DNIPRO UNIVERSITY of TECHNOLOGY 1899

Mining of Mineral Deposits
Volume 15 (2021), Issue 1, 103-111

MMD JOURNAL / MINING.IN.UA

UDC 622.831.3 https://doi.org/10.33271/mining15.01.103

# Research into rock mass geomechanical situation in the zone of stope operations influence at the 10th Anniversary of Kazakhstan's Independence mine

Azamat Matayev[1*], Ainash Kainazarova[1], Ibatolla Arystan[1], Yerkebulan Abeuov[1], Arman Kainazarov[2], Makhmed Baizbayev[1], Vladimir Demin[1], Muratbek Sultanov[3]

[1] *Karaganda Technical University, Karaganda, 10009, Kazakhstan*
[2] *Ekibastuz Engineering and Technical Institute named after Academician K. Satpayev, Ekibastuz, 10008, Kazakhstan*
[3] *Aktobe Regional University named after K. Zhubanov, Aktobe, 10004, Kazakhstan*

**Corresponding author: e-mail mataev.azamat@mail.ru, tel. +77023920146*

**Abstract**

**Purpose.** Predicting the stress-strain state (SSS) of the rock mass in the zone of stope operations influence using the self-caving mining system and the calculation of the load-bearing capacity of mine workings support at the 10th Anniversary of Kazakhstan's Independence mine.

**Methods.** An engineering-geological data complex of the host rocks properties has been analyzed. Numerical modelling of the rock mass stress-strain state and the calculation of the load-bearing capacity of the support types used at the mine have been performed with the help of the RS2 software. This program, based on the Finite Element Method in a two-dimensional formulation, makes it possible to take into account a significant number of factors influencing the mass state. The Hoek-Brown model with its distinctive advantage of nonlinearity is used as a model for the mass behaviour.

**Findings.** The values of the main stresses and load on the support have been obtained. According to the numerical analysis results of the rock mass stress-strain state at a depth of 900 m (horizon -480 m), the principal stresses are close to hydrostatic ones $\sigma_1 = \sigma_3 = \sigma z = 24.8$ MPa. Predicting assessment of mine workings stability margin is performed before and after stope operations. Based on its results, it can be assumed that the stability margin of the mine workings driven in the stope zone is below the minimum permissible, therefore, caving and an increase in the load on the support are possible. Abutment pressure on mine workings support at a mining depth of 900 m (-480 m) has been calculated. The parameters of support in mine workings driven at the horizon -480 m have been calculated.

**Originality.** The nature and peculiarities of patterns of the stress-strain state formation within the boundaries of various stope operations influence in blocks 20-28 at the horizon -480 m have been determined. The quantitative assessment of the values of loads on the support of haulage cross-cuts of the horizon mining is given.

**Practical implications.** The research results can be used for creating a geomechanical model of the field and to design stable parameters of mine workings support.

***Keywords:*** *stress-strain state, principal stresses, support, mine, ore, rock mass*

## 1. Introduction

The 10th Anniversary of Kazakhstan's Independence mine is located in the north of Mugalzhar, on the eastern slope of the East Kempirsay ore district, in the south-eastern part of Khromtau city, Aktobe region, Republic of Kazakhstan. The Rudnichny District infrastructure is well developed. Next to the 10th Anniversary of Kazakhstan's Independence mine, the mines of Donskoy Ore Mining and Processing Plant, Voskhod mine, the 20th Anniversary of the Kazakh S.S.R. mine and Poiskovoye open-pit mine are developing chromite deposits. An enrichment plant for processing of chromite ores produced at these deposits is located three kilometers north of the Molodezhnaya mine.

The main part of the field reserves will be mined by an undercut-caving system. Based on the fact that the ore bodies of the fields have a continuous slightly inclined or inclined angle of occurrence and in some places the ore bodies move abruptly upward within a level, then parts of one block reserves are located at different levels in relation to mine workings of the haulage horizon [1]. Such reserves within one block are prepared to mining by both high and low undercutting of sub-levels [2].

Received: 23 September 2020. Accepted: 18 February 2021. Available online: 5 March 2021

To determine the technical and economic indicators, when mining such ore bodies, a block located at the level -480…-560 m and between sections 23-25 is taken as an analogue of mining.

The main reserves of the block selected for mining are located at the level of the haulage workings roof of the horizon -560 m. The block bottom structure will be designed through the ore at a height of 2.5-3.0 m above the level of the haulage horizon (low undercutting of sub-levels).

An insignificant part of this block reserves is located above the level of the haulage workings of the horizon (at a height of 15-25 m). The bottom for mining the reserves will be designed through the rock (high undercutting of sub-levels).

The block reserves undercutting is performed by blasting the radial wells. The radial wells are drilled every 2-3 m with an NKR-100 m drilling rig to a height of 10-15 m.

Within the mining allotment area, two types of groundwater are developed: pore water – in Cretaceous and Paleogene deposits and fissure water – in the rocky Paleozoic mass. Groundwaters in Cretaceous and Paleogene deposits has sporadic distribution. It does not have an independent significance in the formation of water inflows into underground mine workings [3], [4].

Fissure water developed in the rocky ore-bearing mass is the main source of flooding the mine workings and is subdivided into fissure-ground and fissure-vein. Its distribution is associated to the zones of open fracturing the metamorphosed intrusive rocks of basic and ultrabasic composition, represented by gabbro-amphibolites and serpentinites through dunites and peridotites.

Fissure-groundwater is regionally distributed in open fractures of exogenous genesis in the upper part of the rock mass geological section, belonging to Triassic-Jurassic weathering crust. The depth of fissure-ground water distribution from the mass roof reaches 60-75 m, and in the zones of tectonic disturbances it increases to 150 m. The depth of the groundwater table occurrence in natural conditions varies from 0 to 30 m.

The heterogeneity of the mining-and-geological conditions of the rocks occurrence and an increase in the mining depth require constant monitoring and predicting the stress-strain state (SSS) of rock masses enclosing mine workings for various purposes and with different contours.

Many applied problems of mining geomechanics are related to determining the stress-strain state of technologically disturbed rock mass [5], [6]. Such problems are solved by many researchers using various methods of mathematical and physical modelling. Mathematical modelling has certain advantages over physical modelling, since it has the greatest generality when describing the essence of geomechanical processes, as well as it makes possible to study and predict the latter in the widest range of their constitutive parameters [7]-[10].

As a result of the development of computer technology and methods of mathematical modelling, along with traditional analytical methods, numerical methods are increasingly used [11]-[13]. There are:

– finite difference method (FDM);
– finite element method (FEM);
– boundary element method (BEM).

