ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ
Satbayev University

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

N E W S

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN
Satbayev University

SERIES
OF GEOLOGY AND TECHNICAL SCIENCES

6 (450)

NOVEMBER – DECEMBER 2021

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

«ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).

Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген **№ KZ39VPY00025420** мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Тақырыптық бағыты: геология, мұнай және газды өңдеудің химиялық технологиялары, мұнай химиясы, металдарды алу және олардың қосындыларының технологиясы.

Мерзімділігі: жылына 6 рет.

Тиражы: 300 дана.

Редакцияның мекен-жайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., тел.: 272-13-19

http://www.geolog-technical.kz/index.php/en/

Типографияның мекен-жайы: «Аруна» ЖК, Алматы қ., Мұратбаев көш., 75.

«Известия НАН РК. Серия геологии и технических наук».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **№ KZ39VPY00025420,** выданное 29.07.2020 г.

Тематическая направленность: геология, химические технологии переработки нефти и газа, нефтехимия, технологии извлечения металлов и их соеденений.

Периодичность: 6 раз в год.

Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, оф. 219, тел.: 272-13-19
http://www.geolog-technical.kz/index.php/en/

Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75.

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty).

The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan **No. KZ39VPY00025420,** issued 29.07.2020.

Thematic scope: geology, chemical technologies for oil and gas processing, petrochemistry, technologies for extracting metals and their connections.

Periodicity: 6 times a year.

Circulation: 300 copies.

Editorial address: 28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19

http://www.geolog-technical.kz/index.php/en/

Address of printing house: ST «Aruna», 75, Muratbayev str, Almaty.

NEWS
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 6, Number 450 (2021), 110-117 https://doi.org/10.32014/2021.2518-170X.126

UDC 622.271: 622.83

Sedina S.A.[1]*, Berdinova N.O.[1], Abdikarimova G.B.[1], Altayeva A.A.[1], Toksarov V.N.[2]

[1]Branch of the Republican State Enterprise «National center for complex processing of mineral raw materials of the Republic of Kazakhstan» D.A. Kunayev Mining Institute, Almaty, Kazakhstan;
[2]Mining Institute of the Ural Branch of the Russian Academy of Sciences, Perm, Russia.
E-mail: *SSA2704@mail.ru*

NUMERICAL MODELING OF THE STRESS-STRAIN STATE OF THE KURZHUNKUL OPEN-PIT MINE

Abstract. The stress-strain state of rocks is one of the main factors that determine the magnitude and nature of rock pressure, on which the safety of deep open pit development depends. When conducting mining operations, it is necessary to understand where zones of increased principal components of normal and maximum shear stresses form.

The article presents the results of numerical modeling of the stress-strain state of the Kurzhunkul pit in a two-dimensional formulation by the finite element method in the MIDAS GTS NX software package. In mathematical modeling, the stresses actually acting in the array, determined by field measurements, were taken into account. A model based on the results of modeling is presented, which can be used to predict changes in the maximum gradient of horizontal stress with an increase in the depth of mining of the Kurzhunkul open-pit mine. Based on the results of the modeling of the sides in the southeastern north-western directions, areas were identified where there is an unfavorable effect of the maximum shear stresses on the side rock mass and the maximum shear stresses (τ_{max}) may exceed the shear strength.

Also, an assessment of the influence of the main components of normal and maximum shear stresses on the stability of the near-rock pit rock mass is given. It has been determined that the geomechanical state of the sides of the Kurzhunkul open-pit mine is characterized by the action of low compressive stresses. The values of the maximum compressive stresses vary from 5.52 MPa to 14.25 MPa, increasing from the day surface to the bottom of the open pit. The minimum component of the principal stresses varies from 0.70 to 9.4 MPa. The values of tensile minimum stresses σ_{min} are significantly less than the calculated values of tensile stresses σ_p in the sample and do not affect the stability of the pit edges.

Key words: stress-strain state, pit, distribution of principal stresses, rock mass stability, a two-dimensional numerical model.

Introduction. The problem of predicting the tectonic effect on the stress state of the rock mass is important in geomechanics today. If the natural stresses in the sides of the pit slope are high and exceed the strength of the rock mass, then its deformation occurs and large zones of weakened rocks are created, which can then collapse under the influence of their own weight [1, 2].

Based on the results of field studies, it was determined that the stress-strain state of the rock masses of the Kurzhunkul pit was attributed to the gravitational-tectonic type [3]. The stability of quarry walls in rocky tectonically stressed rocks is determined, first, by the parameters of the stress-strain state, structural disturbance, and strength characteristics of the rock mass.

Materials and methods. To substantiate the rational design parameters of the Kurzhunkul opencast mine, calculations were performed to estimate the stress-strain state of the rock mass in a two-dimensional (2D) formulation by the finite element method using the MIDAS GTS NX software package.

