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VIET NAM NATIONAL UNIVERSITY HO CHI MINH CITY
VIET NAM METEOROLOGICAL AND HYDROLOGICAL ADMINISTRATION

Proceedings of the Sixth International Scientific Conference
EARTH AND ENVIRONMENTAL SCIENCES, MINING FOR DIGITAL TRANSFORMATION, GREEN DEVELOPMENT AND RESPONSE TO GLOBAL CHANGE

SCIENCE AND TECHNICS PUBLISHING HOUSE

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東京大学 THE UNIVERSITY OF TOKYO

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FOREWORD

The fields of Earth, Mines, and Environmental sciences (EME) have emerged and evolved alongside with the evolution of human society, and have created a profound impact on all aspects of life and socio-economic development through utilizing natural resources, impacting the environment, and driving global change. The robust development of these areas serves as the foundation for various other fundamental and applied sciences, and concurrently act as a catalyst for technological advancements worldwide, contributing to the common prosperity and safety of humankind as well as the conservation of the blue Earth.

Global change, rapid development of science and technology, and the fourth industrial revolution (Industry 4.0) create many opportunities and challenges for sustainable development. Vietnam, being one of the most vulnerable countries to climate change and natural disasters, is devoting great efforts to achieve sustainable development goals and achieve net zero emissions by 2050 as well as to improve productivity and national competitiveness. In this context, innovation, digital transformation in training, basic and applied research on EME become more urgent than ever for green, circular development and response to global change, sustainable development, prosperity, and safety of the country, the region and the world.

Against such considerations, Viet Nam National University Ho Chi Minh City, in collaboration with Viet Nam Meteorological and Hydrological Administration, the Interdisciplinary Council for Professorship of Earth - Mining Sciences, as well as various research institutes and local and international higher education institutions, jointly co-organizes the International Conference "Earth Science, Mining, Environment for Digital Transformation, Green Development, Circular Growth, and Response to Global Change" (GREEN EME 2023).

The GREEN EME 2023 is a forum for scientists, administrators, and businesses, who are passionate about Earth Science and Environment, Mining (EME) to meet, present and share their research findings, to engage in discussions, and to exchange solutions for a wide range of overall academic issues in these fields. The specific objectives include:

- Publishing outstanding research results and sharing, replicating achievements and experiences in innovation and digital transformation in fundamental and applied research and technology development in Earth Science, Mining, Environment, and related fields in

order to advance economic efficiency, national competitiveness, sustainable development, national, regional and international safety.

- Proposing solutions to promote innovation in the fields of Earth Science, Mining, and Environment (institutions, policies, promoting educational science and technology, training of high-quality human resource, digital transformation, engagement, and enhancing collaboration with stakeholders, etc.) to meet the requirements of green, circular growth, and response to global changes.

During the preparation for GREEN EME 2023, the Organizing Committee has received 86 scientific manuscripts. After a rigorous reviewing process, 30 highly valued articles were selected for publication in the conference proceedings and other 22 articles will be published in the "IOP Conference Series: Earth and Environmental Science". The Organizing Committee highly appreciates the efforts of the Editorial Board, domestic and international scientists and experts in either submitting their manuscripts or contributing valuable time to review and editing the articles. We would also like to thank the Secretariat for their efforts in preparing and organizing the conference as well as the sponsors for their important contribution. We believe that the GREEN EME 2023 will be successful and all the participants will have opportunities to meet, exchange ideas, and collaborate to propose sustainable development goals for the development of EME sectors.

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DETERMINATION OF THE ROCK PRESSURE BY NUMERICAL MODELING METHOD WHEN DIGGING ROADWAYS UNDER THE OPEN-PIT MINE AREA AT THE HA LAM COAL MINE, QUANGNINH

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Abstract: Currently, Ha Lam Coal Mine is exploiting a number of the longwalls that are located under the open-pit mine area. Therefore, it is very difficult and complicated to calculate the rock pressure when digging the roadways under the open-pit mine area. The potential risks of unsafety are huge. It can be the risk of water flowing into the roadways or the occurrence of water cracking and mud, which is a very dangerous phenomenon in mining.

