UDC 622.831.24
DOI: https://doi.org/10.15407/geotm2023.165.051

STUDY OF PERMANENT WORKINGS STABILITY WHEN THEY ARE DRIVEN THROUGH THE GOB OF RELIEVING LONGWALL

[1]Krukovskyi O.P., [1]Krukovska V.V., [1]Kurnosov S.A., [2]Yanzhula O.S., [1]Bulich Yu.Yu.
[1]M.S. Poliakov Institute of Geotechnical Mechanics of the National Academy of Sciences of Ukraine, [2]Coal Directorate METINVEST HOLDING LLC

Abstract. The method of permanent workings construction, the type of supporting, as well as their location relatively to the boundaries of stoping operations zones greatly affect their stability. In this work, a numerical simulation of the stress state of the layered rock mass with permanent workings located in the gob of previously mined longwall was completed to study these mine workings stability outside the influence of stoping operations and in the zone of their influence. As an example, the mining and geological conditions were considered for the central panel of block 11 in PJSC Colliery Group "Pokrovske", where four permanent mine workings are planned. A series of calculations were performed with variations of such technological parameters as the distance between mine workings, the impact of stoping operations, and the pillar size between the gob of the relieving longwall and the active front of working face.

It is shown that a change in the distance between permanent mine workings in the range of 50–70 m does not affect the lack of mutual influence between these mine workings. When the front of stoping operations in the adjacent longwall approaches the permanent workings, the load on the support pillar between the boundary of stoping operations and the gob of relieving longwall, as well as on support of first permanent mine working, increases considerably. If the support pillar size is 80 m, the impact of the stoping operations spreads close to the first permanent working and affects the stability of the second permanent working. The approach of active longwall leads to an additional lowering of the first mine roof by 120–208% compared to the level at the stage of stabilization of the stress-strain state. The region of increased difference in main stresses around the first permanent working occupies a large area; its stability deteriorates, although thanks to the bolting, the monolithic rock-bolt arch is still preserved in its roof. However, the pillar size of 80 m is critical (for the mining and geological conditions adopted in this work); further reduction of the pillar size will lead to loss of stability of the first permanent mine working. An increase in the depth of permanent workings by 300 m, in addition to a natural increase in the initial stress state of the rock mass, also leads to a 10–12% increase in the boundaries of the influence of the abutment pressure.

Keywords: gob of relieving longwall, numerical simulation, rock bolting, stoping operations, support of permanent workings.

1. Introduction

The method of permanent workings construction, the type of supporting, as well as their location relatively to the boundaries of stoping operations zones greatly affect their stability. Preservation of mine workings during their operation depends on the type, construction and strength of support. But the adopted method of protecting permanent workings from harmful effect of rock pressure has a decisive influence on their condition during stoping operations. The following methods are usually applied to protect permanent mine workings at great depths:

- protection with large pillars [1–3];
- preliminary and following overworking of mine workings [4–6];
- arrangement and support of mine workings within the caved and consolidated rock thickness of previously mined longwall [7];
- protection of mine workings with gob packs within the regional de-stressed zone [8–9].

In the deep horizons of the coal mines, the traditional method of protecting the permanent workings and main drifts with coal pillars and occasionally gob packs is still widely used. Coal pillars with a width of up to 60–80 m, which are left by stoping operations, often cannot withstand the rock pressure and ensure the proper stability of the mine workings [4]. The stability of permanent mine workings under the condition of using this method of protection was considered in the article "Substantiating the parameters for selecting a pillar width to protect permanent mine workings at great depths" [3]. For deep mines, the most promising and economical is the pillarless mining of prepared reserves of the horizon, panel, and block.

It is considered that the most effective way to protect permanent mine workings is their location in regional de-stressed zones. These are the methods of preliminary or following overworking of permanent mine workings by relieving longwalls or their location in the caved and consolidated rocks of previously mined longwall. De-stressed zones are created by mining coal with relieving longwalls (150–250 m). Relieving longwalls, as a rule, do not adjoin the gob of previously mined longwalls [4]. At the same time, if the longwalls neighbouring the de-stressed zone are mined according to the pillarless technology, the activation of displacements and the rock pressure leads to a change in the parameters of the de-stressed zones. Under the influence of stoping operations, these zones can completely disappear or even transform into zones of increased rock pressure. This negatively affects the stability of mine workings and causes the need for repair work. Therefore, in the process of mining operations, regional de-stressed zones should be preserved and the efficiency of supporting should be increased.

The formation of the stress field in the layered coal-rock massif during stoping operations and heading occurs under the joint influence of a number of mining, geological and technical factors. This necessitates a thorough study of geomechanical processes when choosing a method for protecting permanent workings and ensuring their stability during a long period of their operation. Therefore, the aim of this work was to study numerically the stress state of the layered rock massif with permanent workings located in the gob of previously mined longwall to ensure their long-term stability outside the influence of stoping operations and in the zone of their influence.

2. Methods

A stress state of the rock mass near the mine working is described by a system of equations [10, 11]:

$$\sigma_{ij,j} + X_i(t) = 0, \tag{1}$$

where $\sigma_{ij,j}$ – are derivatives from the components of a tensor of main stresses along the horizontal axis x and vertical axis y, Pa/m; $X_i(t)$ – is projections of external forces acting on the unit of body volume, N/m^3.

Boundary conditions for this problem are as follows:

$$u_x\big|_{\Omega_1} = 0; \quad u_y\big|_{\Omega_2} = 0; \tag{2}$$

where u_x, u_y are components of the vector of displacements, m; Ω_1 is vertical boundaries of the external contour; Ω_2 is horizontal boundaries of the external contour.

A Coulomb-Mohr criterion is used to describe mathematically a process of rock transition into a disturbed state [12, 13]. A stress state of rocks is analysed with the help of following geomechanical parameters characterizing different-component nature of a stress field of the rocks [14]:

$$Q^* = \frac{\sigma_1 - \sigma_3}{\gamma H}, \tag{3}$$

where σ_1, σ_3 are maximum and minimum components of a tensor of the main pressures, Pa; γ is average weigh of the overlying rocks, N/m^3; H is mining depth, m.