The effective use of these methods for solving important applied problems of mining geomechanics is substantiated not only by the capabilities of the software package, but also by the availability of an appropriate methodological base for solving such problems [1], [7].

The purpose of the research is to predict the stress-strain state (SSS) in the rock mass within the boundaries of the stope operations influence at the horizon -480 m according to the system of mining, as well as to calculate the load-bearing capacity of the support types used at the 10$^{th}$ Anniversary of Kazakhstan's Independence mine. To achieve this purpose, the following objectives are set:

– analyze the mining-and-geological, as well as mining-engineering conditions of mining at the 10$^{th}$ Anniversary of Kazakhstan's Independence mine;
– perform a numerical analysis of the rock mass stress-strain state at the horizon -480 m of the 10$^{th}$ Anniversary of Kazakhstan's Independence mine;
– to calculate the values of the loads on the mine workings support in the host rocks and in the ore mass at the -480 m horizon;
– to calculate the load-bearing capacity of the support types used at the 10$^{th}$ Anniversary of Kazakhstan's Independence mine using the numerical analysis.

## 2. Methods

Serpentinites through dunites are widespread in the deposits of the 10th Anniversary of Kazakhstan's Independence mine. Serpentinite is less widespread through pyroxene dunites. The mentioned rock types occur to a depth of 35-110 m from the Earth's surface. The maximum value of the desiccation degree is observed at a depth of 10-20 m. The rocks are formed here by fine-grained rocks and change to a clay mass.

According to the laboratory surveys, four main engineering-geological rock complexes are identified [6], [10], [14]:

– complex of ground carbonate, fine-grained serpentinites, with low rock strength ($R_c$ = 15.2 MPa, $R_t$ = 1.3 MPa, strength coefficient on the Protodyakonov scale is $f$ = 2-3, III drilling category), which is typical for the upper part of the field [5], [15];

– serpentinized dunite complex: less crack-resistant dunite is durable ($R_c$ = 55.3 MPa, $R_t$ = 4.3 MPa, strength coefficient on the Protodyakonov scale is $f$ = 9, VII drilling category); root-mean-square dunite is represented by rocks of medium strength ($R_c$ = 27.1 MPa, $R_t$ = 3.1 MPa, strength coefficient on the Protodyakonov scale is $f$ = 8, VII drilling category). Dunite category refers to durable rocks ($R_c$ = 64.5 MPa, $R_t$ = 4.5 MPa, strength coefficient on the Protodyakonov scale is $f$ = 9, VII drilling category); mid-season dunite is medium strength rock ($R_c$ = 35.1 MPa, $R_t$ = 2.7 MPa, strength coefficient on the Protodyakonov scale is $f$ = 8, VII drilling category); extra strong – low strength rocks ($R_c$ = 17.1 MPa, $R_t$ = 1.6 MPa, strength coefficient on the Protodyakonov scale is $f$ = 6, VI drilling category);

– complex of serpentinized peridotites: rocks with low tensile strength ($R_c$ = 58.1 MPa, $R_t$ = 4.7 Mpa, according to the Protodyakonov scale $f$ = 8, VII drilling category); rocks of medium strength ($R_c$ = 29.1 MPa, $R_t$ = 2.7 Mpa, according to the Protodyakonov scale $f$ = 8, VII drilling category); rocks of extra tensile strength ($R_c$ = 8.0 MPa, $R_t$ = 0.8 MPa, according to the Protodyakonov scale $f$ = 2, III drilling category) [16].

With increasing depth, the rock strength increases. The compression strength of low-tonnage rocks and ores at great depths changes to a value of 60-120 MPa.

According to geological data, the main ore deposit is mainly represented by continuous and densely disseminated ores, and the rocks in the field are represented by pyroxene-free dunites, pyroxene dunites and peridotites, serpentinized to varying degrees.

Tables 1 and 2 present the generalized strength and physical-mechanical properties of the rock mass.

***Table 1. Strength properties of rocks and ore***

| Name | Physical properties | | Strength properties | | |
|---|---|---|---|---|---|
| | Rock density, $P$, g/cm$^3$ | | Ultimate compression strength, $R_c$, MPa | | Limit of strength $R_t$, MPa |
| | | | For monolithic-type samples | For samples with primary fractures | |
| Rock | 2.69 | 2.58 | 99.7-128.0 | 41.6-61.0 | 9.02-13.4 |
| Ore | 3.62 | 3.46 | 52.6-68.0 | 30.2-54.0 | 5.55-6.12 |

***Table 2. Strength properties of fracture filler (determined by the samples)***

| Filler type | Cohesion C, MPa | | | Internal friction angle $\varphi$, degree | | |
|---|---|---|---|---|---|---|
| | min | max | med | min | max | med |
| Siliceous-carbonate | 2.4 | 4.5 | 3.1 | 30 | 42 | 37 |
| Talcum-micaceous | 0.45 | 3.1 | 1.9 | 17 | 44 | 33 |
| Serpophytic | 1.8 | 9.6 | 6.0 | 20 | 43 | 35 |
| Serpentine | 7.0 | 15.0 | 10.8 | 30 | 49 | 41 |

Numerical modelling of the rock mass stress-strain state and the calculation of the load-bearing capacity of the support types used at the 10th Anniversary of Kazakhstan's independence Mine have been performed with the help of the RS2 software. This program, based on the Finite Element Method in a two-dimensional formulation, makes it possible to take into account a significant number of factors influencing the mass state. The calculations take into account not only the physical and mechanical rock properties and the stresses acting in the mass, but also the structural characteristics of the mass, as well as the degree of technogenic impact. The Hoek-Brown model with its distinctive advantage of nonlinearity is used as a model for the mass behaviour [14], [17].

The data obtained in the RS2 software is similar to natural processes occurring in the conditions of mineral deposit development, and is widely used in many fields, since it allows to take into account such factors as the physical and mechanical properties of rocks and fractures, the presence of water, stress state, parameters of mine workings, types of support, effects of fixed loads, expected displacements, etc. [18].

## 3. Results and discussion

### 3.1. Numerical analysis of the rock mass stress-strain state at the horizon -480m of the 10th Anniversary of Kazakhstan's Independence mine

To determine the principal stresses acting in the unmined mass of the 10th Anniversary of Kazakhstan's Independence mine, a predicting assessment of the principal stresses acting on the mass has been performed, the results of which are shown in Figure 1. From Figures2a and 2b, which show the stress-strain state of mine workings at the horizon -480 m, it can be seen that possible unstable zones of the border mass with a safety factor (SF) of less than 1.2 can reach up to 1.6 meters along the walls and 0.8 m along the roof.

