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DETERMINATION OF STEEL ARCH SUPPORT DISTANCE FOR ROADWAYS UNDER THE OPEN-PIT MINE: A CASE STUDY AT THE MONG DUONG COAL MINE (VIETNAM)

Purpose. Nowadays, in Quang Ninh coalfield, the mining activity in quarries is increasing. For this purpose, mine roadways are dug and supported. After the mine roadways are dug, they are mainly supported by steel arches. Statistics in fact show that about 85 % of the roadway support structure at the underground coal mines in Quang Ninh are supported by the steel arch support made of SVP profile. The purpose of the study is to calculate and determine a reasonable steel support distance for the roadways located under the open-pit mine to ensure their stability and the safety of exploitation.

Methodology. In this study, the numerical simulation method was used. On the basis of Phase2 software and geological conditions of the mine, the authors established a simulation model to determine the pressure acting on the roadway and select a reasonable support distance.

Findings. The study considered different steel arch support structure distance following the structure of the rock mass under the 790 open-pit area at the Mong Duong Coal Mine, the internal forces in SVP steel arch support structure distance were also studied for one-lane railway and two-lane railways roadway. From the results of internal forces in the steel support structure, a reasonable SVP-22 steel arch distance was selected, which is 0.7 m for the one-lane railway roadway, as well as SVP-27, which is 0.7 m for the two-lane railway roadway.

Originality. Using Phase2 software, the authors created a simulation model of the roadways in Seam L7 located on the West side of Mong Duong Coal Mine, which allowed analyzing and describing the condition of the surrounding rock mass. This study utilized a numerical modeling approach to simulate and establish the bending moment and axial force of both single and double lane railway roadways, across a range of support distances. Based on the results of pressure calculation for the roadways, the authors have selected a reasonable support distance for each corresponding roadway.

Practical value. The findings of the study serve as the foundation for the practical application of production methods at the Mong Duong Coal Mine. On the basis of calculating the pressure acting on the roadways at the Seam L7 in the West Side under the 790 open-pit area, the distance of steel arch support was determined, from which the roadway support plan has been developed. This research result will also serve as a basis for other mines with similar geological conditions in Quang Ninh coalfield to consider and apply.

Keywords: *roadways, steel arch support, open-pit mine, Mong Duong Coal Mine*

Introduction. Currently, in Quang Ninh coalfield, many underground coal mines are exploiting the coal seams located under open-pit mine areas that have been dumped, especially such as the Nui Beo open-pit mine of the Ha Lam Coal Mine, the 790 open-pit mine of the Mong Duong Coal Mine, the Central Area and Northeastern Area open-pit mines of the Duong Huy Coal Mine, etc. There are many different conditions of open-pit coal mine including area, depth, the distribution of coal seams in the pits area; there are coal seams located from a few meters to hundreds of meters from the open-pit mine bottom; there are also coal seams located at the open-pit mine edge [1]. The pits are still in the process of dumping waste soil and rock. In many areas, the waste rock in the pits has stabilized. The pits have different groundwater levels depending on the topography of the open-pit compared to the surrounding ground. Thus, it can be seen that formation for each coal mine pit will have different natural and technical conditions, so the pressure acting on the support structure is also different [2, 3].

The 790 open-pit mine has been fully exploited and has also been dumped. The coal seams located below the 790 open-pit area continue to be exploited by the Mong Duong Coal Company (according to the deep mining project and the mining plan of the Mong Duong Coal Mine). The fact shows that the 790 open-pit mine has been filled with waste rock through. However, the dumping continues, so this area has formed a very large dump with its height up to hundreds of meters. In addition, the hydrogeological conditions in this area are very complicated; according to forecasts and calculations, the amount of water contained in the 790 open-pit is still high, even though it has been filled. Thus, when digging roadways under the 790 open-pit area, there will be potential risks of unsafety such as the roadways being destroyed due to increased pressure, the risk of water cracking and mud. In order for the roadways to be stable and safe during exploitation, we need to study and calculate some reasonable solutions. One of the solutions is the determination and selection of the structure of the support and reasonable distance for these roadways. This is a necessary issue for the Mong Duong Coal Mine and some other mines with similar conditions in Quang Ninh coalfield, Vietnam at the moment and in the following years.

Currently, a number of studies on bearing capacities in steel support structure have been conducted in a wide range of mines engineering [4, 5]. Many studies have used numerical modeling methods to simulate the behavior of pressure acting on the roadways and surrounding rock mass [6–8], numerical modeling method for calculation and selection of support type [9–11]. Studies on pressure calculation for deep roadways at coal mines to propose support solutions to ensure its stability [12–14]. The research proposes and selects the suitable type of support for the tunnels in complex geological conditions [15–17], as well as studies on the type of bolt to support the tunnels [18–20]. The studies calculate the effect of excavation of the tunnels on the surrounding rock mass and surface structures [21–23]. In addition, there are many other studies related to the stability of the roadways by calculating the natural equilibrium arch parameters [24, 25]. However, selection of steel support distance for roadway excavation under coal mines pit is not well understood.