The problem is solved in the elastoplastic statement with the application of a finite element method [15–17] with the help of author's software. The model has been calibrated to meet the real conditions of block 10 in PJSC Colliery Group "Pokrovske".

3. Problem definition

The preparation of an inclined part of a field, panel, or block is usually performed with two or three inclined mine workings. In rocks with high gas-bearing capacity, four mine workings are sometimes driven. For example, we considered the mining and geological conditions of the central panel of block 11 in PJSC Colliery Group "Pokrovske", where four permanent mine workings are planned at a depth of 930–1230 m. The calculation of their stability was performed in the case of their location in the gob of a previously mined relieving longwall. The following situations were simulated:

1) the mine workings are outside the influence of stoping operations;

2) the mine workings are in the zone of influence of stoping operations.

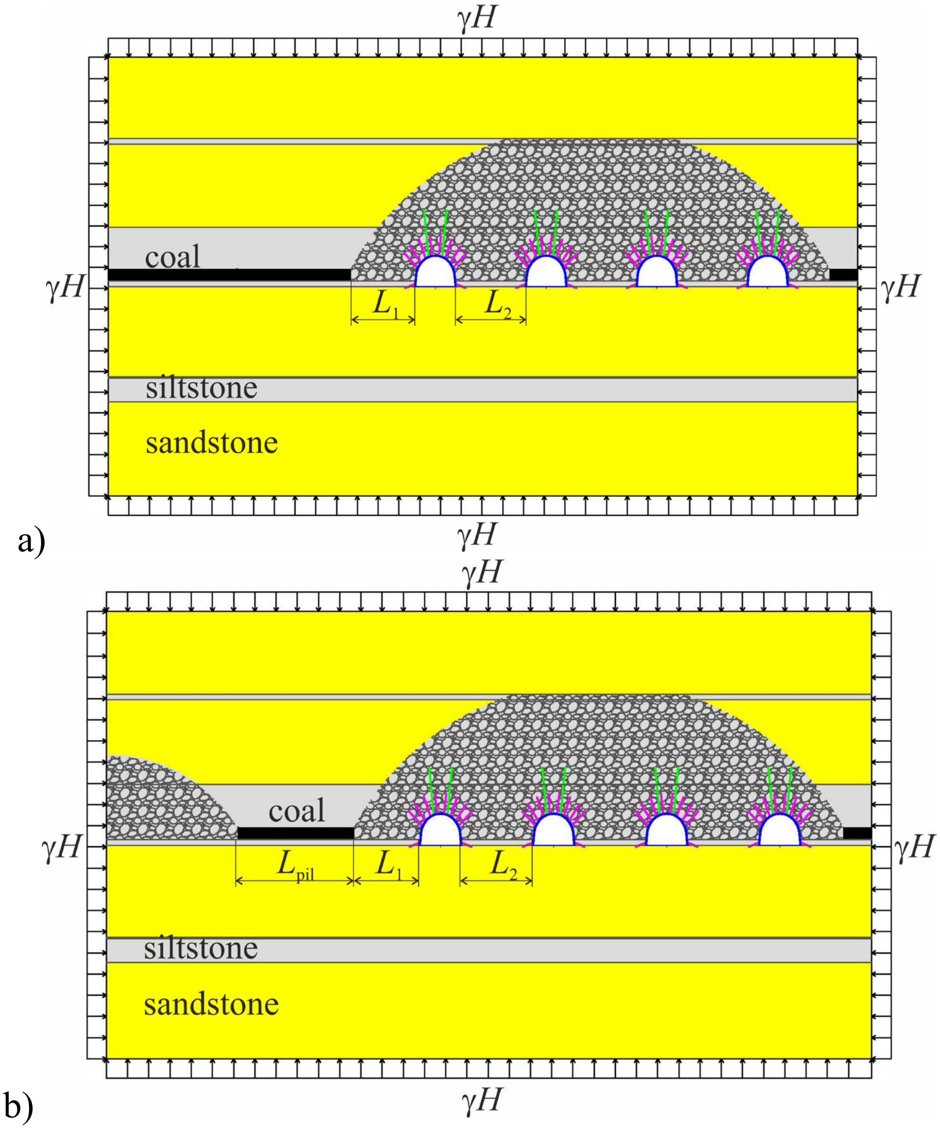
Table 1 shows the properties of the rocks which are used during the calculation.

Table 1 – Mechanical parameters of rock

Rock	Thickness m, m	Axial compressive strength σ_c, MPa	Deformation modulus E, MPa	Poisson's ratio of rock mass, v	Cohesion C, MPa	Friction angle ϕ,°
Sandstone	20	82	$1.3\cdot10^4$	0.36	21.3	35
Siltstone	0.8	50	$1.1\cdot10^4$	0.32	14.9	28.5
Sandstone	12	90	$1.3\cdot10^4$	0.36	23.4	35
Siltstone	6.0	35	$1.1\cdot10^4$	0.32	10.4	28.5
Coal	1.6	12	$0.3\cdot10^4$	0.25	3.6	28.5
Siltstone	0.8	27	$1.1\cdot10^4$	0.32	8.0	28.5
Sandstone	13	80	$1.3\cdot10^4$	0.36	20.8	35
Coal	0.2	12	$0.3\cdot10^4$	0.25	3.6	28.5
Siltstone	3.4	35	$1.1\cdot10^4$	0.32	10.4	28.5
Sandstone	13	82	$1.3\cdot10^4$	0.36	21.3	35

The calculation schemes are represented in figure 1.

The use of a combined bolting and frame support with an installation step of 0.5 m is provided for supporting the permanent mine workings [18, 19]. It includes frame support KSPU-M-20.3 of profile SVP-33. In each row, 8 steel-polymer bolts, being of 2.9 m long, are installed in the mine roof, 2 steel-polymer bolts, being of 1.5 m long, are installed under the coal bed and 2 cable bolts, being 7 m long, are installed in the mine roof, figure 2.