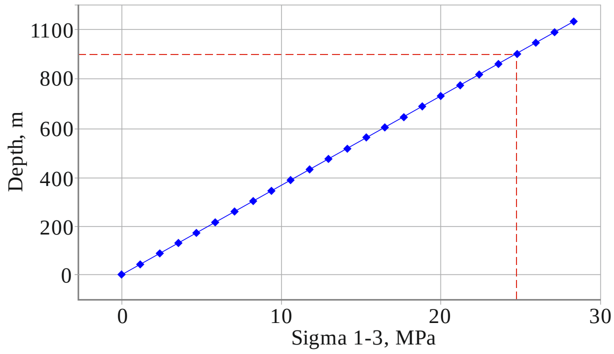


***Figure 1. Graph of a change in maximum stress (Sigma 1-3) depending on the depth***

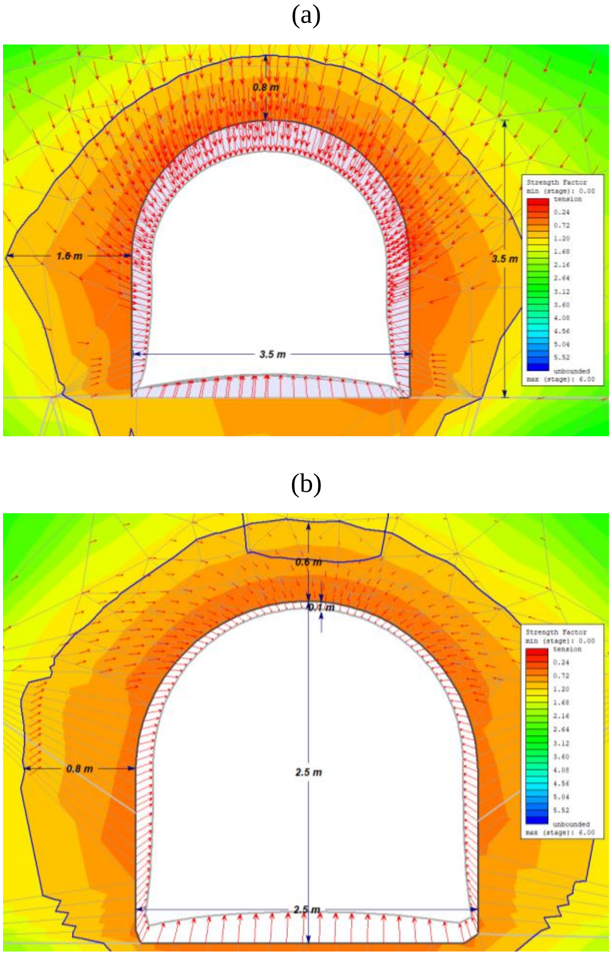


***Figure 2. Stress-strain state of mine workings at the horizon -480 m: (a) mine working width is 3.5 m; (b) mine working width is 2.5 m***

According to international ISRM standards, a mass with SF ≤ 1.2 is unstable. Figures 2a and 2b also demonstrate the directions of principal stresses acting on the mine working, from which it can be seen that mines are exposed to pressure from all sides, which can lead to a rock pressure dynamic manifestation in the form of fractures, artefacts, heaving in the mine working bottom, the SCP frames deformation, etc.

Figure 3 shows a schematic diagram of a mining system with previously driven mine workings prior to stope operations. An aquifer rock mass is generally stable, a safety factor is higher than 1.2, except for the zones adjacent to mine workings.

Figure 4 shows a schematic diagram of mining system after the stope operations. After mining of the crosscut, a redistribution of stresses occurs and mine workings change to unstable state, since they are in the zone of stope operations influence.

Figures 5 and 6 present the results of a numerical analysis by the finite element method before the start of stope operations and after breaking of the crosscut.