In this research, the numerical method was used. Based on Phase2 software and geological conditions of the Ha Lam Coal Mine, the authors built a simulation model to determine the rock pressure acting on the roadways that are located underneath the open-pit mine area. Through the actual study at Ha Lam Coal Mine, the authors calculated the rock pressure when digging the roadways underneath the open-pit mine area of Seam 14 at the West Side at level -54. This open-pit mine is located on the longwall in Seam 11, the stratigraphic distance from the longwall to the bottom of the open-pit mine is about 100 ÷ 120 m.

The findings of the study serve as the foundation for the practical application of production methods at the Ha Lam Coal Mine. Based on calculating the rock pressure acting on the roadways at Seam 11, from which the support plan has been developed. The research result of the article will also serve as a basis for other underground mines with similar geological conditions in Quang Ninh province to consider and apply.

Keywords: *rock pressure, roadways, numerical method, open-pit mine, Ha Lam Coal Mine.*

1. INTRODUCTION

The process of exploiting the longwalls of the coal seams located underneath the open-pit mine area is extremely difficult and complicated [1]. To ensure the safe and effective exploitation of these longwalls, we need a reasonable solution for excavation and protection, as well as calculating the rock pressure acting on the tunnels under this area. Currently, calculating the rock pressure acting on the tunnels are done using many different methods [2]. Depending on each specific condition, we can select a reasonable method to calculate the rock pressure acting on the tunnel. If the calculation of rock pressure acting on the tunnel is more accurate, the more reasonable the choice of support will be, the tunnel will be well protected and meet the requirements for use in actual mine production [3; 4].

When digging and supporting, as well as calculating the rock pressure acting on the tunnels that are located under the open-pit mining area (completed or under exploitation), it is necessary to pay attention to potential risks unsafe which is related to the amount of water contained in the open-pit mine. Thus, the water is one of the factors affecting on the rock pressure, as well as the stability of the tunnels during the exploitation of coal seams underneath the open-pit mine area. From the actual survey, it has been shown that, although open-pit mining has ended, but according to calculations, the open-pit area still contains a very large amount of water, especially in the rainy season [5]. Therefore, during the excavation process, it can lead to the risk of water cracking and mud. This phenomenon is very complicated, if it occurs, it will disrupt the production of the entire mine, threatening the safety of workers as well as destroying equipment in the mine, leading to economic loss of the mine [6; 7].

Ha Lam Mine is one of the mines exploited by underground mining method with a big capacity in the Quang Ninh coalfield of Vietnam. Currently, in some mines in the Quang Ninh province, including Ha Lam Mine, which is facing many difficulties in exploitation the seams, the coal reserves located underneath the open-pit mine area have finished exploitation. This problem is not only concerned by the leaders of the underground mines, but also by the leaders of the Vietnam National Coal – Mineral Industries Holding Corporation Limited [8].

The longwall in Seam 11 at the Ha Lam Coal Mine is located underneath the of Seam 14 open-pit mine area of Nui Beo Coal Mine, including open- pit at levels -54; -80; -60. The stratigraphic distance to the bottom of the ope- pit is about 100 ÷ 120 m, the stratigraphy consists of a layer of siltstone with a thickness of about 5 ÷ 6m, sandstone with a thickness of about 5 ÷ 18m, gravel with a thickness of about 15 ÷ 35m, and siltstone mixed with sandstone with a thickness of about 12 ÷ 40 m [9]. Digging the roadways in the coal Seam 11 will result the rock pressure in the mining area affecting these roadways are very complicated, as well as the influence of the water contained in the open-pit mine area on the underground mining is very large, the risk of the water cracking and mud in the mine. In order to avoid potential water risks, it is necessary to forecast and calculate the rock pressure acting on the tunnel that has been dug in coal Seam 11 at the Ha Lam Coal Mine [9]. On this basis, it is possible to assess the level of influence of water on digging the roadways. In this research, the authors uses the numerical method, by using Phase2 software to calculate the rock pressure acting on the tunnel that was dug in coal Seam 11 at Ha Lam Coal Mine under the Seam 14 open-pit area of Nui Beo Coal Mine. Input parameters of rock and coal conditions were collected from the actual mine, build a model and analyze model results based on the excavation plan corresponding to the longwall mining process. Research result of this article is also the basis for the Ha Lam

Mine to be proactive in deploying and selecting a reasonable support plan for the current conditions of this Coal Mine.