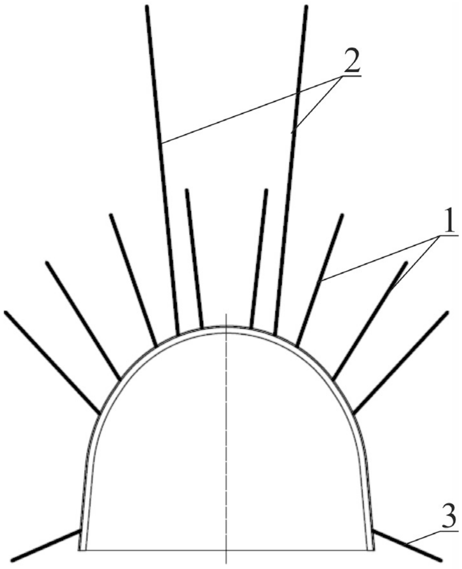


a) outside the influence of stoping operations; b) in the zone of influence of stoping operations

L_1 – the distance between the first mine working and the coal seam; L_2 – the distance between mine workings; L_{pil} – the pillar length

Figure 1 – Calculation scheme

Simulation was performed in three steps. First, the influence of the relieving longwall on the host rocks was calculated. At the second step, the driving of four permanent workings in the consolidated rocks in the gob of relieving longwall was simulated. To simulate the properties of the rocks in the gob of the previously mined relieving longwall, the compressive strength of sandstone and siltstone was reduced by 2 times, the modulus of their elasticity was reduced by 5 times. The operation of the adjacent longwall was simulated at the third step.



1 – steel-polymer bolts 2.9 m long; 2 – cable bolts 7 m long;
3 – steel-polymer bolts 1.5 m long

Figure 2 – Scheme of bolting

4. Stress state of host rocks outside the influence of stoping operations

As a result of the calculations, the stress fields around four permanent workings located in the consolidated rocks of previously mined relieving longwall outside the influence of stoping operations were obtained, for the cases when the distance L_2 between the mine workings was 50 m and 70 m.

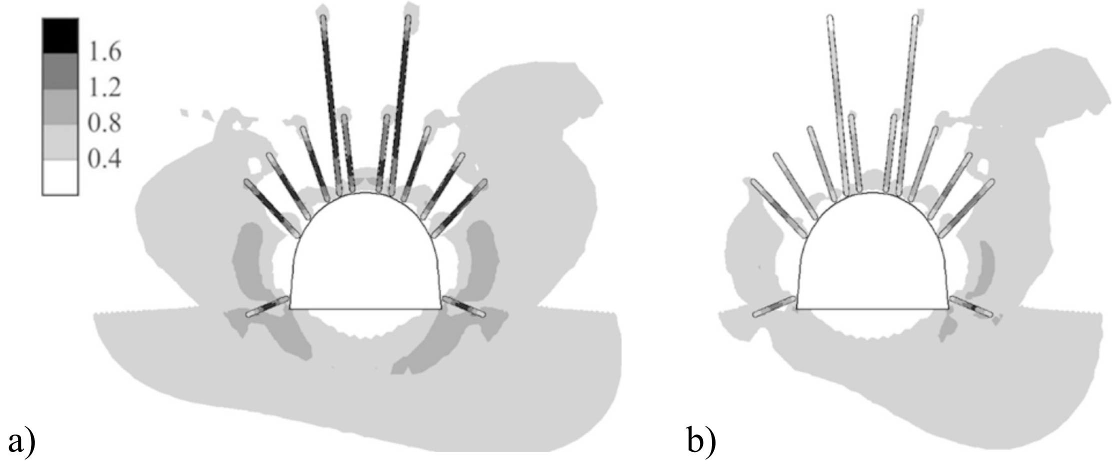
Figure 3 shows distributions of Q parameter values, which characterizes the different-component nature of a stress field, in these cases.

a) L_2 = 50 m, L_1 = 60 m; b) L_2 = 70 m, L_1 = 30 m

Figure 3 – Distributions of Q parameter values around the permanent workings outside the influence of stoping operations, H = 930 m

The *Q* parameter values (difference in main stresses) increases around each of the four permanent mine workings (Fig. 3), which leads to the cracks formation of varying degrees of intensity in the host rocks. If the values of this geomechanical parameter decrease, the mine working becomes more stable. The *Q* parameter takes the largest values on the border of the zone of caved and consolidated rocks of the previously mined longwall, on both sides of the four permanent workings.

The analysis of the distribution of *Q* parameter values around the permanent workings outside the influence of stoping operations shows that the change in the pillar width L_2 from 50 m to 70 m does not affect the lack of mutual influence between the mine works, figure 3. Figure 4 shows enlarged fragments of the calculation area around the first permanent mine working in the considered cases.