Therefore, the application of the numerical method to calculate the selection of SVP steel arch support distance for the roadway excavation under and near the open-pit edge area is very important to ensure the selection of suitable steel support distance and improve the stability of the roadway during excavation as well as in use. The research results help designing, constructing companies in their selection of SVP steel arch support distance.

Research Methods. ***Introduction of the Mong Duong Coal Mine***. Vinacomin-Mong Duong Coal Joint Stock Company, formerly known as Mong Duong Coal Mine, was established on April 1, 1982. The opening area is 10.9 km^2; the North borders on Mong Duong River; the South borders with 790 factory; West borders Khe Cham Coal Company; the East borders with Bai Tu Long Bay. Location of the Mong Duong coal mine is shown in Fig. 1.

Typical geological cross-section of the 790 open-pit mine of the Mong Duong Coal Mine. According to the typical geological cross-section in the 790 open-pit mine of the Mong Duong Coal Mine, it can be seen that the bottom of the 790 pit stops mining at –25 m level.

The Mong Duong Coal Mine has dumped waste rock up to +200 m level, so the height of dumping from the deepest point of the pit bottom to the surface of the waste rock is more than 200 m.

Due to a long time of dumping, the waste rock in the 790 open-pit mine has been stabilized, but the porosity coefficient is still very large.

Therefore, the amount of water trapped in the waste rock of the 790 pit is also very large. This is one of the potential causes of the risk of water cracking when exploiting coal seams at the edge and bottom of the 790 open-pit mine. In addition, the water contained in the waste rock of the 790 pit is also one of the causes of the mine pressure acting on the roadway support structure in excavation under the pit. The Mong Duong Coal Mine is one of the mines that are forecasted to have potential risks of water cracking and mud in Quang Ninh coalfield. In fact, the phenomenon of water cracking occurred at the Mong Duong Coal Mine in 2006. Over the past years, the Mong Duong Coal Mine has actively researched and applied mining options, drainage solutions, as well as an option for roadway protection to minimize the risk of water cracking that may occur at the mine.

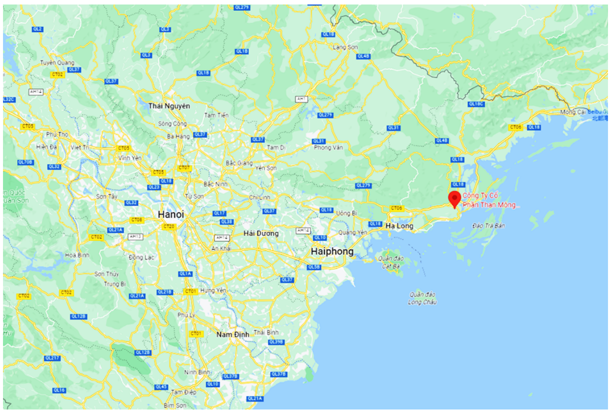


Fig. 1. The geographic position of Mong Duong Coal Mine

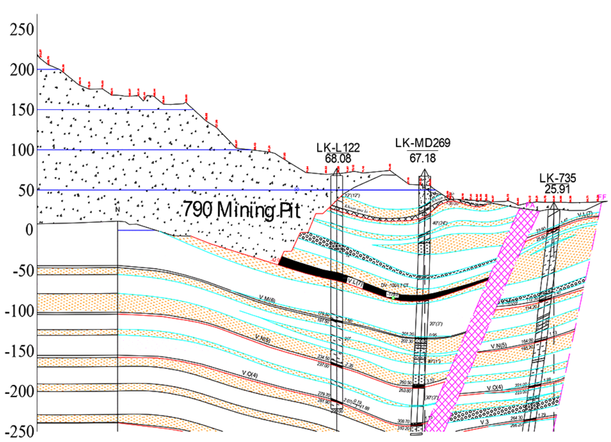


Fig. 2. The typical geological cross-section of the 790 open-pit mine filled with waste rock

The typical geological cross-section in the 790 open-pit mine is shown in Fig. 2.

On the typical geological cross-section in the 790 pit, it can be seen that the coal Seam L7 at the 790 open-pit edge in West side of the Mong Duong Coal Mine has been partially exploited by the open mining method; the remaining coal will be exploited by the underground mining method. The Seam L7 has an average thickness of about 7 m, an average slope is about 15°.

In order to ensure safety of mining the remaining of the Seam L7 by the underground mining method, it is necessary to provide protective coal pillars for the roadway, in the mining plan of the Mong Duong Coal Mine, the coal pillar protects the roadway at 50 m from the open-pit edge [26, 27].

Geological conditions of the study site. The study site includes layers of rocks including cobblestone, gravelstone, sandstone, siltstone, claystone and coal.