2. THEORETICAL BASIS AND RESEARCH METHODS

2.1. Introduction of the Ha Lam Coal Mine and typical cross-section of the study site

+ Introduction of the Ha Lam Coal Mine

Ha Lam Coal Mine is located in Ha Tu - Ha Lam mineral deposits, about 7 km east - northeast from Ha Long city [9].

- The East borders Nui Beo Coal Mine.
- The West borders Binh Minh Coal Mine.
- The South borders Road 18A.
- The North borders Suoi Lai Coal Mine.

The boundary of Ha Lam Coal Mine has been approved by the Ministry of Natural Resources and Environment according to Decision No. 2497/GP-BTNMT November 28th, 2008. According to this decision, Ha Lam Coal Joint Stock Company - Vinacomin belongs to the Vietnam National Coal – Mineral Industries Holding Corporation Limited is allowed to exploit coal seams V.14(10), V.11(8), V.10(7), V.7(4), V.6(3), V5 (2) from level -50 to level -300 by underground mining method. Those coal seams belong to Ha Lam Coal Mine, Ha Lam ward, Ha Long city, Quang Ninh province. Location of the Ha Lam Coal Mine is shown in figure 1.

***Figure 1**. The geographic location of Ha Lam Coal Mine area [10]*

+ The typical geological cross-section of the study site.

Based on the typical geological cross-section in the Seam 14 open-pit mine area of the Nui Beo Coal Mine, it can be shown that the bottom of its stops mining at the West Side at the -54 level. The Nui Beo Coal Mine has dumped waste rock in that open-pit mine. Because of a long time of dumping, the waste rock in the Seam 14 open-pit mine has been stabilized, but the porosity coefficient is still very large. So , the amount of water trapped in the waste rock of the Seam 14 open-pit mine is also very large. That is one of the potential causes of the risk of water cracking when digging the roadways in the coal seams at the edge and bottom of the Seam 14 open-pit mine. Simultaneously, the water contained in the waste rock of the Seam 14 open-pit mine is also one of the causes of the rock pressure acting on the roadway support structure in digging it under the open-pit mine area. The typical geological cross-section in the Seam 14 open-pit mine is shown in figure 2.

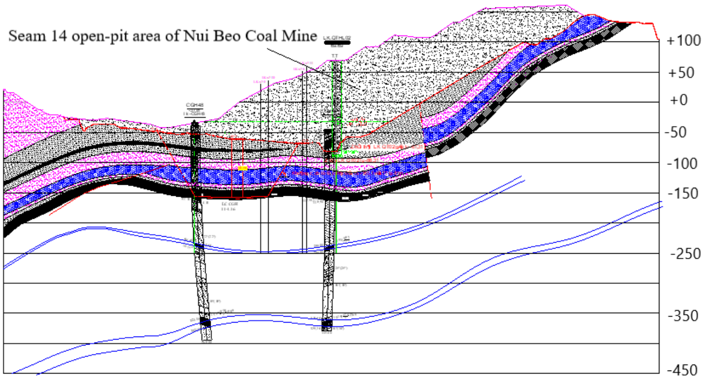

Figure 2. *The typical geological cross-section of the Seam 14 open-pit mine filled with waste rock [11]*

2.2. Geological conditions of the study site

The study site includes layers of rocks including cobblestone, gravelstone, sandstone, siltstone, claystone, and coal [11; 12].

- *Gravelstone:* This type of rock accounts for 19% of the rocks in the area. It is white-gray to ash-gray in color, mostly distributed far from the coal seam roof and floor. Its grain composition is selected quartz, cementitious cement is silica, quartz sand. The gravelstone usually have a lenticular structure or with thin to medium-thickness layers. The layers of gravelstone are strongly fractured and irregular, the exposed part of the seam is weathered and fractured with a yellow-gray color.