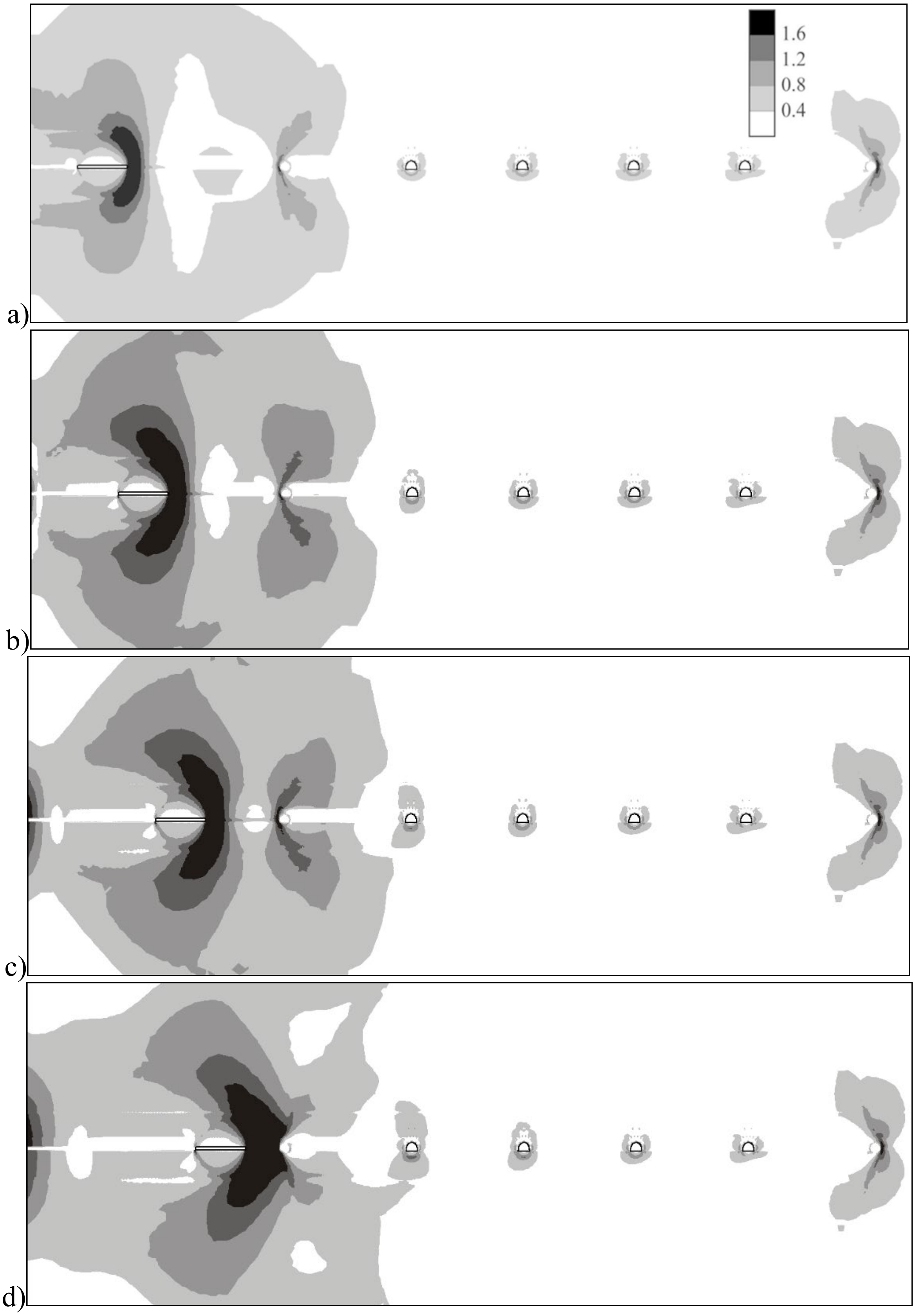
a) L_2 = 50 m, L_1 = 60 m; b) L_2 = 70 m, L_1 = 30 m

Figure 4 – Distributions of *Q* parameter values around the first permanent working outside the influence of stoping operations, H = 930 m

It can be seen that in the second case (figure 4b), the first permanent working is in the more protected zone; the difference of the stress tensor components in the host rocks around this mine working is much smaller, which prevents the development of the process of crack formation.

5. The influence of stoping operations on the stress-strain state of rocks around the permanent workings

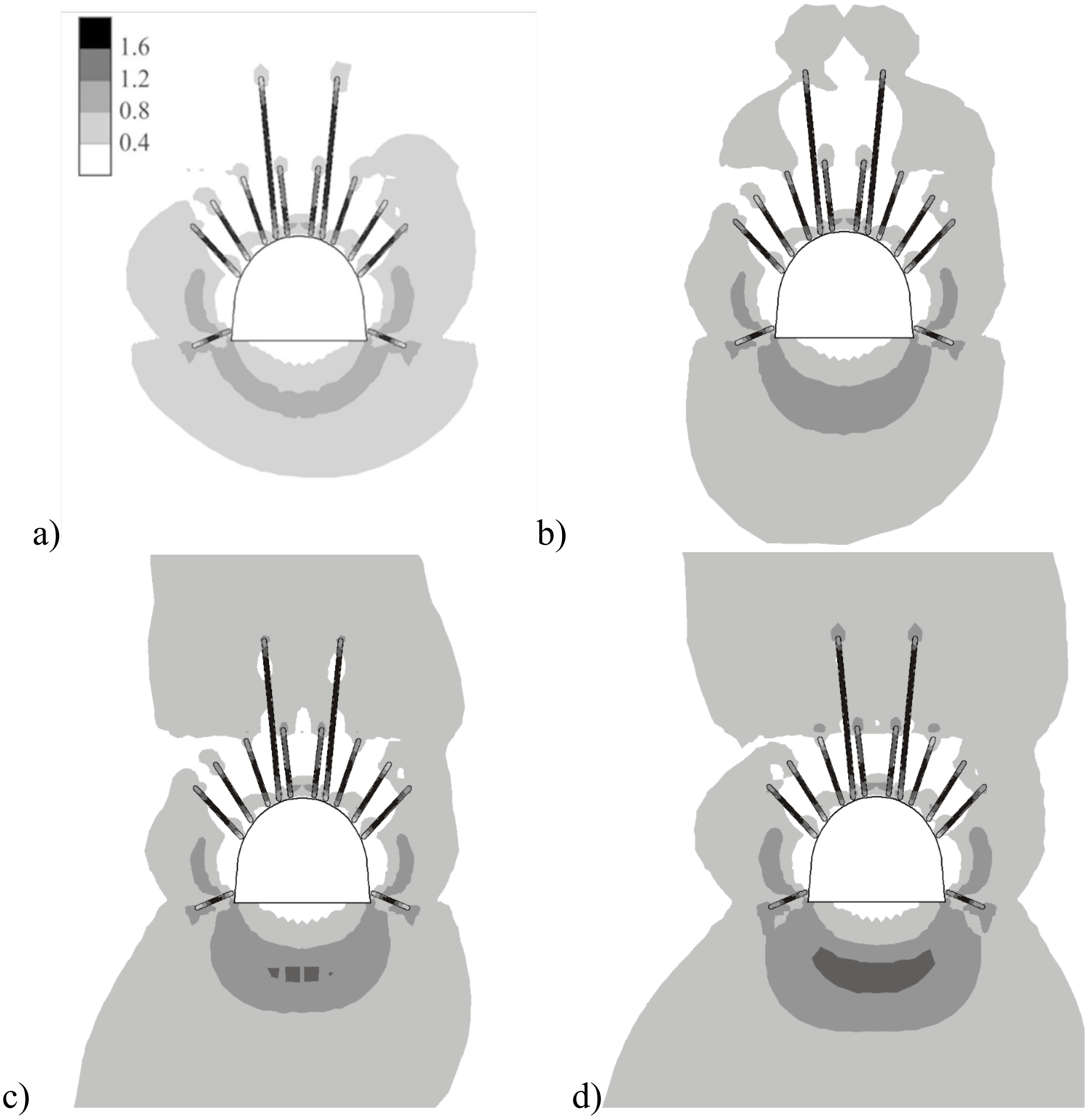
When the front of stoping operations in the adjacent longwall approaches the permanent workings, the stress field in the rocks changes significantly. The load on the support pillar between the boundary of stoping operations and the gob of relieving longwall, as well as on support of the first permanent working, increases considerably. In order to evaluate the impact of the pillar size L_{pil} on the stress state of the rocks around the four permanent workings, let's consider how the geomechanical parameter *Q* changes in this area under the condition that L_2 = 50 m and H = 930 m. Figure 5 shows the distributions of this parameter under the influence of stoping operations. The pillar size L_{pil} in the calculations varied from 140 to 80 m.