Cobblestone: The cobblestone is gray to light gray in color, the grain composition is mainly quartz. The quartz grains are relatively rounded, the grain diameter is irregular, the grain size varies within 2–15 mm. In the rock there are many cracks, in the cracks there are many traces of iron oxide, gray-brown color.

Gravelstone: This is a relatively common rock in the stratigraphic column, the graininess transitions from cobblestone to sandstone. The sandstone is light gray in color, the grain composition is mainly quartz, silicon, with irregular grain size, sharp edges. The rock has a solid block structure.

Sandstone: This is the most widely distributed and common rock in the stratigraphic column. The stone is light grey to dark grey. The grain composition is mainly quartz sand, the grain size is uniform, the cohesion is tight, the structure is thick layered. In rocks, there are usually few cracks that are filled by quartz and iron oxide veins.

Siltstone: This is a rock usually distributed in stratigraphy between coal seams or close to the roof and floor of coal seams. The stone is gray to dark gray in color, with layered structure, relatively solid cohesion. The rock contains fossils of plants. Occasionally there is iron oxide mineralization and piercing quartz veins.

Claystone: This type of rock is usually located near the roof and floor or sandwiched in coal seams. The rock is gray to dark gray in color, fine-grained, strongly compressed, so it has a schist structure.

Coal: Coal seams are often formed adjacent to layers of fine-grained rock such as siltstone, claystone and locally sandstone. In the stratigraphic column of the mine area, there are 13 coal seams, the order of seams from seam 1 to seam Y (13), of which 11 are of industrial value. The existence and distribution of coal seams from relatively stable to very unstable over the mine area and the distance between the seams is less uniform. Coal is anthracite to semi-anthracite. Coal has black color, metallic luster, shell-shaped fracture, ladder shape, block structure, thick layering; it is brittle, easy to break, medium to weak hardness, mostly bran coal, black color. The average thickness of coal seams is from 1.45 to 4.64 m.

SVP steel properties. Currently, the predominant method for supporting underground coal mines in Vietnam is through the use of yielding steel arch support crafted from SVP profiles (namely SVP17, SVP22, SVP27, and SVP33). In general, a single railway of roadway is upheld by yielding steel arch support composed of SVP22 or SVP17, while two-lane railways of roadway are upheld by yielding steel arch support constructed from SVP27 or SVP33. SVP steel properties are shown in Table 1.

Table 1

The SVP-22 and SVP-27 steel arch support properties

Descriptions	Symbol	SVP22	SVP27
High, mm	*h*	110	123
Area of cross-section, cm^2	*S*	27.91	34.37
Anti-bending moment, cm^3	W_x	74.8	100.2
Inertia of moment, cm^4	I_x	428.6	646.1
Young's module, MPa	*E*	210,000	
Poisson's coefficient	ν	0.25	
Compression strength, MPa	σ_c	500	
Tensile strength, MPa	σ_t	500	

Building a numerical model. Numerical analyses in plane strain were conducted using the finite element Phase2 software. Modeling steps to simulate mine pressure acting on the roadway include:

Step 1. Determining the study site (the roadway and the surrounding boundary).

Step 2. Meshing the finite element and setting the initial boundary conditions (conditions for limiting displacement at the model boundary).

Step 3. Determining the primary stress field conditions and groundwater level.

Step 4. Determining the properties of materials and structures for support.

Step 5. Digging the soil and rock inside the roadway boundary and installation of the supporting structure (if any).

Based on typical geological cross-section of the 790 open-pit mine of the Mong Duong Coal Mine in Fig. 2, on the basis of a parametric analysis, numerical models with dimensions of 469 × 529 m have been developed and are shown in Fig. 3. The water level in the 790 open-pit mine is at +20.

The option to support roadways dug under the 790 open-pit mine of the Mong Duong Coal Mine includes:

- the one-lane railway roadway with SVP-22 steel structure, steel arch distance is calculated and compared in the case of 0.3, 0.5 and 0.7 m;

- the two-lane railway roadway with SVP-27 steel structure, steel arch distance is calculated and compared in the case of 0.3, 0.5 and 0.7 m.

This research has a purpose to choose the steel arch support distance for the roadway excavation in coal Seam L7. The shape of the roadway is an arch-profile crown, with a cross section of one-lane and two-lane railway roadway.

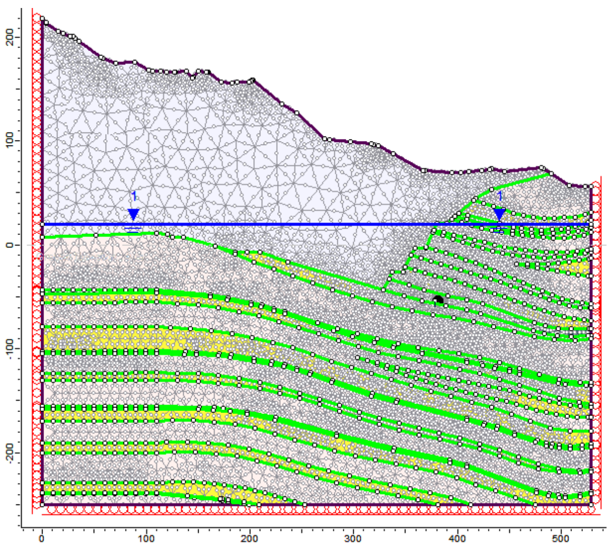


Fig. 3. Layout of numerical model

The roadway cross section was assumed as vertical sidewalls with dimension of 3.69 m wide, 3.17 m high and 5.2 m wide, 3.75 m high. It has been excavated at a depth of 110 m from the ground surface. The numerical analyses were performed for steel arch support made of SVP roadway. The location and size of roadway in the numerical model are shown in Fig. 4.