- *Sandstone:* This type of rock accounts for 25% of the rocks in the area. It is relatively widely distributed in the mine, the rock has coarse to fine grain, white gray to dark gray color. Its grain composition is mainly quartz sand, cementitious cement is silica clay. The rock has a blocky structure, thick to medium layers, and is heavily fractured. Distributed both on the roof and under the floor of the coal seam, but not continuously. The cracks develop from moderate to strong, the change in the degree of cracking with depth is not clear. Along with the gravelstone, sandstone can store and conduct water.

- *Siltstone:* This type of rock accounts for 33% of the rocks in the area, it is ash gray, and dark gray. Its main component is clay, but also mixed with plant humus. The siltstone is widely distributed throughout the mine and is often located near the roof and floor or interbedded within coal seams. The siltstone layer has a relatively stable thickness of 3 to 5 m, with special places having a thickness of up to 70 m. The siltstone is a type of rock commonly found in coal seam roof and floor and is the main roof. Its degree of cracking ranges from moderate to strong and is non-directional.

- *Claystone:* This type of rock accounts for 9% of the rocks in the area, it is dark gray in color. Distributed directly on the roof and under the floor of coal seams and interbedded within coal seams, thin layers, sometimes soft and friable. The claystone is often a false roof of coal seams and often collapses during mining.

- *Coal clay:* This type accounts for about 1% of the area. It is dark gray in color, thinly layered, soft, and swells when exposed to water. The coal clay is often found on the roof and floor of coal seams and interbedded within coal seams.

- *Coal:* This type accounts for about 12% of the area, black, metallic, broken in the form of shells and stairs.

- Parameters of the rock mass has been analyzed and shown in Table 1.

Table 1. Input parameters of the simulation model [12]

Descriptions	Unit	Value	Descriptions	Unit	Value
Model size parameter			*Roadway size parameter*		
Width	m	471	Width	m	3.69
Height	m	680	Height	m	3.17
Depth of digging roadway	m	120	Radius	m	
Conglomerate mass parameters			*Sandstone mass parameters*		
Compression resistane strength	kG/cm^2	1595.49	Compression resistane strength	kG/cm^2	927.35
Tensile strength	kG/cm^2	118.26	Tensile strength	kG/cm^2	93.64
Volumetric weight	g/cm^3	2.58	Volumetric weight	g/cm^3	2.65
Poisson’s coefficient	-	0.2	Poisson’s coefficient	-	0.2
Siltstone mass parameters			*Claystone mass parameters*		
Compression resistane strength	kG/cm^2	521.78	Compression resistane strength	kG/cm^2	206.22
Tensile strength	kG/cm^2	55.38	Tensile strength	kG/cm^2	27.35
Volumetric weight	g/cm^3	2.66	Volumetric weight	g/cm^3	2.70
Poisson’s coefficient	-	0.2	Poisson’s coefficient	-	0.2
Coal mass parameter			*Interbedded rock mass parameters*		
Compression resistane strength	kG/cm^2	222.270	Compression resistane strength	kG/cm^2	363.65
Tensile strength	kG/cm^2	27.223	Tensile strength	kG/cm^2	42.67
Volumetric weight	g/cm^3	1.361	Volumetric weight	g/cm^3	2.64
Poisson’s coefficient	-	0.12	Poisson’s coefficient	-	0.12

2.3. Hydrogeological conditions around the area of the longwall in coal Seam 11

- The Seam 14 open-pit mine at West Side at level -54 (Figure 3). This open-pit mine is located on the longwall in Seam 11, the stratigraphic distance from the longwall to the bottom of the open-pit mine is about 100 ÷ 120 m, and the stratigraphy consists of a siltstone layer lying on the coal seam with a thickness of about 5 ÷ 6 m, followed by a sandstone layer with a thickness of about 5 ÷ 18 m, above the sandstone layer is a layer of gravel with a thickness of about 15 ÷ 35 m, above the gravel layer is a layer of siltstone mixed with sandstone with a thickness of about 12 ÷ 40 m.