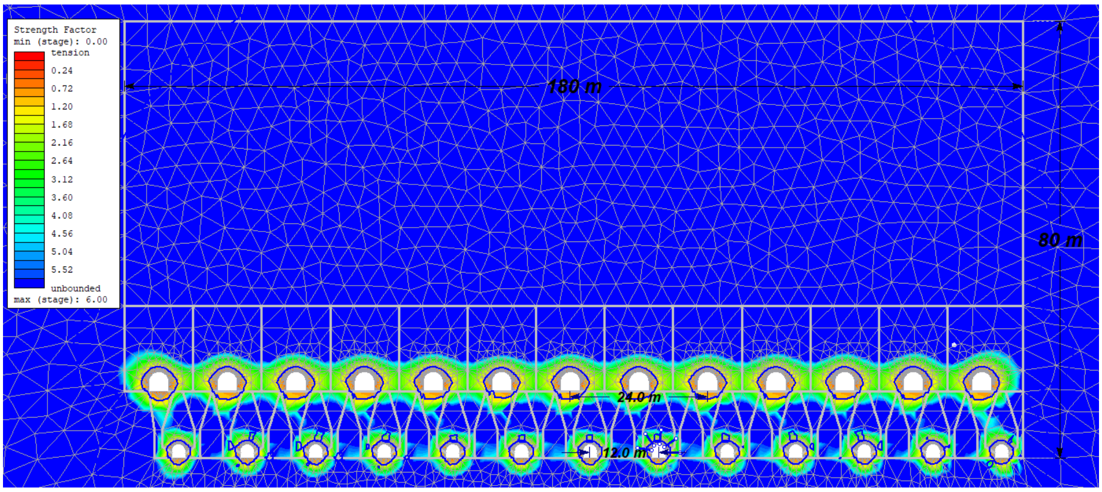


*Figure 3. Stress-strain state of mine workings before mining of the crosscut*

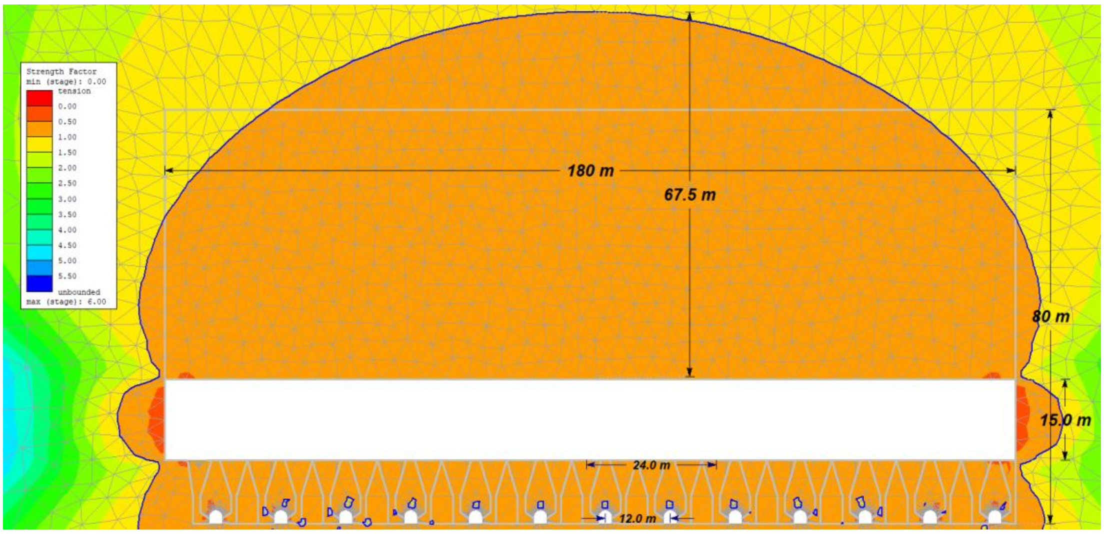


*Figure 4. Stress-strain state of mine workings after mining of the crosscut*

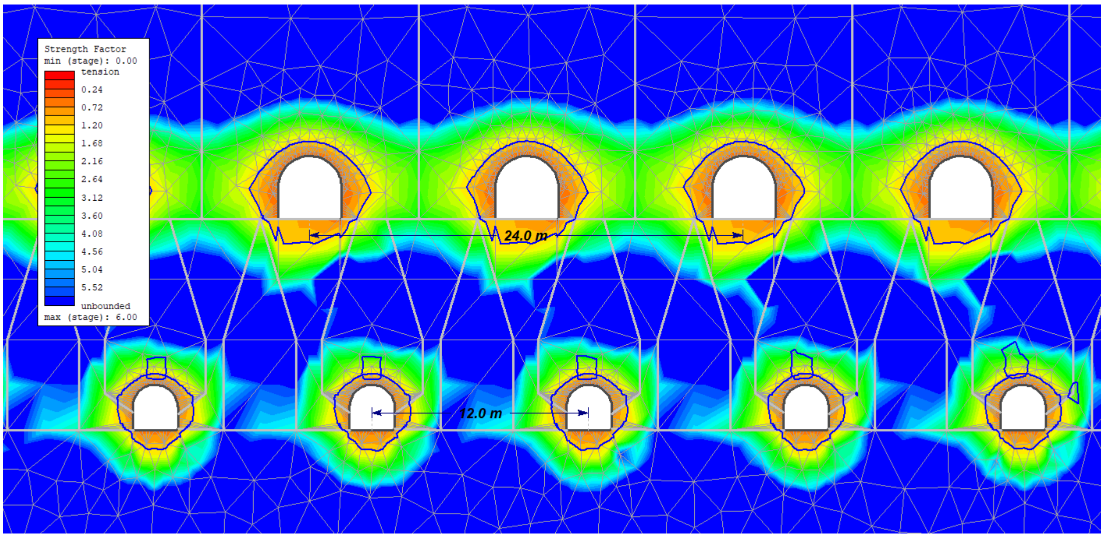


*Figure 5. Stress-strain state of mine workings before the start of stope operations*

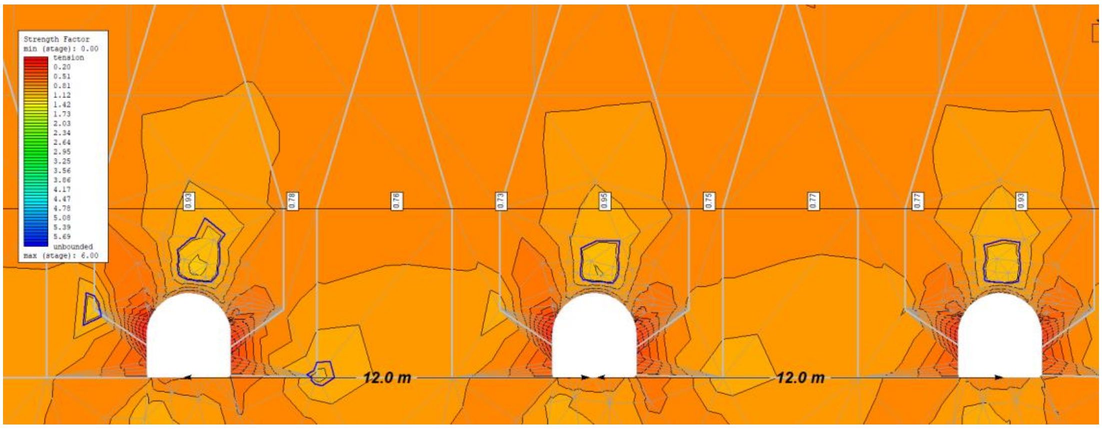


*Figure 6. Stress-strain state of mine workings after the stope operations*

According to the results of the numerical analysis in Figure 7, after mining the manhole for the box hole, the stability margin of the room fenders is below the maximum permissible.

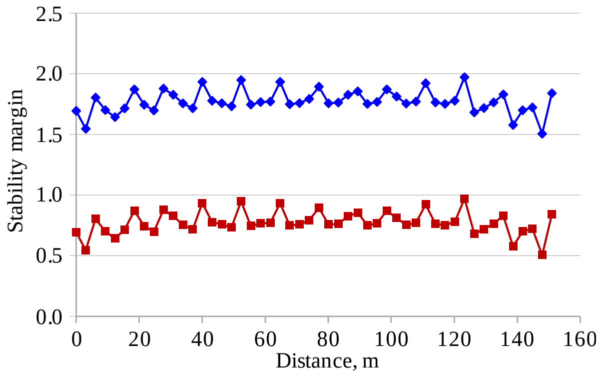


*Figure 7. Graph of a change in the stability margin of mine workings: 1 – before the start of well breaking; 2 – after the crosscut well breaking*

Figures 8 and 9 represent the graphs of the principal stresses redistribution nearby the mine workings. According to the graph in Figure 8, the stresses concentration is observed in the mine working roof, which sharply increases approximately at a distance of 2-3 m from the mine working contour, and then the stress flattens and reaches its natural state.