The numerical model is built for a typical cross-section of the mining area located under the 790 open-pit mine of the Mong Duong Coal Mine. The size of the simulation model is very important, it affects the accuracy of the analysis results. To determine the reasonable size of the model, the authors performed a series of tests on numerical models with different sizes. From there, it is possible to determine the minimum model size while ensuring the required accuracy. The size of the 790 open-pit mine simulation model of the Mong Duong coal mine is a two-dimensional flat deformation model simulated according to the actual cross-sectional dimensions with a width of 529 m and a maximum height of 469 m. The location of excavation of the roadways is at –50 level at the East side of Seam L7. On the basis of the fact that using the cross-sectional dimensions of a single railway and two-lane railway roadways at the Mong Duong Coal Mine, the simulation model is built for these roadways, corresponding to the area of cross-sections of the roadways being 9.6 and 17.9 m^2. Fig. 4 also shows the dimensions of those roadways. To be able to choose the steel arch distance for these tunnels, we continue to use the computer to run the simulation model, the analysis results from the model are the basis for allowing calculation and selection the best.

Results and discussion. Numerical analysis was carried out to investigate the behavior of the rock mass enclosing the underground workings, the stress levels of the steel arch support, and the interaction between the steel arch support and the rock mass. This analysis utilized Phase2 software, which is based on finite element method algorithms.

The analysis utilized the distribution of internal forces among the elements of the steel arch support, which was obtained through calculations. The detailed analysis results are as follows:

For One railway roadway: Figs. 5 and 6 illustrate the numerical calculation results in the form of graphs depicting the axial forces and bending moments of a single railway roadway.

From the results of the axial force distribution chart shown in Fig. 5, it can be seen that the axial force in the supporting structure has the largest value at the arch foot. Specifically, with steel arch distance of 0.3, 0.5 and 0.7 m axial forces are equal to 0.33324 (Fig. 5, *a*), 0.41572 (Fig. 5, *b*) and 0.44278 MN (Fig. 5, *c*).

From the results of the bending moments distribution chart shown in Fig. 6, it can be seen that the bending moments in the supporting structure have the largest value at the arch foot. Specifically with steel arch distance of 0.3, 0.5 and 0.7 m bending moments are equal to 0.0002 (Fig. 6, *a*), 0.0003 (Fig. 6, *b*) and 0.00039 MNm (Fig. 6, *c*).

The calculated values of maximum axial forces and maximum bending moments for one-lane railway roadway of steel arch support made of SVP22 profile are presented in Table 2.