The progress of dumping waste at this landfill in recent years has been carried out in the form of a circumference, dumping in the order of exploitation (when the mining was finished, dump the waste there), the height of the waste layer is from 30÷50 m, almost no floor has entered the end position [11; 13].

In the study area, the reserves of the coal Seam 14 were exploited by the open-pit mining method of the Nui Beo Coal Mine. Open-pit mining activities had destroyed the original topography, creating on the topography open-pit mine and dumps that can be placed for water to accumulate. The reserve of coal Seam 11 below the upper open-pit mine has been mobilized by Ha Lam Coal Mine to exploit by the underground mining method according to the planning of the build mining investment project below the -50 level of Ha Lam Coal Mine. The coal Seam 11 belongs to the type of thick and gentle seam, exploited and using the roof control method by full caving. Thus creating collapsed and fractured areas capable of developing from the mining area to the topographic surface, if the mining depth is not too large [15; 16; 17].

Figure 3. *The bottom of Seam 14 open-pit mine at West Side at level -54} of Nui Beo Coal Mine (it shows that before dumped waste) [14]*

Synthesized hydrogeological information in the area shows that the water source affecting underground mining is mainly water from open-pit mines that have been exploited with a flow of about 500 000 m^3 [18]. So, in the process of digging and exploiting the longwall in coal Seam 11 at Ha Lam Coal Mine located underneath the coal Seam 14 open-pits mine of Nui Beo Coal Mine, it is necessary to have solutions to prevent the risk of water cracking into the roadways. In order to select reasonable solutions, it is necessary to study and assess the risk of water cracking from the upper open-pit mine into the longwall in coal Seam 11.

2.4. Establishing a numerical model

+ Modeling establishing steps

Numerical analyses in plane strain were conducted using the finite element Phase2 software. Modeling establishing steps to simulate rock pressure acting on the roadway include [19].

- Step 1. Determination of the study site (the roadway and the surrounding boundary);
- Step 2. Meshing the finite element and establishing the initial boundary conditions (conditions for limiting displacement at the model boundary);
- Step 3. Determination of the primary stress field conditions and groundwater level;
- Step 4. Determination of the properties of materials (Characteristics of rock mass types);
- Step 5. Digging the rock inside the roadway boundary.

+ Simulation model

Based on the typical geological cross-section of the Seam 14 open-pit mine of the Nui Beo Coal Mine in Figure 2, based on a parametric analysis in Table 1, a numerical simulation model with dimensions of 471 x 680 m has been established and is shown in Figure 4. The water level in the Seam 14 open-pit mine is at -50.