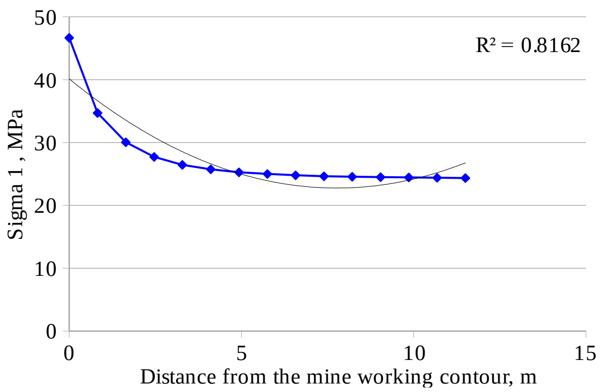


*Figure 8. Graph of the maximum stresses redistribution nearby the mine working contour*

The stresses acting on the mine working walls (Fig. 9), on the contrary, flatten (they work to rupture) nearby the mine working at a distance of 3-4 m, after which they reach their natural state. Figure 9 below demonstrates the changes in the safety factors of the aquifer rocks before the start of stope operations and after breaking of the blast-hole rings of the crosscut.

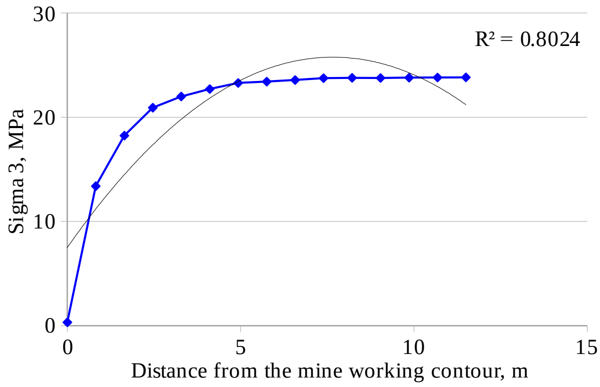


*Figure 9. Graph of the minimal stresses redistribution nearby the mine working contour*

### 3.2. Calculating the load-bearing capacity of the support types used at the 10th Anniversary of Kazakhstan's Independence mine by numerical analysis

At the 10th Anniversary of Kazakhstan's Independence mine, horizontal mine workings and shaft insets are fastened with SCP-22 metal arch support in combination with concrete, while chamber mine workings are fastened with SCP-27 metal arch support in combination with concrete. The haulage workings are first fastened with a 2.0 m long roof bolt in combination with shotcrete, then reinforced with cable bolts and SCP-22 frames.

To determine the load-bearing capacity of haulage workings, a numerical analysis of the rock mass is performed in the specialized RS2 software.

The RS2 software provides a wide range of options for modelling the support. Lining elements can be used in modelling the shotcrete, concrete, steel typesetting systems, retaining walls, piles, multilayer composite linings, geotextiles, etc. [16].

Figure 10 presents the numerical analysis results of the load-bearing capacity of the combined support (mine working on the left) and the border mass state without fastening (mine working on the right). The mine working on the left is fastened with a 2.0 m long roof bolt, a 12-15 m long cable-bolt fastening, SCP-22 and 20 cm thick shotcrete.

(a) (b)

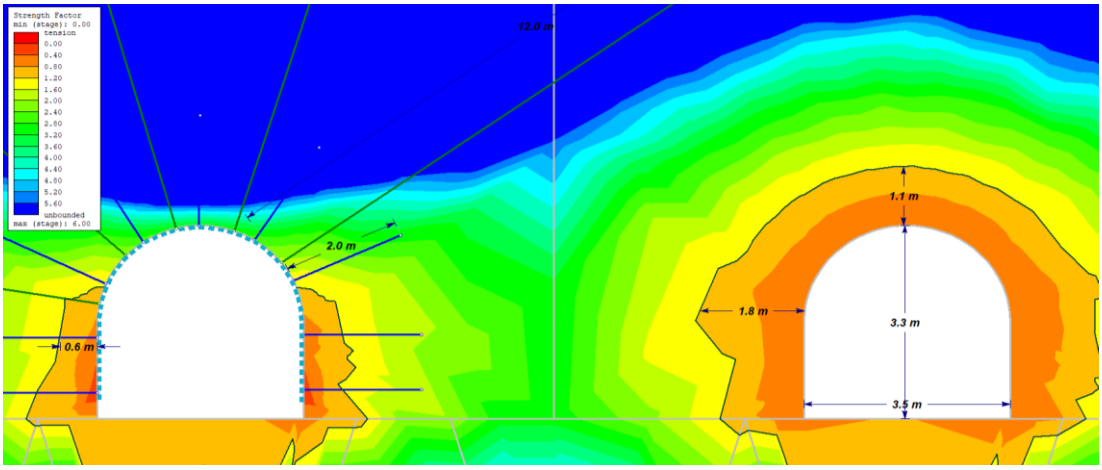

**Figure 10. Stress-strain state of the combined support**

The data for modelling are obtained from a typical passport for fastening the haulage workings. According to the modelling results, it can be seen that with such a fastening, the safety factor of the aquifer mass is in a stable state. Figures 11 and 12 below show the safety factors around mine working with and without fastening.

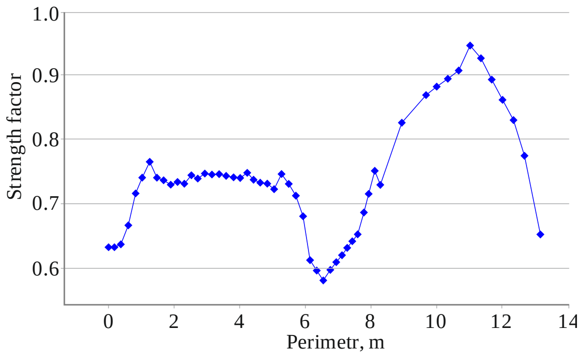


**Figure 11. Graph of a change in the safety factor of the border mass without fastening**

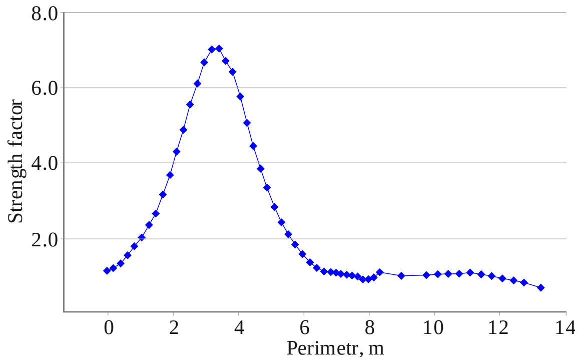


**Figure 12. Graph of a change in the safety factor of the border mass with combined fastening**

Based on the modelling results, it should be argued that with this option for fastening mine workings, the load-bearing capacity of the combined support has a margin.