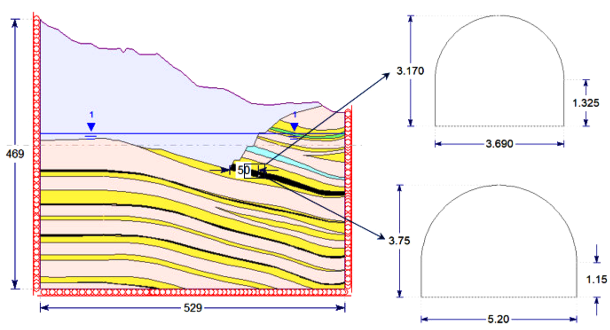


Fig. 4. Location and size of roadway in the numerical model

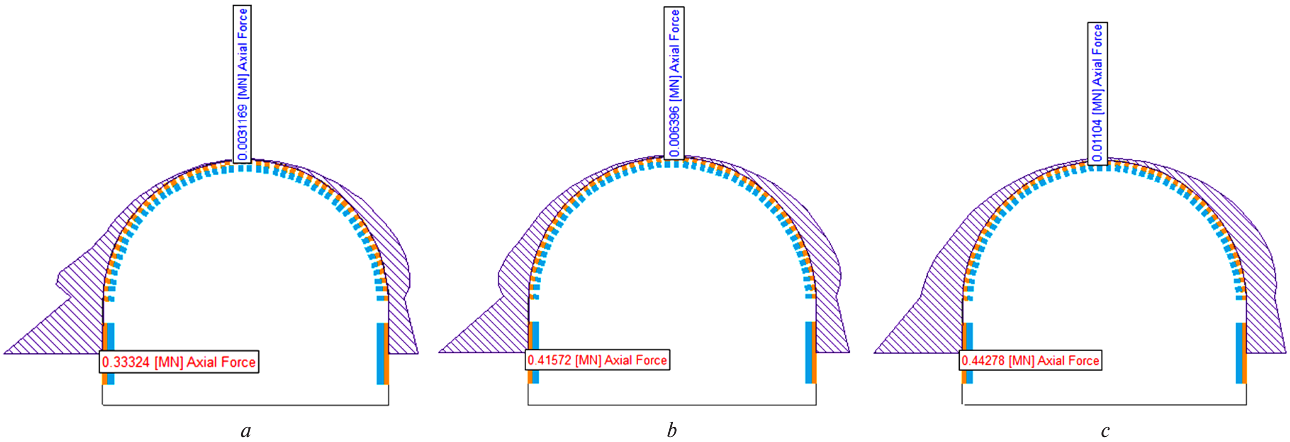


Fig. 5. Axial forces in the elements of steel arch made of SVP22:
a, b, c – steel arch distance 0.3, 0.5 and 0.7 m

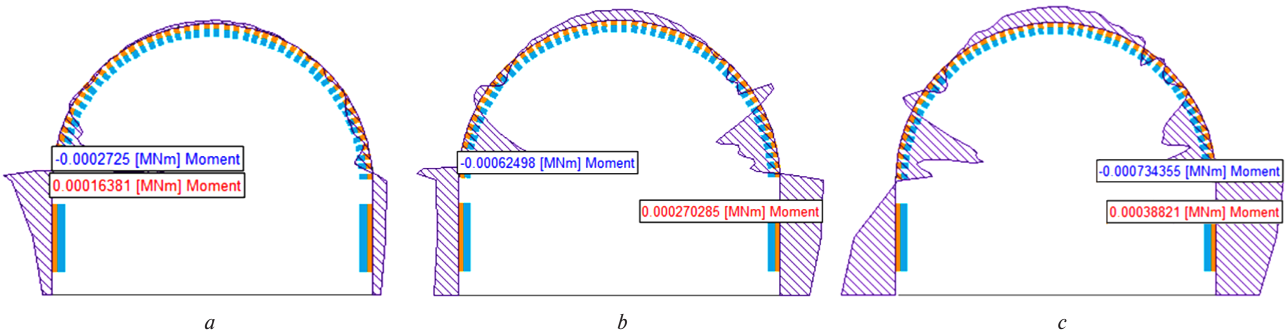


Fig. 6. Bending moments in the elements of steel arch made of SVP22:
a, b, c – steel arch distance 0.3, 0.5 and 0.7 m

From the table of internal forces in the steel arch support structure corresponding to the types of SVP22 steel distance for the one-lane railway roadway, it can be seen that when the distance between the steel arch support increases, the moment and axial force in the internal structure also increase, or when the distance of the steel arch support increases, the rock mass pressure surrounding rocks acting on the supporting structure also increases, thereby causing the internal force to increase accordingly. Specifically, the maximum moment value in the case of 0.3 m steel arch support distance is 0.0002 MNm, the maximum moment value in the case of 0.5 m steel arch support distance is greater by more than 1.5 times compared to the 0.3 m distance and the maximum moment value in case the 0.7 m steel arch support distance is 1.95 times greater than the 0.3 m distance.

The axial force value in case of 0.3 m distance is 0.333 MN, the axial force value in case of 0.5 m steel arch support distance is 1.24 times greater than 0.3 m distance and the axial force value in case the 0.7 m steel arch support distance is 1.32 times greater than the 0.3 m distance.

For two-lane railway roadway: Figs. 7 and 8 depict the bending moments and axial forces of two railways of roadway, respectively, as obtained through numerical calculations.

From the results of the axial force distribution chart shown in Fig. 7, it can be seen that the axial force in the supporting structure has the largest value at the arch foot. Specifically with steel arch distance of 0.3, 0.5 and 0.7 m are equal to 0.17232 (Fig. 7, *a*), 0.24692 (Fig. 7, *b*), and 0.34636 MN (Fig. 7, *c*).

Table 2

SVP22 steel arch support of maximum internal forces

Steel arch distance	0.3 m	0.5 m	0.7 m
Axial forces, MN	0.33324	0.41572	0.44278
Moments, MNm	0.0002	0.0003	0.00039