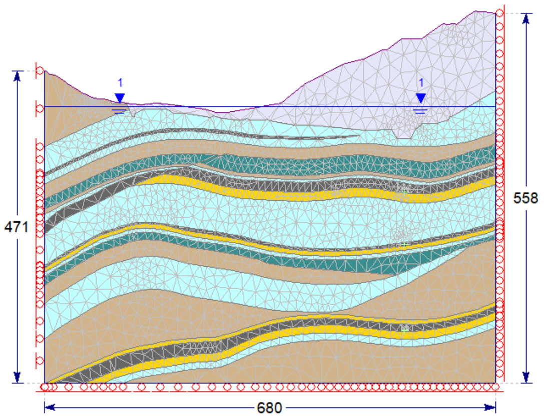

***Figure 4**. Layout of numerical simulation model*

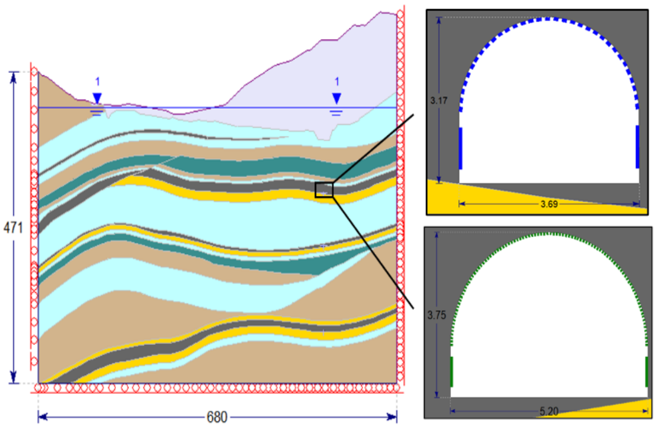

***Figure 5**. Position and size of roadway in the numerical simulation model*

The roadways cross-section was assumed as vertical sidewalls with dimensions of 3.69 m wide, 3.17 m high (corresponding to an area of 9.6 m^2, and it is also a single railway roadway) and 5.2 m wide,

3.75 m high (corresponding to an area of 17.9 m^2, and it is also a double railway roadway). The roadways have been dug at a depth of 120 m from the ground surface. The location and size of the roadway in the numerical model are shown in Figure 5. To be able to calculate the rock pressure acting on these roadways, we continue to use the computer to run the simulation model, the analysis results from the models are the basis for allowing calculation and selection the best.

3. RESULTS AND DISCUSSION

3.1. Analyze the maximum stress acting on the roadways

The maximum principal stress in the rock mass around the single railway roadway is shown in Figure 6, the double railway roadway is shown in Figure 7.

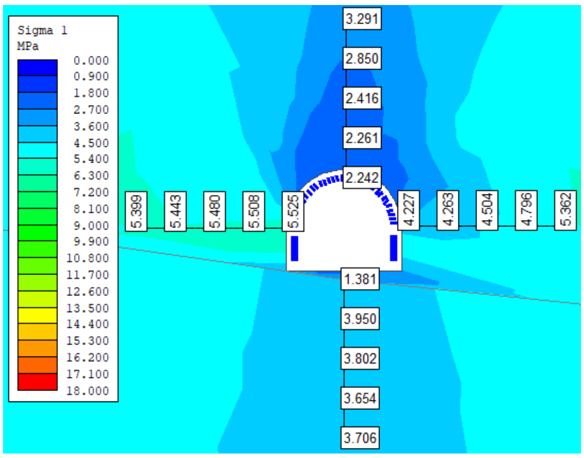

***Figure 6.** The maximum principal stress in the rock mass around the single railway roadway*

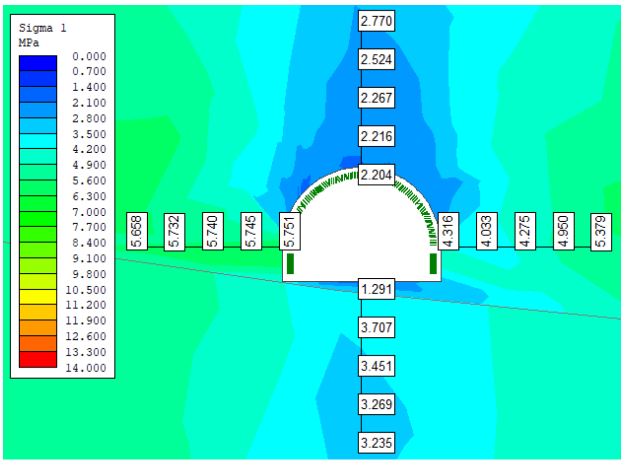

***Figure 7.** The maximum principal stress in the rock mass around the double railway roadway*

Analyzing the simulation model results from Figure 6 and Figure 7 shows that the maximum principal stress (Sigma 1) is distributed according to the law of decreasing from the rock mass to the roadway boundary. In other words, the observed principal stress on the roadway boundary has the minimum value. It is explained that when performing the digging roadway process, the primary stress in the rock mass is released, and the rock mass tends to move inside the tunnel space. At the same time, when digging the tunnel, the primary stress state of the rock mass is broken, forming a secondary stress state, the rock mass is redistributed in its stress state. As the tunnel is dug deeper into the rock mass, the influence of stress distribution gradually decreases, and the rock mass returns to its original state of primary stress.