(a) (b)

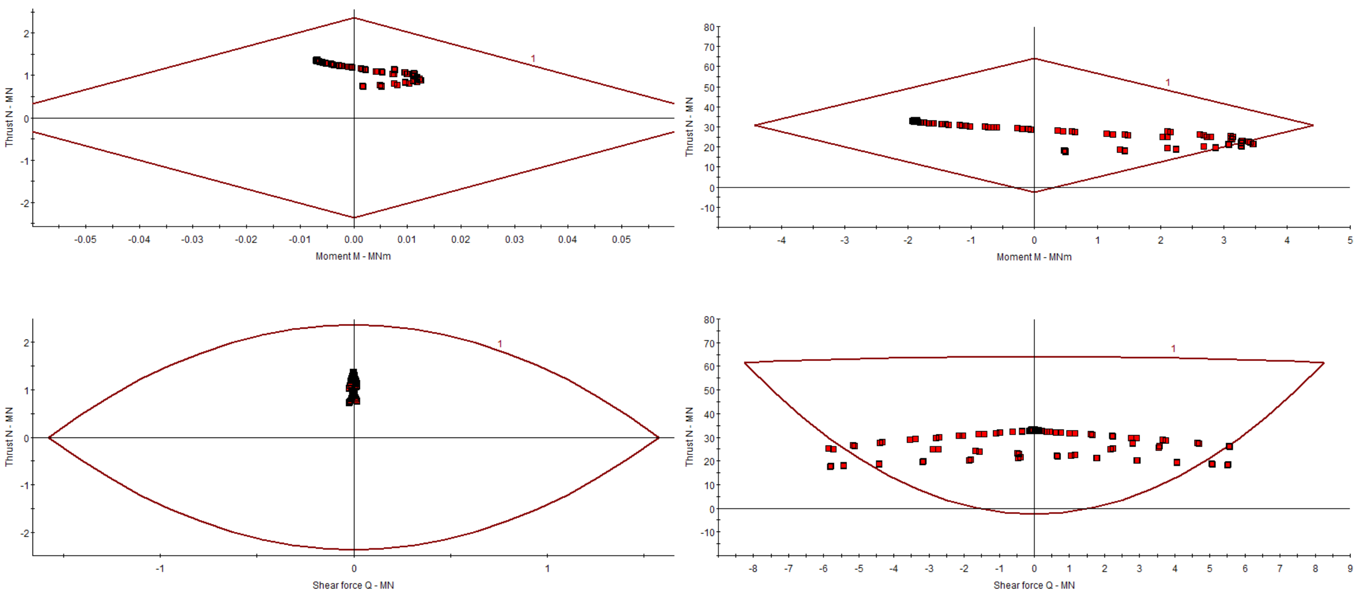


**Figure 13. Graphs of the load-bearing capacity of SCP and shotcrete: (a) graph of the load bearing capacity of frame fastening; (b) fastening, induced by axial shocks and bending moment**

Figure 13 presents the graphs of the load-bearing capacity of shotcrete and SCP, from which it follows that Figure 13a shows the load-bearing capacity of the frame fastening. Figure 13b shows the load-bearing capacity of fastening, induced by axial shocks and bending moment, which indicate the pressure on the fastening. Based on the modelling results, Figure 14a shows the mine working fastened by SCP frames in combination with 20 cm thick shotcrete without roof-bolt and cable-bolt fastening. Figure 14b shows the mine working fastened by SCP frames in combination with 20 cm thick shotcrete, as well as roof-bolt and cable-bolt fastening. As can be seen from the model, the safety factors in both cases are close.

(a) (b)

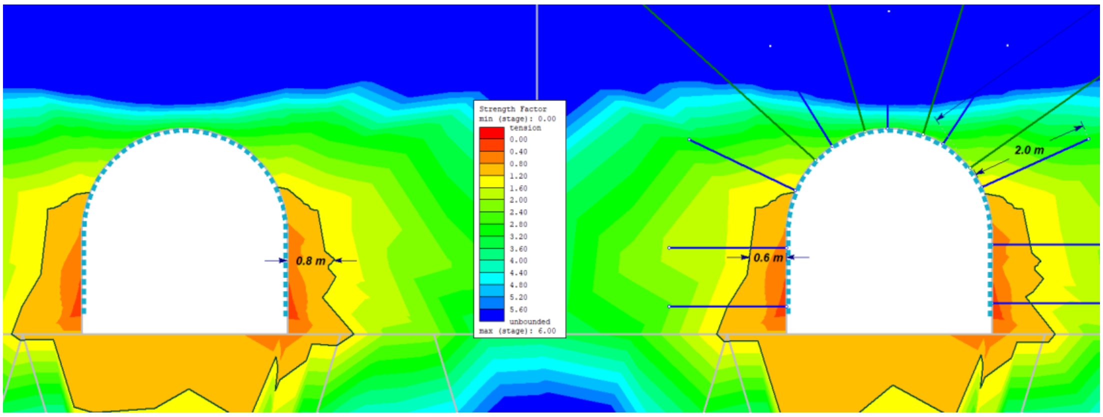


***Figure 14. Stress-strain state of two options of combined support: (a) mine working is fastened by SCP frames; (b) mine working is fastened by SCP frames with roof-bolt and cable-bolt fastening***

According to Figure 15 it can be argued that the use of roof-bolt and cable-bolt fastening to maintain mine workings does not significantly influence on the load-bearing capacity of mine workings. The main stability of mine workings is provided by the frame support SCP-22 (27) in combination with shotcrete.

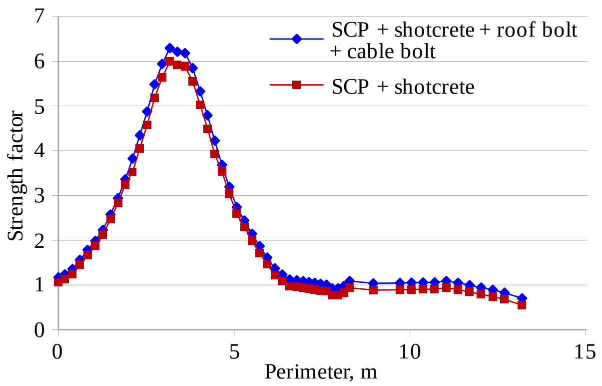


***Figure 15. Graph of comparing the safety factors of two combined support types***

During the research, there was almost no data on the structural properties of the mass. For a more detailed analysis of the rock mass stress-strain state, it is recommended to collect data on the rock mass structure by geotechnical mapping of the mine working walls.