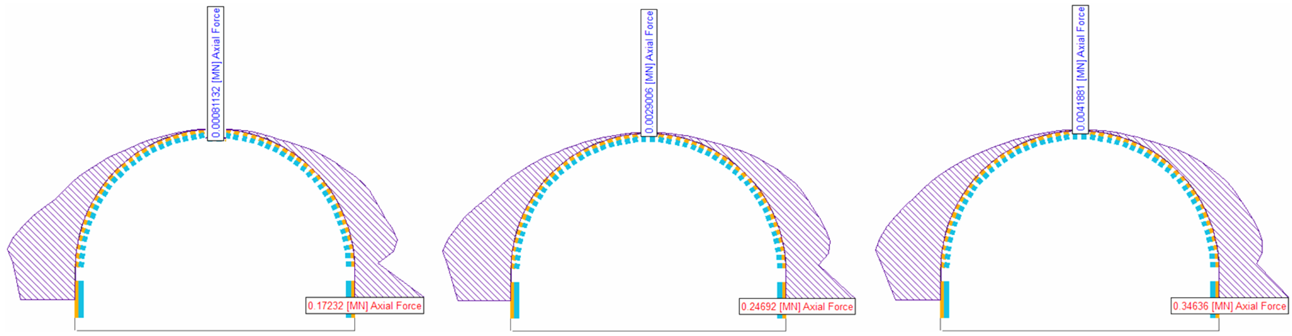
From the results of the bending moments distribution chart shown in Fig. 8, it can be seen that the bending moment in the supporting structure has the largest value at the arch foot. Specifically with steel arch distance of 0.3, 0.5 and 0.7 m, they are equal to 0.0003 (Fig. 8, *a*), 0.00045 (Fig. 8, *b*) and 0.00063 MNm (Fig. 8, *c*).

The calculated values of maximum axial forces and maximum bending moments for two-lane railway roadway of steel arch support made of SVP27 profile are presented in Table 3.

From the table of internal forces in the steel arch support structure corresponding to the types of SVP27 steel arch distance for the two-lane railway roadway, it can be seen that when the distance between the steel arch support increases, the moment and axial force in the internal structure also increase, or when the distance of the steel arch support increases, the rock mass pressure of surrounding rocks acting on the supporting structure also increases, thereby causing the internal force to increase accordingly. Specifically, the maximum moment value in the case of 0.3 m steel arch support distance is 0.0003 MNm, the maximum moment value in the case of 0.5 m steel arch support distance is 1.5 times greater than the 0.3 m distance and the maximum moment value in case the 0.7 m steel arch support distance is 2.1 times greater than the 0.3 m distance.

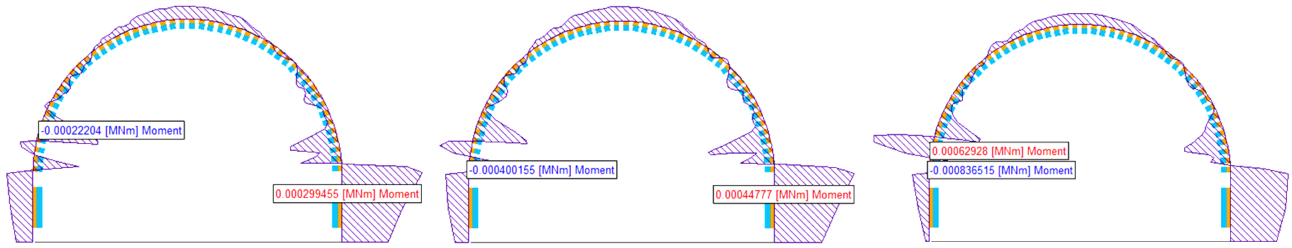
The axial force value in case of 0.3 m distance is 0.17232 MN, the axial force value in case of 0.5 m steel arch support distance is 1.43 times greater than 0.3 m distance and the axial force value in case the 0.7 m steel arch support distance is 2 times greater than the 0.3 m distance.

Testing the durability assessment and determining the steel arch support distance when mining under the 790 open-pit mine



a *b* *c*

Fig. 7. Axial forces in the elements of steel arch made of SVP27:
a, b, c – steel arch distance 0.3, 0.5 and 0.7 m



a *b* *c*

Fig. 8. Bending moments in the elements of steel arch made of SVP27:
a, b, c – steel arch distance 0.3, 0.5 and 0.7 m

Table 3

SVP27 steel arch support of maximum internal forces

Steel Arch distance	0.3 m	0.5 m	0.7 m
Axial forces, MN	0.17232	0.24692	0.34636
Moments, MNm	0.0003	0.00045	0.00063

of the Mong Duong Coal Mine. Summary table of internal force calculation results and durability test in the case of the one-lane railway and the two-lane railway roadway with different steel arch support distance are presented in Table 4.

In Table 4 σ_{max} is the stress in the steel arch support structure was determined as follows [28]

$$|\sigma_{max}| = \left| \frac{N}{F} + \frac{M_{max}}{W_x} \right|, \quad (1)$$

where σ_{max} is the stress in the structure at the point of maximum moment; N is axial forces in the structure at the maximum bending moments, MN; M_{max} is maximum moment in the steel arch support structure, MNm; F is a cross-sectional area of steel arch structure, cm^2 (SVP22 – F = 27.91 cm^2; SVP27 – F = 34.37 cm^2); W_x is section modulus, SVP22 – W_x = 74.8 m^3; SVP27 – W_x = 100.2 m^3.