Furthermore, when the tunnel size changes, the level of impact on the rock mass also changes, leading to stress differences. Specifically, it can be seen that the maximum principal stress at the roof and floor area of the single railway roadway is bigger than the maximum principal stress of a double railway roadway. This is explained as follows, because the roof and floor of the roadway are mainly subject to compression, the larger the cross-section of the roadway, the greater the degree of displacement of the rock mass into the roadway space. In other words, the degree of stress release is bigger than that of a roadway with a smaller cross-section.

3.2. Analyze the minimum stress acting on the roadways.

The minimum principal stress in the rock mass around the single railway roadway is shown in figure 8, the double railway roadway is shown in Figure 9.

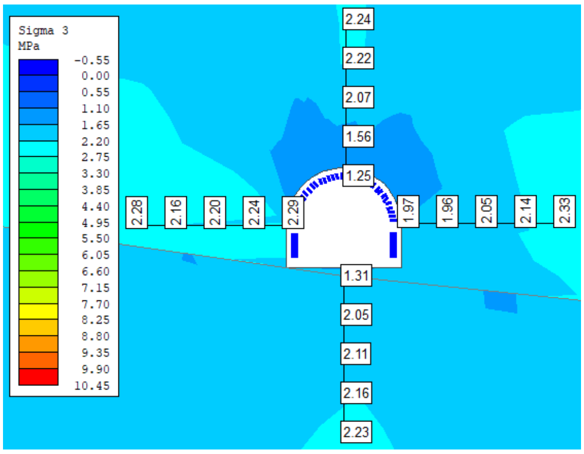

Figure 8. *The minimum principal stress in the rock mass around the single railway roadway*

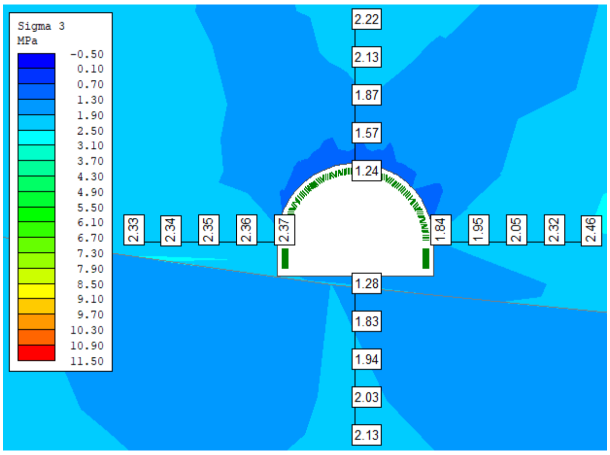

Figure 9*. The minimum principal stress in the rock mass around the double railway roadway*

Analyzing the results of the simulation model in figure 8 and figure 9, it can be seen that the minimum principal stress (Sigma 3) is distributed in the rock mass around the roadway gradually increases from the roadway boundary to deeper inside rock mass, but bigger than 15 m from the roadway boundary, the stress begins to decrease and gradually returns to the primary stress state. This can be explained that when digging the tunnel, the rock mass around the tunnel is divided into 4 zones including: crumbling zone, this area has a strong decrease in stress; plastic zone, this area the stress begins to increase; the elastic region, this region increases stress; primary stress zone, this zone is the rock mass area that is not affected by the digging work of the tunnel. Analysis results from figures 8 and 9 can be seen that the stress of the roadway boundary is biggest at the roaway roof position is 1.25 MPa, the stress on both sides of the roadway is 1.84 MPa, and the furnace floor stress is 1.31 MPa. However, analysis results from the model also show that the deeper inside the rock mass, the biggest principal stresses appear on both sides of the tunnel. This is explained that when digging the tunnel, the rock mass under the roof of the tunnel space was taken away, so the load on the roof of the tunnel is not supported by the rock mass below, but the load on the roof is transferred to the rock mass on both sides of the tunnel, so the rock mass on both sides of the tunnel are subjected to large concentrated stress.

3.3. Analyze the vertical stress acting on the roadways

The vertical stress in the rock mass around the single railway roadway is shown in Figure 10, the double railway roadway is shown in Figure 11.