a) L_{pil} = 140 m; b) L_{pil} = 120 m; c) L_{pil} = 100 m; d) L_{pil} = 80 m

Figure 5 – Distributions of Q parameter values around four permanent mine workings under the influence of stoping operations, L_2 = 50 m, L_1 = 60 m, H = 930 m

Figure 6 shows enlarged fragments of the calculation area around the first permanent working for convenient analysis.



a) L_{pil} = 140 m; b) L_{pil} = 120 m; c) L_{pil} = 100 m; d) L_{pil} = 80 m

Figure 6 – Distributions of Q parameter values around the first permanent working under the influence of stoping operations, L_2 = 50 m, L_1 = 60 m, H = 930 m

When support pillar size is 140 m, the influence of stoping operations approaching the permanent workings is minimal, figure 5a. The boundaries of the region where $Q > 0.4$ between the pillar and the first mine working almost do not exceed the boundaries shown in figure 3a, in case the stoping operations have not yet started. The distribution of Q parameter values around the first mine working, close to the active longwall, does not change noticeably, figures 4a and 6a. With this size of the support pillar, the combined bolting and frame support fully ensures the necessary stability of all four permanent mine workings. Most of the pillar is in an intact state, $Q < 0.4$, white colour in figure 5a. That part of the pillar, which is adjacent to the working face, is subjected to significant loads; Q parameter values here reach 1.6 and higher. This is due to the decrease to almost zero of the minimum component of the principal stress tensor σ_3 in the immediate vicinity of the working face and a significant increase of the maximum component σ_1 in the zone of bearing pressure.

If $L_{\text{pil}} = 120$ m, the influence of stoping operations increases, although it does not extend beyond the first permanent working, figure 5b. With the approach of the front of working face and the reduction of the support pillar size by 20 m, the area of region around the first working where $Q > 0.4$ increases, figure 6b. The zone of ultra-high difference in main stresses ($Q > 1.6$) in the left part of the pillar is noticeably expanding, and, at the same time, the pillar area, where $Q < 0.4$, is greatly reduced.

Under the condition $L_{\text{pil}} = 100$ m, the boundaries of influence of stoping operations almost reach the first permanent working, the stress field around which undergoes significant changes. Its stability deteriorates, although, thanks to the bolting in the mine roof, a monolithic rock-bolt arch, in which $Q < 0.4$, is preserved (figure 6c).

When the support pillar size is 80 m, the impact of the stoping operations spreads close to the first permanent working (figures 5d and 6d) and affects the stability of the second permanent working. The region of increased difference in main stresses ($Q > 0.4$) around the first permanent working occupies a large area and connects with the same fractured zone surrounding the gob of relieving longwall and the active longwall. In the case when $L_{\text{pil}} = 80$ m, the area of undisturbed, monolithic rocks in the rock-bolt arch decreases even more (figure 6d), the pillar size L_{pil} reaches a critical limit, exceeding which will lead to a loss of the first permanent working stability.

Let's consider how the amount of rock displacement in the roof of the first mine working, which is closest to the active longwall, changes during the approach of the front of working face. Graphs in figure 7 is constructed using the polynomial approximation of the calculated data on displacements of the central point of the mine roof outside the influence of stoping operations ($L_{\text{pil}} = 400$ m) and when the active working face is approaching ($L_{\text{pil}} = 140$ m; $L_{\text{pil}} = 120$ m; $L_{\text{pil}} = 100$ m; $L_{\text{pil}} = 80$ m).