Table 4

The SVP-22 and SVP-27 steel arch of force and durability test

Section, m^2	a m	Steel arch	N, MN	M_{max}, MNm	σ_{max}, MPa	K
9.6 (one-lane railsway)	0.3	SVP22	0.333	0.0002	119.3	2.3
	0.5		0.415	0.0003	148.7	1.8
	0.7		0.442	0.0004	158.4	1.7
17.9 (two-lane railsway)	0.3	SVP27	0.172	0.0003	50	5.5
	0.5		0.246	0.0004	71.6	3.8
	0.7		0.346	0.0006	100.7	2.7

The factor of safety K is calculated according to the following formula [28]

$$K = \frac{[\sigma]}{[\sigma_{max}]}, \quad (2)$$

where $[\sigma]$ is bending strength of steel, for a low alloy steel plate, 100–120 mm thickness: 275 MPa.

From the calculation results in Table 4, we can determine the type of steel arch and its distance for the roadway areas under the 790 open-pit mine of the Mong Duong Coal Mine as follows:

- for the one-lane railway roadway: the safety factor K of the one-lane railway roadway with a cross section of S = 9.6 m^2 using SVP22 steel arch is 1.7, so the steel arch distance is 0.7 m;
- for the two-lane railways roadway: the safety factor K of the two-lane railways roadway with a cross section of S = = 17.9 m^2 using SVP27 steel arch is 2.7, so the steel arch distance is 0.7 m.

Passport of roadway support. Thus, after determining the type of steel arch and its distance for the roadway, we can build a passport of those roadways. The passports are shown in Figs. 9 and 10.

The calculation and selection of the type of support as well as the establishment of a passport of roadway support is very necessary and important in underground mining method. When exploiting the coal seams located under the open-pit mine area, the calculation, selection and establishment of a passport of roadway support becomes more difficult and complicated. In Figs. 9 and 10 the support passports are shown for a single railway and two-lane railways roadways with sections of 9.6 and 17.9 m^2, the steel arch distance is 0.7 m. These tunnels are located under the edge of the 790 open-pit mine, which has a potential risk of water cracking into underground workings during the mining process.

Currently, in the Mong Duong Coal Mine and some other coal mines in Quang Ninh coalfield, the tunnels are dug at a deep level (level –300), so they are often under great pressure (mainly influenced by the stratigraphic displacement by mining); as a result, they are often deformed, and the cost of keep-

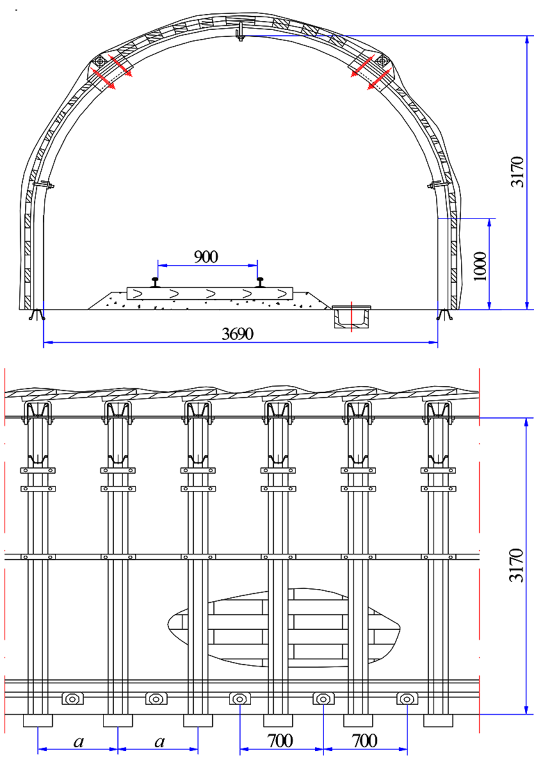


Fig. 9. SVP-22 steel arch support passport with steel arch distance 0.7 m (one-lane railway roadway)

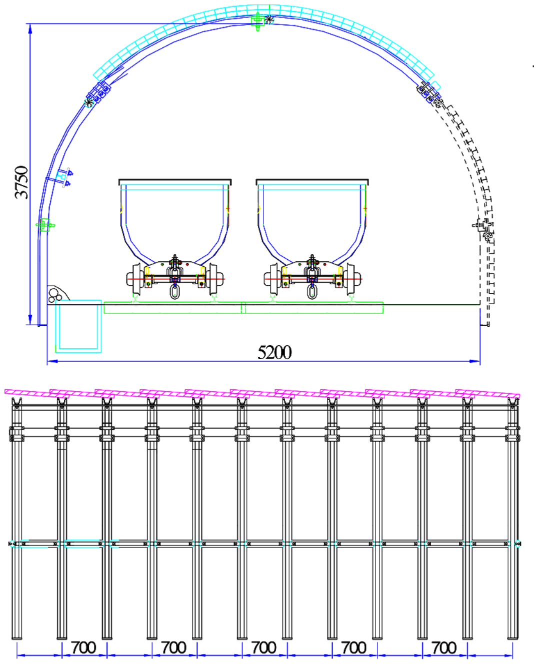


Fig. 10. SVP-27 steel arch support passport with steel arch distance 0.7 m (two-lane railway roadway)

ing and protecting them is high. In addition, there are tunnels dug under the open-pit mine area and under the dumping area. This is also a problem that is being concerned by researchers and they have also proposed a solution to handle. In the paper, the authors calculated the mine pressure acting on the roadways by the numerical simulation method. However, this method requires input information, as well as reliable geological conditions, the results of numerical model analysis will achieve a higher and more accurate level.