Analyzing the results of the simulation model in figure 10 and figure 11, it can be seen that the vertical stress (Sigma Z) is distributed in the rock mass around the roadway also tends to increase gradually from from the roadway boundary to deeper inside rock mass, but bigger than 15 m from the roadway boundary, the stress begins to decrease and gradually returns to the primary stress state. Analysis results from figures 10 and 11 can be seen that the stress of the roadway boundary is biggest at the roaway roof position is 1.24 MPa, the stress on both sides of the roadway is 3.11 MPa, and the furnace floor stress is 1.29 MPa. However, analysis results from the model also show that the deeper inside the rock mass, the biggest principal stresses appear on both sides of the tunnel. This is explained that when digging the tunnel, the rock mass under the roof of the tunnel space was taken away, so the load on the roof of the tunnel is not supported by the rock mass below, but the load on the roof is transferred to the rock mass on both sides of the tunnel, so the rock mass on both sides of the tunnel are subjected to large concentrated stress.

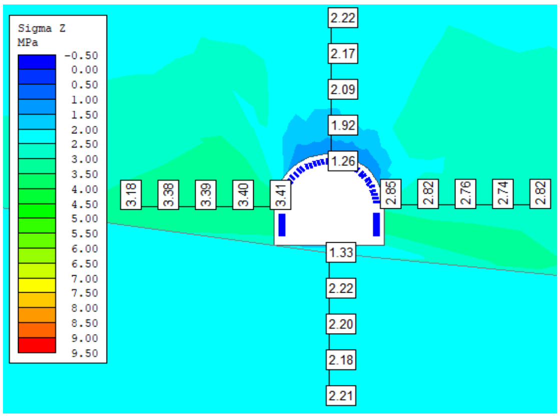

Figure 10. *The vertical stress in the rock mass around the single railway roadway*

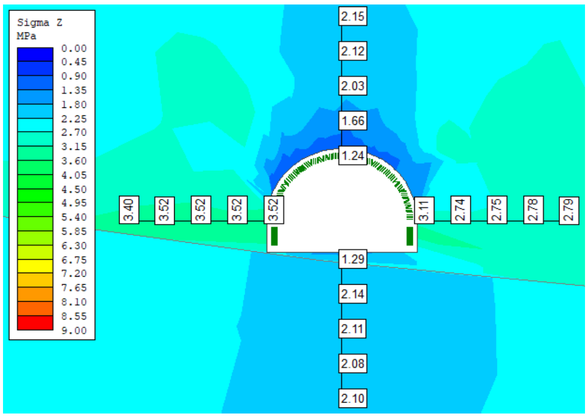

Figure 11. *The vertical stress in the rock mass around the double railway roadway*

4. CONCLUSIONS

These authors have generalized the geological conditions, hydrogeological conditions, and topography of the Seam 14 open-pit mine area of Nui Beo Coal Mine. The selection of numerical method is Phase2 software to build numerical simulation model to calculate rock pressure acting on the roadway under the Seam 14 open-pit mining area.

Based on geological conditions, topographical conditions, and groundwater conditions, the authors have built a model to calculate rock pressure acting on the roadway when exploiting coal seam 11 of Ha Lam Coal Mine under the Seam 14 open-pit mining area of Nui Beo Coal Mine. The authors have chosen a typical size to simulate and calculate the rock pressure acting on the roadway, including two types of areas: the cross-sectional size of the roadway of 9.6 m^2 (for single railway roadway) and the cross-sectional size of the roadway of 17.9 m^2 (for double railway roadway).

From the selected size, proceed with modeling to simulate the stress acting on the tunnel with the size of a single railway roadway and the tunnel with the size of a double railway roadway when digging the tunnels under the Seam 14 open-pit mining area of Nui Beo Coal Mine. Analysis results from the model show that the maximum principal stresses, minimum principal stresses, and vertical stresses all have the rule of gradually increasing from the roadway boundary to deeper inside the rock mass and decreasing gradually return to the state of primary stress at the location of the rock block more than 15 m from the roadway boundary.

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