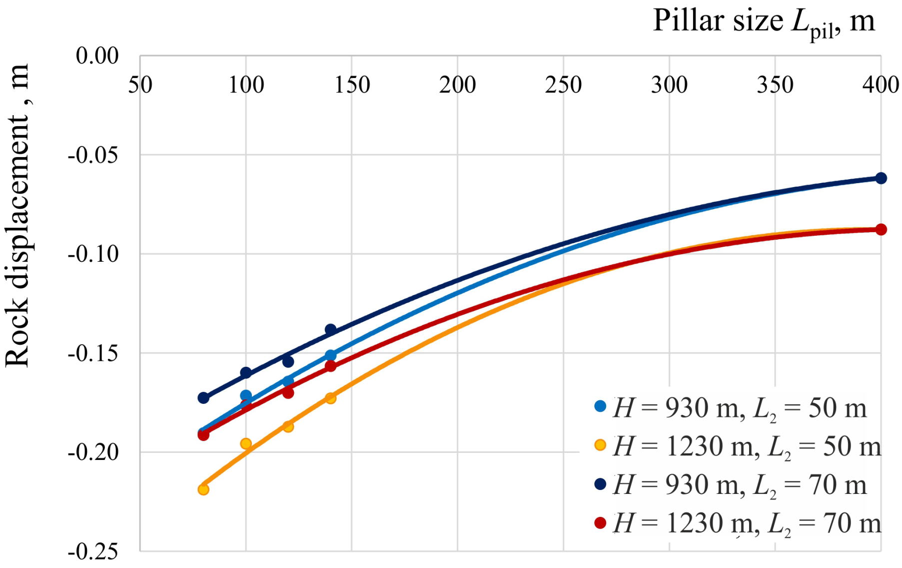
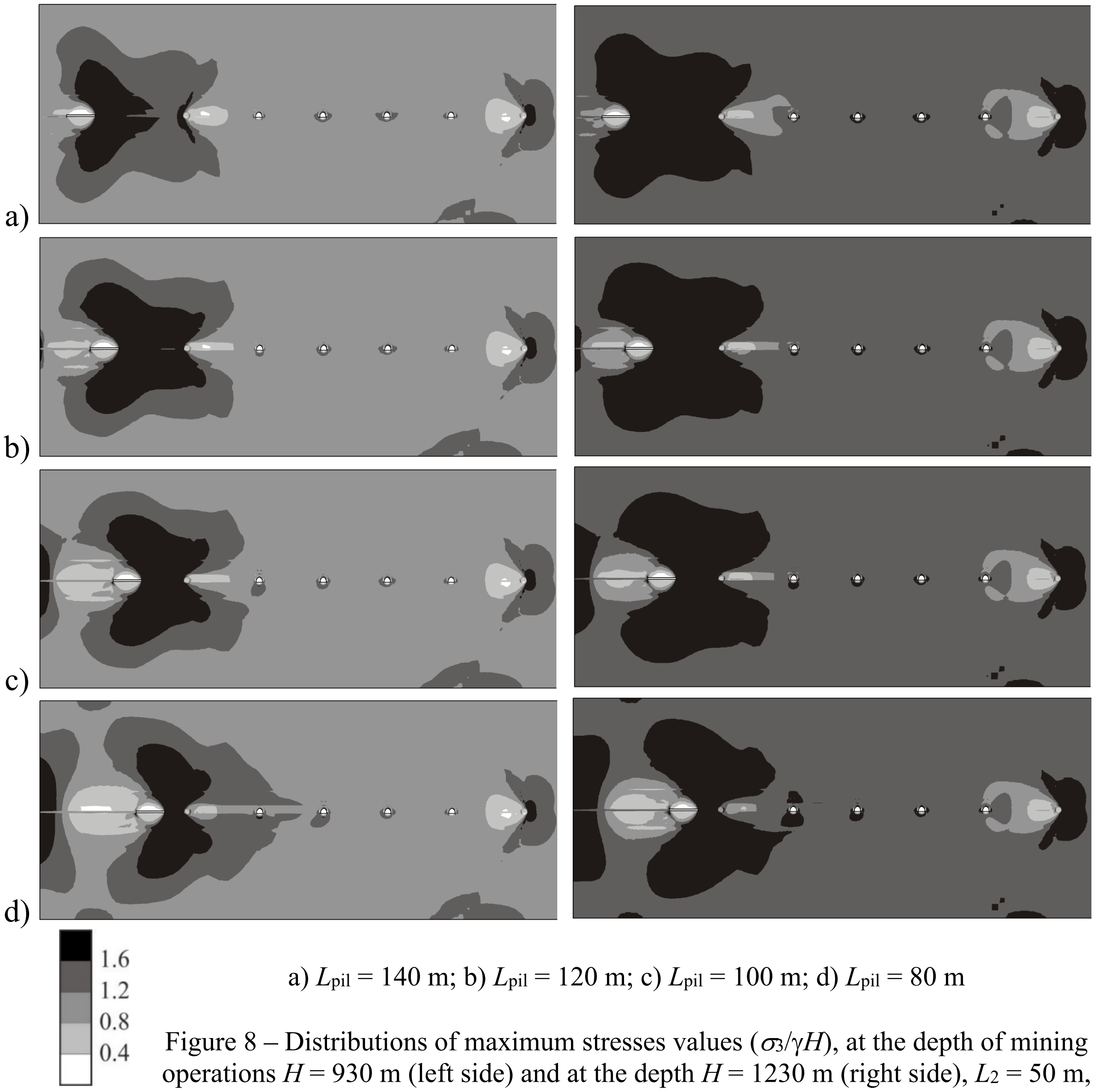


Figure 7 – Rock displacement in the roof of the first permanent mine working

We can see that after stabilization of the mine working state outside the influence of stoping operations ($L_{\text{pil}} = 400$ m), the displacement of its roof is 60 mm under the condition $H = 930$ m and 90 mm under the condition $H = 1230$ m. The approach of active longwall leads to an additional lowering of the mine roof by 120–208% in the case when $L_{\text{pil}} = 80$ m. Reducing the pillar size from 140 to 80 m for every 20 m causes the mine roof lowering by 12–15 mm.

6. The effect of mining depth on the stress field around permanent workings

To study the influence of the mining depth, parameters of the stress field were calculated at the lower and upper boundaries ($H = 930$ m and $H = 1230$ m) of stoping operations on d4 coal seam in the central panel of block 11. Figure 8 shows distributions of maximum stresses values ($\sigma_3/\gamma H$) characterizing the abutment pressure zone.



a) $L_{\text{pil}} = 140$ m; b) $L_{\text{pil}} = 120$ m; c) $L_{\text{pil}} = 100$ m; d) $L_{\text{pil}} = 80$ m

Figure 8 – Distributions of maximum stresses values ($\sigma_3/\gamma H$), at the depth of mining operations $H = 930$ m (left side) and at the depth $H = 1230$ m (right side), $L_2 = 50$ m, $L_1 = 60$ m

It can be seen from the figure 8 that with an increase in the depth of mining operations, the values of the maximum stresses in the entire studied area increase. A large zone of abutment pressure is located between the front of working face and the gob of the previously mined relieving longwall. A much smaller zone of abutment pressure covers the right side of the gob near the fourth mine working.