Conclusions. In this study, the authors selected the option to support the roadways dug under the 790 open-pit area of the Mong Duong Coal Mine. On the basis of numerical model analysis, calculation and selection for SVP-22 steel arch, its distance is 0.3, 0.5 and 0.7 m for one-lane railway roadway. Used for SVP-27 steel arch, its distance is 0.3, 0.5 and 0.7 m for two-lane railways roadway.

From the results of calculation of internal force in the supporting structure, it is shown that when the steel arch distance increases, the internal force in the structure also increases. Therefore, when increasing the steel arch distance, the support has to bear a larger load, the internal force in the supporting structure also increases.

From the results of the internal force calculation in the supporting structure, in this study, the authors tested and evaluated the durability of the SVP-22 steel arch structure for the one-lane railway roadway, with an area of 9.6 m^2 and the SVP-27 steel arch structure for the two-lane railways roadway with an area of 17.9 m^2. On that basis, it is determined that the steel arch distance is 0.7 m by the SVP-22 steel arch for the one-lane railway roadway with an area of 9.6 m^2 and 0.7 m by the SVP-27 steel arch for the two-lane railway roadway with an area of 17.9 m^2. This is the basis for the authors to build a passport to support the tunnels dug under the 790 open-pit area of the Mong Duong Coal Mine.

The findings of the study can be utilized by the Mong Duong Coal Mine in their actual production process to ensure the safety of tunnels excavated under the open-pit region. At the same time, this study is also used as a reference for other mines with similar conditions in the Quang Ninh coalfield.

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Визначення відстані між арочним кріпленням у гірничих виробках під кар'єром: тематичне дослідження на вугільній шахті Монг Дуонг (В'єтнам)

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Мета. У даний час у вугільному басейні Куангнінь зростає гірничодобувна діяльність на кар'єрах. З цією метою готують і впорядковують шахтні виробки. Після підготовки шахтних виробок їх в основному підтримують рамним арочним кріпленням. Статистика показує, що близько 85 % конструкцій виробок на підземних вугільних шахтах у Куангнінь підтримуються металевим арочним кріпленням зі спецпрофілю СВП. Мета даного дослідження – розрахувати та обґрунтувати прийнятну відстань між арочним кріпленням для виробок, що знаходяться під кар'єром, щоб забезпечити їх стабільність і безпеку експлуатації.

Методика. У цьому дослідженні використовувався чисельний метод моделювання. На основі програмного забезпечення Phase2 і геологічних умов шахти автори створили імітаційну модель, щоб визначити тиск, що діє на виробку, і вибрати прийнятну відстань між рамами.

Результати. У ході моделювання розглядалися різні відстані між металевим арочним кріпленням, ураховуючи структуру гірничої маси під розрізом № 790 на вугільній шахті Монг Дуонг, а також досліджувалися внутрішні напруження в рамній конструкції з металевих арок спецпрофілю СВП для проведення гірничих виробок з однією і двома коліями. На основі результатів дії внутрішніх сил у металевому рамному кріпленні була обрана прийнятна відстань між металевими арками СВП-22, що дорівнює 0,7 м для виробки з однією колією і СВП-27, що дорівнює 0,7 м для виробки із двома коліями.

Наукова новизна. На основі програмного забезпечення Phase2 автори розробили імітаційну модель для гірничих виробок, які проходять пластом L7 на Західній стороні вугільної шахти Монг Дуонг, що дозволило проаналізувати та описати стан масиву гірських порід. У даному дослідженні застосовується чисельний метод моделювання для симуляції й визначення згинальних моментів та осьових сил у гірничих виробках з однією та двома коліями при різних відстанях між рамами. Виходячи з результатів розрахунку тиску на вироблення, автори обрали прийнятну відстань між рамами для відповідних виробок.

Практична значимість. Результати дослідження використовуються як основа для впровадження у виробництво на вугільній шахті Монг Дуонг. На основі розрахунку тиску, що діє на виробки пласта L7 на Західній стороні під розрізом № 790, була визначена відстань між металевим арочним кріпленням, на основі якої був розроблений план підтримки виробок. Ці результати дослідження також стануть основою для розгляду та впровадження іншими шахтами з аналогічними геологічними умовами у вугільному басейні Куангнінь.

Ключові слова: *шахтні виробки, металеве арочне кріплення, кар'єр, вугільна шахта Монг Дуонг*

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