m; (g) 96 m; (h) 166 m; (i) 188 m; (g) 220 m

Figure 6c shows that the longwall cuts 28 m along the strike, then, in the immediate roof there is a phenomenon of delamination and caving into voids, while the height of its collapse is greater than before. The roof pressure ranges within 3-7 MPa. At this time, the longwall roof is intensively displaced, but the direct wall stone is a siltstone with a relatively large thickness (about 29 m), so the caving process can be more complex than that in the roofs of other longwalls.

Figure 6d shows that the longwall cuts 38 m along the strike. At this time, the longwall 31104 immediate roof has a clear displacement, the main roof moves to the caving area, and the fracture system also begins to form and develop. The roof pressure ranges within 3-7 MPa.

Figure 6e shows that the longwall cuts 46 m along the strike. At this time, the immediate roof is clearly collapsed, the collapse height is about 20 m, and the main roof continues to move into the caving area, the fracture system grows stronger with a thickness of about 1.5-2.0 m. The roof pressure ranges within 3-8 MPa.

Figure 6f shows that a big change occurs in the longwall 31104 roof in Seam 11 at the Nui Beo Coal Mine. At this time, the longwall cuts 66 m along the strike, the immediate roof collapses over most of its thickness, and the fracture system continues to develop intensively. In the longwall, the pressure also gradually stabilizes, if there is no local geological disaster, the roof pressure ranges within 3-7 MPa.

Figure 6g shows that the longwall cuts 96 m along the strike, and the immediate roof is completely collapsed. At this time, the displacement process is intense, and the fracture system develops quickly and spreads over the area of the longwall 31104 roof influence. The process of surface subsidence also occurs due to the rock mass displacement in this area. The pressure value still ranges within 3-6 MPa if there is no local geological disaster in the mining area.

Figure 6h shows that the longwall cuts 166 m along the strike, the process of the roof displacement very intensively. Surface subsidence is evident over a wide area around the longwall. There is waste rock on the topographic surface of this longwall, so the displacement zone in this area is very large due to the influence of mining activities. At this time, the pressure in the longwall 31104 area still ranges within 3-7 MPa, if there is no local geological disaster.

Figure 6i shows that the rock displacement zone and its density in the longwall 31104 tend to be concentrated in the vertical area. The density gradually decreases towards the two longwall sides, which is completely consistent with the reality of underground mining, because the caving area is the place where the highest concentration of the roof displacement. This is also the place that causes the highest surface subsidence.

Figure 6g shows that the longwall cuts 220 m along the strike. At this time, the longwall roof state does not differ from when the longwall cuts 188 m (Fig. 6i). The roof pressure still ranges within 3-7 MPa. The degree of subsidence in the vertical area from the surface to the longwall is almost unchanged. The process of moving the rock mass to both sides of the longwall takes place and gradually decreases towards the end if the longwall is completed.

The results of monitoring using a numerical model show that the total height of the displacement zone when exploiting the longwall 31104 in Seam 11 is about 63 m, as shown in Figure 7.

The analysis results from Figures 6a-g are summarized in Table 5 below.

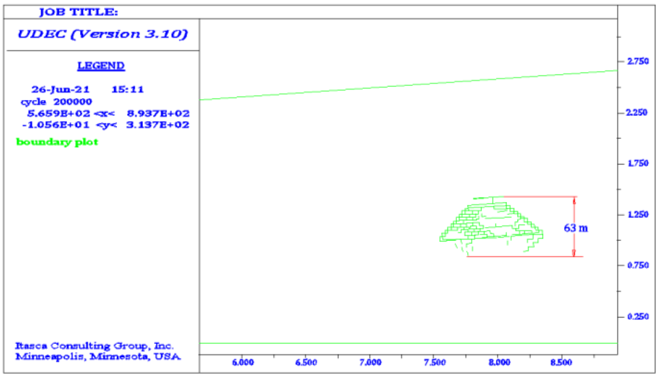

Figure 7. The total displacement zone height when exploiting the longwall 31104 in Seam 11 at the Nui Beo Coal Mine

Table 5. Summary table of results of state/height of the roof displacement and pressure when exploiting the longwall 31104 in Seam 11 at the Nui Beo Coal Mine

No.	Cut length along the strike (m)	State or displacement height of the roof (m)	Roof pressure (MPa)
1	2	not expressed yet	3-4
2	18	fracture	2-5
3	28	starting to collapse	3-7
4	38	intense displacement	3-7
5	46	20	3-8
6	66	36	3-7
7	96	63	3-6
8	166	63	3-7
9	188	63	3-7
10	220	63	3-7

Analysis of the results in Table 5 shows that the rock wall of the longwall 31104 in Seam 11 is a hard rock with a thickness of 29 m. Therefore, the caving process is complex. Model observation shows that when the longwall cuts 29 m along the strike, the immediate roof itself begins to collapse, and this is a very intense caving step. This is also a problem that can cause unsafety in the process of exploiting this longwall. The total height of the displacement zone is 63 m.