When the pillar size is reduced, the impact of stoping operations on the rocks stress state increases, as well as the load on support of the permanent workings. At $L_{pil} = 140$ m, stoping operations do not affect the first permanent mine working (figure 8a). At $L_{pil} = 120$ m, the boundaries of influence increase, the influence on the first mine working is insignificant and with the pillar size $L_{pil} = 100$ m, the impact of stoping operations approaches this mine working. At $L_{pil} = 80$ m, this influence spreads further beyond the first mine working and reaches the second one, according to the distribution of maximum stresses (figure 8d).

An increase in the depth of permanent workings from 930 m to 1230 m, in addition to a natural increase in the initial stress state of the rock mass $\sigma_0 = \gamma H$ from 23.25 MPa to 30.75 MPa, also leads to a 10–12% increase in the boundaries of the influence of the abutment pressure.

7. Conclusions

The method of permanent workings construction, the type of supporting, as well as their location relatively to the boundaries of stoping operations zones greatly affect their stability. In this work, a numerical simulation of the stress state of the layered rock mass with permanent workings located in the gob of previously mined longwall was completed to study these mine workings stability outside the influence of stoping operations and in the zone of their influence. As an example, the mining and geological conditions were considered for the central panel of block 11 in PJSC Colliery Group "Pokrovske", where four permanent mine workings are planned at a depth of 930–1230 m. A series of calculations were performed with variations of such technological parameters as the distance between mine workings, the impact of stoping operations, and the pillar size between the gob of the relieving longwall and the active front of working face.

It is shown that a change in the distance between permanent mine workings in the range of 50–70 m does not affect the lack of mutual influence between these mine workings.

When the front of stoping operations in the adjacent longwall approaches the permanent workings, the load on the support pillar between the boundary of stoping operations and the gob of relieving longwall, as well as on support of first permanent mine working, increases considerably. If the support pillar size is 80 m, the impact of the stoping operations spreads close to the first permanent working and affects the stability of the second permanent working. The approach of active longwall leads to an additional lowering of the first mine roof by 120–208% compared to the level at the stage of stabilization of the stress-strain state. The region of increased difference in main stresses around the first permanent working occupies a large area; its stability deteriorates, although, thanks to the bolting, the monolithic rock-bolt arch is still preserved in its roof. However, the pillar size of 80 m is critical (for the mining and geological conditions adopted in this work); further reduction of the pillar size will lead to loss of stability of the first permanent mine working.

An increase in the depth of permanent workings by 300 m, in addition to a natural increase in the initial stress state of the rock mass, also leads to a 10–12% increase in the boundaries of the influence of the abutment pressure.

REFERENCES

1. Lin'kov, A. (2001), "On the Theory of Pillar Design", *Journal of Mining Science*, vol. 37, no. 1, pp. 10–27. https://doi.org/10.1023/A:1016724616864.

2. Hodyrev, E.D. (2010), "Determination of the limiting dimensions of protective coal pillars and the stresses acting in them", *Transactions of UkrNDMI NAN Ukraine*, no. 6, pp. 170–180.

3. Krukovskyi, O., Bulich, Y., Kurnosov, S., Yanzhula, A. and Dyomin, V. (2022), "Substantiating the parameters for selecting a pillar width to protect permanent mine workings at great depths", *IOP Conference Series: Earth and Environmental Science*, no. 970, 012049. https://doi.org/10.1088/1755-1315/970/1/012049.

4. Zborshchyk, M.P. and Nazymko, V.V. (1991), *Ohrana vyirabotok glubokih shaht v zonah razgruzki* [Protection of deep mine workings in unloading zones], Tekhnika, Kyiv, Ukraine.

5. Ju, J., Xu, J. and Zhu, W. (2015), "Longwall chock sudden closure incident below coal pillar of adjacent upper mined coal seam under shallow cover in the Shendong coalfield", *International Journal of Rock Mechanics and Mining Sciences*, no. 77, pp. 192–201. https://doi.org/10.1016/j.ijrmms.2015.04.004

6. Kovalevska, I., Samusia, V., Kolosov, D., Snihur, V. and Pysmenkova, T. (2020), "Stability of the overworked slightly metamorphosed massif around mine working", *Mining of Mineral Deposits*, vol. 14, no. 2, pp. 43–52. https://doi.org/10.33271/mining14.02.043

7. Zborshchik, M., Kasian, N., Kliuev, A. and Azamatov, R. (1996), "Geomechanical processes in the zone of destroyed rocks in the vicinity of supported workings", *Coal of Ukraine*, no. 4, pp. 7–9.

8. Nehrii, S., Nehrii, T. and Piskurska, H. (2018), "Physical simulation of integrated protective structures", *E3S Web Conf., Ukrainian School of Mining Engineering*, no. 60, pp. 00038. https://doi.org/10.1051/e3sconf/20186000038

9. Tripolski, V.N., Buryak, N.A. and Vojtovich, T.G. (2018), "Technological schemes for supporting reused gate roads by the cast strips", *Geo-Technical Mechanics*, no. 140, pp. 13–22. https://doi.org/10.15407/geotm2018.03.013

10. Vinogradov, V. (1989), *Geomehanika kontrolja sostojanija gornyh massivov vblizi gornyh rabot* [Geomechanics of Massif Condition Control Near Mine Working], Naukjva Dumka, Kyiv, Ukraine.

11. Krukovskyi, O.P. (2011), "Modeliuvannia zminy napruzheno-deformovanoho stanu prykonturnoho masyvu pry vidkhodi zaboiu hirnychoi vyrobky" [Modelling changes of stress-strain state of solid edge during the distance of working face of mine workings], *Problemy obchysliuvalnoi mekhaniky i mitsnosti konstruktsii*, no. 17, pp. 175–181.

12. Labuz, J.F. and Zang, A. (2012), "Mohr-Coulomb Failure Criterion", *Rock Mechanics and Rock Engineering*, no. 45, pp. 975–979. https://doi.org/10.1007/s00603-012-0281-7

13. Wang, H.C., Zhao, W.H., Sun, D.S. and Guo, B.B. (2012), "Mohr-Coulomb yield criterion in rock plastic mechanics", *Chinese Journal of Geophysics*, no. 55, pp. 733–741. https://doi.org/10.1002/cjg2.1767

14. Bulat, A.F. and Vynohradov, V.V. (2002), *Oporno-ankerne kriplennia hirnychykh vyrobok vuhilnykh shakht* [Bearing-bolt supporting of mine workings in coal mines], IGTM NAS of Ukraine, Dnipropetrovsk, Ukraine.