To collect data on the mass structure, the rating classification of the mass is used, accepted by the International Society for Rock Mechanics ISRM. A database is created for geotechnical mapping of the mine working walls, from which, in turn, a structural block model is constructed. Using the block model, stronger and weaker zones of the field can be identified, which can help in the design of further mine workings.

To clarify the predicting assessment of the mass stress-strain state using the finite element method, it is recommended to perform in-situ measurements of the natural stress field by the "hydraulic fracturing" method.

The main task of the research by hydraulic fracturing method is to determine the value and directions of the principal stresses and the natural stress field. However, the method of hydraulic fracturing is a very time consuming and costly.

## 4. Conclusions

The paper analyses the mining-geological and mining-technical conditions of mining at the 10th Anniversary of Kazakhstan's Independence mine, as well as the methods for determining the stress-strain state. A numerical analysis of the stress-strain state of the rock mass at the horizon -480 m is also performed.

A predicting assessment of the mass stress-strain state has been conducted, which is based on the use of effective numerical methods and which allows to increase the reliability of predicting the "mining and geomechanical" situation at the extraction area.

The load values on the mine working support in the host rocks and in the ore mass of the -480 m horizon and the load-bearing capacity of the support types used at the 10th Anniversary of Kazakhstan's Independence mine have been calculated on the basis of numerical analysis.

According to the numerical analysis results of the rock mass stress-strain state at a depth of 900 m (horizon -480 m), the principal stresses are close to hydrostatic ones $\sigma_1 = \sigma_3 = \sigma_z = 24.8$ MPa.

Predicting assessment of mine workings stability margin is performed before and after stope operations. Based on its results, it can be assumed that the stability margin of the mine workings driven in the stope zone is below the minimum permissible, therefore, caving and an increase in the load on the support are possible.

The load-bearing capacity of the support types used at the 10th Anniversary of Kazakhstan's Independence mine has been calculated on the basis of numerical analysis in the RS2 software. The safety factors of the rock mass near mine workings have been determined. From the numerical analysis results it can be seen that the roof-bolt and cable-bolt fastening does not greatly increase the stability of mine workings, therefore there is no urgent need to increase the stability of mine workings.


## Acknowledgements

We would like to express our gratitude to all the editorial staff and reviewers for the quality work on our material. We are pleasantly surprised by the prompt and well-organized feedback from the editors. We wish the journal prosperity and look forward to further fruitful cooperation! Of special note is the well-organized and well-coordinated team work.

I would like to express my gratitude to Arystan Ibatolla Daiyrovich, my Academic Advisor, for valuable advice in planning the research and recommendations for the paper design. In addition, I am very grateful to my colleagues who have supported me for several months while I was working on the manuscript. I hope to find this journal in the Scopus and Web of Science citation database!


## References


[1] Arystan, I.D., Abeuov, E.A., & Abdrashev, R.M. (2019). Kreplenie gorizontal'nykh gornykh vyrabotok v usloviyakh shakht Donskogo GOKa. V Materialakh *VIII Mezhdunarodnoi nauchno-prakticheskoi konferentsii "Sovremennye Tendentsii i Innovatsii v Nauke i Proizvodstve"*. Kemerovo, Rossiya: KuzGTU.

[2] Kuandykov, T., Nauryzbayeva, D., Yelemessov, K., Karmanov, T., Kakimov, U., & Kolga, A. (2020). Development and justification of a hydro-impulse method for increasing ore permeability in conditions of uranium borehole production. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences*, (6), 126-133.

[3] Sejtmuratova, E.J., Arshamov, J.K., Baratov, R.T., Dautbekov, D.O. (2016). Geological and metallogenic features of volcano-plutonic belt Kazakhstan. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences*, *3*(416), 60-86.

[4] Seitmuratova, E., Arshamov, Y., Bekbotayeva, A., Baratov, R., & Dautbekov, D. (2016). Priority metallogenic aspects of late paleozioc volcanic-plutonic belts of Zhongar-Balkhash fold system. *International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management*, (1), 511-518. https://doi.org/10.5593/sgem2016/b11/s01.064

[5] Baizbaev, M.B., Abdrashev, R.M., Mataev, A.K. (2020). Tekhnologii provedeniya i krepleniya gornykh vyrabotok. *Intellektual'naya Sobstvennost'*, #8706.

[6] Griffiths, D.V., & Lane, P.A. (1999). Slope stability analysis by finite elements. *Geotechnique*, *49*(3), 387-403. https://doi.org/10.1680/geot.1999.49.3.387

[7] Kurlenya, M.V., & Popov, S.N. (1983). *Teoreticheskie osnovy opredeleniya napryazheniy v gornykh porodakh*. Novosibirsk, Rossiya: Nauka, SO RAN.

[8] Fanchi, J. R. (2018). Petroelastic modeling and geomechanical modeling. *Principles of Applied Reservoir Simulation*, 59-80. 0.1016/b978 https://doi.org/-0-12-815563-9.00004-5

[9] Abdiev, A.R., Mambetova, R.S., & Mambetov, S.A. (2017). Geomechanical assessment of Tyan-Shan's mountains structures for efficient mining and mine construction. *Gornyi Zhurnal*, (4), 23-28. https://doi.org/10.17580/gzh.2017.04.04

[10] Arystan, I.D., Baizbaev, M.B., Mataev, A.K., Abdieva, L.M., & Bogzhanova, Z.K. (2020). Selection and justification of technology for fixing preparatory workings in unstable massifs on the example of the mine "10 years of independence of Kazakhstan". *Ugol'*, (06), 10-14. https://doi.org/10.18796/0041-5790-2020-6-10-14

[11] Demin, V.F., Isabek, T.K., & Demina, T.V. (2012). Komp'yuternoe modelirovanie napryazhennogo sostoyaniya prikonturnykh porod vokrug vyrabotok. *Trudy Mezhdunarodnogo Simpoziuma "Informatsionno-Kommunikatsionnye Tekhnologii v Industrii, Obrazovanii i Nauke"*, (3), 109-111.

[12] Arystan, I.D., Baizbaev, M.B., & Abdrashev, R.M. (2019). *Tekhnologii provedeniya i krepleniya gornykh vyrabotok*. Aktobe, Kazakhstan: ARGU im. K. Zhubanova, 99 s.