3.2. The fracture angle of the longwall roof

This section presents an analysis of numerical modeling results to determine the fracture angle of the roof at longwall 31104 in Seam 11. According to the model results, the roof displacement range in longwall 31104, corresponding to the fracture angle, is about 52°. The model has also clearly defined this displacement range, and the results are shown in Figure 8.

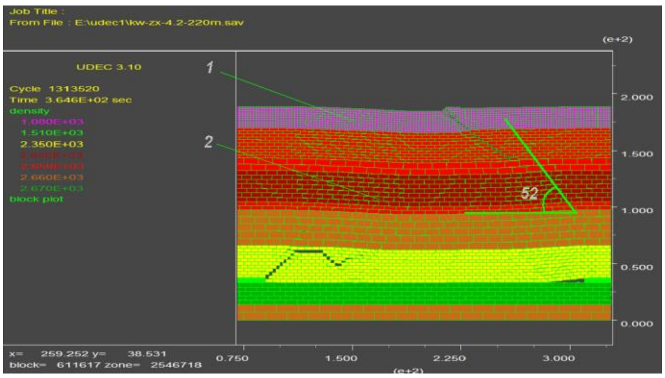

Figure 8. The roof fracture process in the longwall 31104 in Seam 11 at the Nui Beo Coal Mine (1 – surface waste rock area; 2 – intense rock mass displacement zone)

Thus, we can see that the roof rock fracture angle depends on each mining method and different types of roof rock. In the geological conditions and mining method of the longwall 31104 in Seam 11 of the Nui Beo Coal Mine, the results of numerical simulation model analysis have determined that the roof fracture angle is 52°. This result is the basis for determining the boundary of mining influence on the topographical surface.

3.3. Displacement zone caused by exploiting the longwall

This section presents the boundary of the influence of the displacement zone caused by exploiting the longwall 31104 on the topographic surface in the corresponding cross-sections. As shown in Figure 2, within the mining area of the longwall 31104 in Seam 11, the geological cross-sections of 1-1; 7-7 will be cut. Applying to these areas the calculation results based on the fracture angle model of the roof, it is possible to determine the boundary of the displacement influence, caused by the mining activities of the longwall 31104, on the topographic surface. This result is shown in Figure 9 and 10.

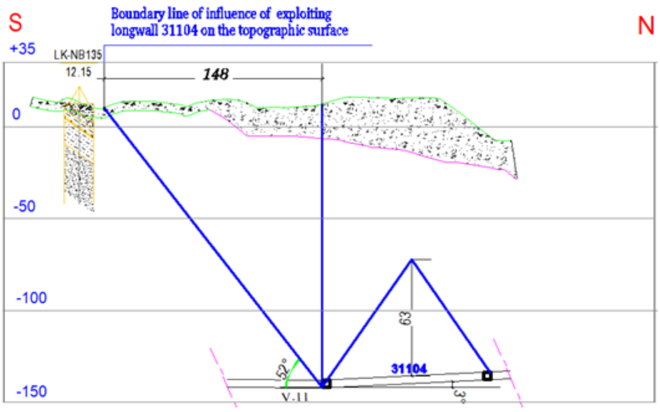

Figure 9. Boundary of influence of displacement caused by exploiting the longwall 31104 on the cross-sections 1-1

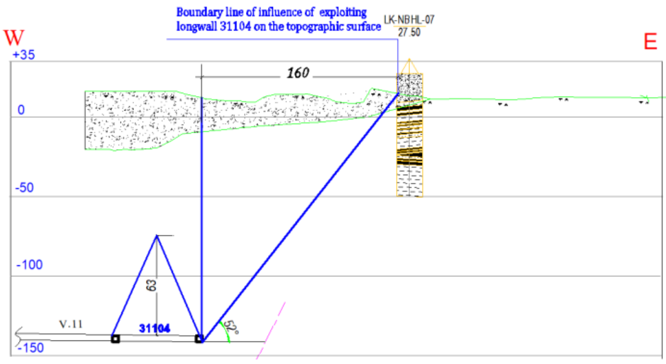

Figure 10. Boundary of influence of displacement caused by exploiting the longwall 31104 on the cross-sections 7-7

Figures 9 and 10 show that when exploiting the longwall 31104 in Seam 11 at the Nui Beo Coal Mine, the total height of the displacement zone is 63 m, the fracture angle is 52°. On the basis of the corresponding cross-sections, the degree of influence (influence boundary line) of exploiting this longwall on the topographic surface has been determined which is 148 m (in section 1-1) and 160 m (in section 7-7).