15. Zienkiewicz, O.C., Taylor, R.L. and Zhu, J.Z. (2013), *The Finite Element Method: Its Basis and Fundamentals*, Butterworth-Heinemann. https://doi.org/10.1016/C2009-0-24909-9

16. de Borst, R., Crisfield, M.A., Remmers, J.J.C. and Verhoosel, C.V. (2012), *Non-linear finite element analysis of solids and structures*, John Wiley & Sons. https://doi.org/10.1002/9781118375938

17. Eslami, M.R. (2014), *Finite Elements Methods in Mechanics*, Springer International Publishing. https://doi.org/10.1007/978-3-319-08037-6

18. Krukovskyi, O.P., Krukovska, V.V., Bulich, Yu.Yu. and Zemlianaia, Yu.V. (2020), "Some aspects of development and application of the bearing-bolt supporting technology", *Resource-saving technologies of raw-material base development in mineral mining and processing. Multi-authored monograph,* Universitas Publishing, Petroșani, Romania, pp. 123–142. https://doi.org/10.31713/m908

19. Krukovskyi, O.P., Krukovska, V.V., Adorska, L.H. and Bulich, Yu.Yu. (2022), "Development and application of the bearing-bolt supporting technology in the conditions of Ukrainian coal mines", *Journal of Donetsk Mining Institute*, vol. 2, no. 51, pp. 55–68. https://doi.org/10.31474/1999-981X-2022-2-54-66

About the authors

Krukovskyi Oleksandr Petrovych, Corresponding Member of the NAS of Ukraine, Doctor of Technical Sciences (D. Sc), Deputy Director of the Institute, M.S. Poliakov Institute of Geotechnical Mechanics of the National Academy of Sciences of Ukraine (IGTM of the NAS of Ukraine), Dnipro, Ukraine, igtm@ukr.net.

Krukovska Viktoriia Viktorivna, Doctor of Technical Sciences (D. Sc), Senior Researcher, Senior Researcher in Department of Pressure Dynamics Control in Rocks, M.S. Poliakov Institute of Geotechnical Mechanics of the National Academy of Sciences of Ukraine (IGTM of the NAS of Ukraine), Dnipro, Ukraine, vikakrukk@gmail.com.

Kurnosov Serhii Anatoliovych, Doctor of Technical Sciences (Sci.D), Senior Researcher, Senior Researcher in Department of Mineral Mining at Great Depths, M.S. Poliakov Institute of Geotechnical Mechanics of the National Academy of Sciences of Ukraine (IGTM of the NAS of Ukraine), Dnipro, Ukraine, sakurnosov@gmail.com.

Yanzhula Oleksii Serhiovych, Candidate of Technical Sciences (Ph.D.), Director for Technical Development and Investments, Coal Directorate METINVEST HOLDING LLC, Pokrovsk, Ukraine, aleksey.yanzhula@metinvestholding.com.

Bulich Yurii Yuriiovych, Master of Science, Researcher in Department of Rock Mechanics, M.S. Poliakov Institute of Geotechnical Mechanics of the National Academy of Sciences of Ukraine (IGTM of the NAS of Ukraine), Dnipro, Ukraine, bulicurij@gmail.com.

ДОСЛІДЖЕННЯ СТІЙКОСТІ КАПІТАЛЬНИХ ВИРОБОК ПРИ ЇХ ПРОВЕДЕННІ ПО ВИРОБЛЕНОМУ ПРОСТОРУ РОЗВАНТАЖУВАЛЬНОЇ ЛАВИ

Круковський О.П., Круковська В.В., Курносов С.А., Янжула О.С., Буліч Ю.Ю.

Анотація. Спосіб проведення капітальних виробок, їх кріплення, а також розташування щодо меж очисних робіт дуже впливають на їх стійкість. В даній роботі виконано чисельне моделювання напруженого стану шаруватого породного масиву з капітальними виробками, розташованими у виробленому просторі раніше відпрацьованої лави, для дослідження стійкості цих виробок поза впливом і у зоні впливу очисних робіт. Для прикладу розглянуто гірничо-геологічні умови центральної панелі блоку 11 ПРАТ «ШУ Покровське», де планується проведення чотирьох капітальних виробок. Виконано серію розрахунків з варіюванням таких технологічних параметрів, як відстань між виробками, вплив очисних робіт і довжина цілика між виробленим простором розвантажувальної лави і діючим очисним вибоєм.

Показано, що варіювання ширини ціликів між капітальними виробками в діапазоні 50–70 м не впливає на відсутність взаємного впливу між виробками. Коли до розглянутих капітальних виробок наближається фронт очисних робіт, навантаження на опорний цілик між границею зупинки очисних робіт і виробленим простором розвантажувальної лави, так само, як і на кріплення першої капітальної виробки, значно зростає. При розмірі опорного цілику 80 м вплив очисних робіт поширюється впритул до першої виробки і позначається на стійкості другої виробки. Наближення лави призводить до опускання покрівлі першої виробки на 120–208% порівняно з рівнем на етапі стабілізації напружено-деформованого стану. Область підвищеної різнокомпонентності порід навколо першої виробки займає велику площу, її стійкість погіршується, хоча завдяки анкерному кріпленню в її покрівлі ще збережено монолітне породно-анкерне перекриття. Але ширина цілика 80 м є критичною (для прийнятих в роботі гірничо-геологічних умов), подальше зменшення ширини цілику призведе до втрати стійкості першої виробки. Збільшення глибини проведення капітальних виробок на 300 м крім природного збільшення вихідного напруженого стану породного масиву також призводить до розширення на 10–12% межі впливу опорного тиску.

Ключові слова: вироблений простір розвантажувальної лави, чисельне моделювання, анкерне кріплення, очисні роботи, кріплення капітальних виробок.