[13] Grebenkin, S.S., Pavlysh, V.N., Samoylov, V.L., & Petrenko, Yu.A. (2010). *Upravlenie sostoyaniem massiva gornykh porod*. Donetsk, Ukraina: DonNTU, 193 s.

[14] Hoek, E., Carranza-Torres, C., & Corkum, B. (2002). Hoek-Brown criterion. *Proceedings of the 5th North American Rock Mechanics Symposium and the 17th Tunnelling Association of Canada*, (1), 267-273.

[15] Sultanov, M.G., Mataev, A.K., Kaumetova, D.S., Abdrashev, R.M., & Kuantay, A.S. (2020). Development of the choice of types of support parameters and technologies for their construction at the "Voskhod" field. *Ugol'*, (10), 17-21. https://doi.org/10.18796/0041-5790-2020-10-17-21

[16] Turchaninov, I.A., Iofis, M.A., & Kaspar'yan E.V. (1989). *Osnovy mekhaniki gornykh porod*. Leningrad, Rossiya: Nedra, 488 s.

[17] Duncan, J.M. (1996). State of the art: Limit equilibrium and finite-element analysis of slopes. *Journal of Geotechnical Engineering*, *122*(7), 577-596. https://doi.org/10.1061/(asce)0733-9410(1996)122:7(577)

[18] Haimson, B.C., & Cornet, F. (2003). ISRM suggested methods for rock stress estimation – Part 3: Hydraulic fracturing (HF) and/or hydraulic testing of pre-existing fractures (HTPF). *International Journal of Rock Mechanics & Mining Sciences*, *40*(7-8), 1011-1020. https://doi.org/10.1016/j.ijrmms.2003.08.002


## Дослідження геомеханічної ситуації в масиві гірських порід у зоні впливу очисних робіт в умовах шахти "10 років Незалежності Казахстану"

А. Матаєв, А. Кайназарова, І. Аристан, Є. Абеуов, А. Кайназаров, М. Баізбаєв, В. Дьомін, М. Султанов


**Мета.** Прогноз напружено-деформованого стану (НДС) в масиві гірських порід у зоні впливу очисних робіт при використанні системи розробки самообвалення та розрахунок несучої здатності кріплення гірничих виробок, що застосовуються на шахті "10 років Незалежності Казахстану".

**Методика.** Проаналізовано комплекс геолого-інженерних даних властивостей вміщуючих порід. Виконано чисельне моделювання напружено-деформованого стану масиву гірських порід і розрахунок несучої здатності видів кріплення, що застосовуються на шахті у програмі RS2, яка працює на основі методу скінченних елементів (Finite Element Method) у двовимірній постановці, що дозволило врахувати значну кількість факторів, що впливають на стан масиву. В якості моделі поведінки масиву використовувалася модель Хоека-Брауна, відмітною перевагою якої є її нелінійність.

**Результати.** Отримано значення головних напружень і навантаження на кріплення. За результатами чисельного аналізу напружено-деформованого стану масиву гірських порід на глибині 900 м (гор. -480 м) головні напруження близькі до гідростатичним $\sigma_1 = \sigma_3 = \sigma_z = 24.8$ Мпа. Виконана прогнозна оцінка запасу стійкості гірничих виробок до і після очисних робіт, за результатами якого слід припускати, що запас стійкості пройдених виробок у зоні очисного простору нижче мінімально допустимого, а отже, можливі обвалення й збільшення навантаження на кріплення. Розраховано опорний тиск на кріплення виробок на глибині відпрацювання 900 м (гор. -480 м). Виконано розрахунок параметрів кріплення виробок, закладених на горизонті -480 м.

**Наукова новизна.** Встановлено характер та особливості закономірностей формування напружено-деформованого стану в межах впливу різних варіантів очисних робіт блоку 20-28 на горизонті -480 м і надана кількісна оцінка величин навантажень на кріплення відкотних ортів виробок горизонту.

**Практична значимість.** Результати виконаних досліджень можуть бути застосовані при створенні геомеханічної моделі родовища та проектуванні стійких параметрів кріплення гірничих виробок.


***Ключові слова:*** *напружено-деформований стан, головні напруження, руда, гірські породи*

## Исследование геомеханической ситуации в массиве горных пород в зоне влияния очистных работ в условиях шахты “10 лет Независимости Казахстана”

А. Матаев, А. Кайназарова, И. Арыстан, Е. Абеуов, А. Кайназаров, М. Баизбаев, В. Демин, М. Султанов

**Цель.** Прогноз напряженно-деформированного состояния (НДС) в массиве горных пород в зоне влияния очистных работ при использовании системы разработки самообрушением и расчет несущей способности крепи горных выработок, применяемых на шахте “10 лет Независимости Казахстана”.

**Методика.** Проанализирован комплекс геолого-инженерных данных свойств вмещающих пород. Выполнено численное моделирование напряженно-деформированного состояния массива горных пород и расчет несущей способности видов крепи, применяемых на шахте в программе RS2, которая работает на основе метода конечных элементов (Finite Element Method) в двумерной постановке, что позволило учесть значительное количество факторов, влияющих на состояние массива. В качестве модели поведения массива использовалась модель Хоека-Брауна, отличительным преимуществом которой является ее нелинейность.

**Результаты.** Получены значения главных напряжений и нагрузки на крепь. По результатам численного анализа напряженно-деформированного состояния массива горных пород на глубине 900 м (гор. -480 м) главенствующие напряжения близки к гидростатическим $\sigma_1 = \sigma_3 = \sigma_z = 24.8$ МПа. Выполнена прогнозная оценка запаса устойчивости горных выработок до и после очистных работ, по результатам которого следует предполагать, что запас устойчивости пройденных выработок в зоне очистного пространства ниже минимально допустимого, следовательно, возможны обрушения и увеличение нагрузки на крепь. Рассчитано опорное давление на крепь выработок на глубине отработки 900 м (гор. -480 м). Выполнен расчет параметров крепи выработок, заложенных на горизонте -480 м.

**Научная новизна.** Установлен характер и особенности закономерностей формирования напряженно-деформированного состояния в границах влияния различных вариантов очистных работ блока 20-28 на горизонте -480 м и дана количественная оценка величин нагрузок на крепь откаточных ортов выработок горизонта.

**Практическая значимость.** Результаты исследований могут быть применены при создании геомеханической модели месторождения и проектировании устойчивых параметров крепи горных выработок.

***Ключевые слова:*** *напряженно-деформированное состояние, главные напряжения, крепь, рудник, руда, горные породы*