Thus, when exploiting the longwall 31104 in Seam 11 of the Nui Beo Coal Mine, it is very important to determine the displacement zone of the rock mass. In this study, the authors have developed a numerical simulation model for specific conditions of the longwall at the Nui Beo Coal Mine using reliable data provided by an actual mine. Based on this, the authors have determined the boundary that affects the topographic surface when exploiting this longwall, as calculated above.

4. Conclusions

Based on the research results of the paper, the following conclusions can be drawn:

1. Numerical modeling method applied to simulate, monitor and predict displacement areas in underground mining is extremely necessary. Using the UDEC software, the authors have constructed a numerical simulation model of the mining process of longwall 31104 in Seam 11 at the Nui Beo Coal Mine in order to identify and predict the displacement and affected areas of exploiting this longwall on the topographic surface.

2. The numerical model analysis results show that the immediate roof caving step is 28 m. The fact shows that due to the thick and hard roof, the caving step is very long, which creates unsafe mining process. Therefore, the Nui Beo Coal Mine needs a suitable roof control solution to ensure safety. The model analysis results also show that the total height of the vertical displacement zone is about 63 m.

3. The boundary of influence of exploiting the longwall 31104 in Seam 11 on the topographic surface is shown by the roof fracture angle during caving. The results of the model analysis show that the roof fracture angle of the longwall 31104 is 52°. The results of determining and calculating the influence area on two sections show that in section 1-1 (Fig. 9) is about 148 m, in section 7-7 (Fig. 10) is about 160 m. This result also shows that when exploiting the longwall 31104 in Seam 11 with the mining height of 2.2 m, the thickness of the top coal recovery is 2.3 m, the affected area of this longwall mining on the topographic surface is 160 m. Therefore, to ensure safety and not affect the works on the topographic surface, they need to be arranged and constructed outside a radius of 160 m. When the rock mass in the affected area (within a radius of 160 m) is stable, this area will be considered for construction works.

4. The model analysis results also show that the pressure around the longwall 31104 in Seam 11 mining area is also relatively stable, when the longwall is at a stable stage, the mining area does not have geological changes, the pressure is about 3-7 MPa.

5. The research results of the paper provide a basis for the Nui Beo Coal Mine to decide and predict the state of roof when exploiting the longwall 31104 in Seam 11. At the same time, it is also the basis for the Nui Beo Coal Mine to choose appropriate technical solutions to ensure safety and high efficiency in the process of exploiting this longwall.

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Визначення зони зсуву породного масиву методом чисельного моделювання при відпрацюванні лави на вугільній шахті Нуй Бео, В'єтнам

Т.Т. Ву, С.А. До

Мета. Аналітичні дослідження щодо виявлення параметрів зони зсуву, спричиненого гірничими роботами при відпрацюванні лави 31104, пласта 11 на вугільній шахті Нуй Бео, та чисельне моделювання процесу – визначення висоти зони зсуву і межі зони впливу на топографічній поверхні.

Методика. У цьому дослідженні автори використовують метод чисельного моделювання. Моделі розроблені на основі програмного забезпечення UDEC (Universal Distinct Element Code). Також застосовані методи польових досліджень і статистичного аналізу.

Результати. На підставі аналізу результатів чисельного моделювання встановлено, що загальна висота зони зсуву при відпрацюванні лави 31104, пласта 11 становить близько 63 м. Аналіз результатів чисельного моделювання також показує, що кут обвалення покрівлі складає 52°, що визначає зону впливу на топографічну поверхню у діапазоні 160 м.

Наукова новизна. Вперше розроблено імітаційну модель процесу відпрацювання лави 31104, пласта 11 та визначено стан зони зсуву навколишнього масиву порід на основі програмного забезпечення UDEC.

Практична значимість. Результати дослідження є основою для прийняття рішення та прогнозування стану покрівлі під час експлуатації лав вугільної шахти Нуй Бео. Водночас це є базисом для вибору відповідних технічних рішень для забезпечення безпеки та високої ефективності у процесі експлуатації даної лави.

Ключові слова: *видобуток корисних копалин, зсув, лава, породний масив, чисельне моделювання*