Finite element method (FEM) calculation in MIDAS GTS NX can be conditionally divided into the following stages:

- setting the computational domain with the selection of characteristic areas and mechanical properties for the selected areas;

- setting limiting conditions at the boundaries of the computational domain and selected areas;
- splitting the computational domain into finite elements (selection of the type and size of finite elements in the selected areas);
- selection of the nature of material deformation (elastic, plastic, etc.) and the criterion of destruction (Coulomb-Mohr, Drucker-Prager, Hook-Brown, etc.);
- calculation of stresses (deformations, displacements), graphic presentation, and interpretation of the calculation results.

When calculating the stress-strain state in the MIDAS GTS NX software package, in all cases, it is assumed that the output compressive stresses and forces are negative, and the tensile stresses and forces are positive [4].

Numerical modeling of the stress-strain state of the Kurzhunkul pit was carried out within the framework of solving the plane problem (2D). The design schemes for the construction of the finite element mesh were used for the sections of the final contour of the Kurzhunkul pit (with a deepening up to minus 290 m) in the direction of the southeast (SE) and northwest (NW) sides [5, 6]. The finite element mesh of design models contains 96866 ÷ 119935 elements. The minimum linear dimension of the finite element based on the thickness of the minimum geological layer is 1 -2 m, the maximum is 10-20 m.

The length of the rock mass is modeled within certain boundaries. The boundaries of the model are chosen in accordance with Saint-Venant's principle, according to which the zone of influence of a feature extends to a distance of no more than three of its characteristic dimensions. For the calculation, the calculated physical and mechanical characteristics of the rocks were used, determined from the survey data, and given in tables 1 and 2.

Table 1. Average physical and mechanical properties of soils of the Kurzhunkul deposit

EGE name	Module of deformation, MPa	Water saturation coefficient	Porosity	Density, t / m^3	Internal friction angle, degrees	Coupling, \MPa
Loam (edQ$_{IV}$)	3,36	0,85	0,74	1,99	12,33	0,09
Clay (N2ks)	4,7	0,75	0,625	1,96	11,00	0,10
Loam (P$^3_3$)	3,8	0,88	0,81	2,04	7,50	0,05
Sandy loa m (P$^2_3$)	4,13	0,74	0,69	2,19	10,54	0,04
Clay (P$_{2cg}$)	4,11	0,92	1,04	1,80	11,22	0,08
Clay with sandstone interlayers (P$_{2ts}$)	4,86	0,92	1,23	1,72	11,22	0,12
Heavily crushed clay eMz	5,49	0,92	0,80	1,98	13,42	0,09

Table 2. Physical and mechanical characteristics of rocks of the SE and NW sides used in modeling the stress-strain state

Parameter	Desig-nation	Units of measure	SE				NW	
			limestone	porphyrite	metasomatite	andesite	porphyrite	metasomatite
Density	γ	t/m^3	2,74	2,72	2,73	2,79	2,68	2,65
Module of deformation	E	x 10^4, MPa	5,47	5,53	5,27	5,23	5,42	4,34
Poisson's ratio	μ		0,29	0,28	0,30	0,27	0,27	0,29
Internal friction angle	φ	degrees	28	27,44	27,6	25,4	28,8	27,0
Coupling	C	t/m^2	42,41	47,24	46,23	40,10	60,2	0

The correspondence of the calculated stress field to the real geomechanical state of the mass largely depends on the reasonable choice of model dimensions and boundary conditions.

Determination of horizontal stresses of the Kurzhunkul pit was carried out by the method of borehole unloading in two experimental areas. The unloading method is sufficiently accurate and methodologically justified, which makes it possible to use it to determine the complete stress tensor of the studied pore array [3, 7, 8].

The stress-strain state of the rocks of the near-edge mass of the Kurzhunkul quarry in its present state, as shown by measurements by the borehole unloading method, is characterized by a relatively low level of stress.

When creating a numerical model of the stress-strain state of a rock mass, the boundary conditions were set as following:

- calculated two-dimensional model with linear dimensions in the horizontal direction - 2984 m, and in the vertical direction - 1036 m;
- the values of the component of tectonic stresses T_x and T_y, obtained based on the results of measurements by the borehole unloading method, are taken to be the same throughout the depth and equal to the calculated values of T_x = - 3.99 MPa and T_y = - 4.39 MPa;
- the values of gravitational stresses in the areas of the rock mass, varying along the depth of the quarry and corresponding to the weight of the overlying rocks;
- the starting initial stress state of the mass is modeled using the values of the coefficient of lateral soil pressure λ = 2 in two mutually perpendicular directions of the principal stresses. Comparison of the measured stress values with the calculated stress values based only on the own weight of the rocks shows that the effective values of the maximum components of the principal stresses exceed the maximum calculated stresses from the own weight of the overlying rocks by almost 2 times.

Results. The finite element model was built in SE-NW orientation in accordance with the general direction of maximum horizontal stress. Figures 1-3 show the isolines of the distribution of the main maximum component of stresses τ_{xy}, the main minimum component of stresses σ_{max}, shear stresses σ_{min} according to the results of numerical modeling in a two-dimensional setting in the SE and NW direction of the walls of the Kurzhunkul open-pit mine.

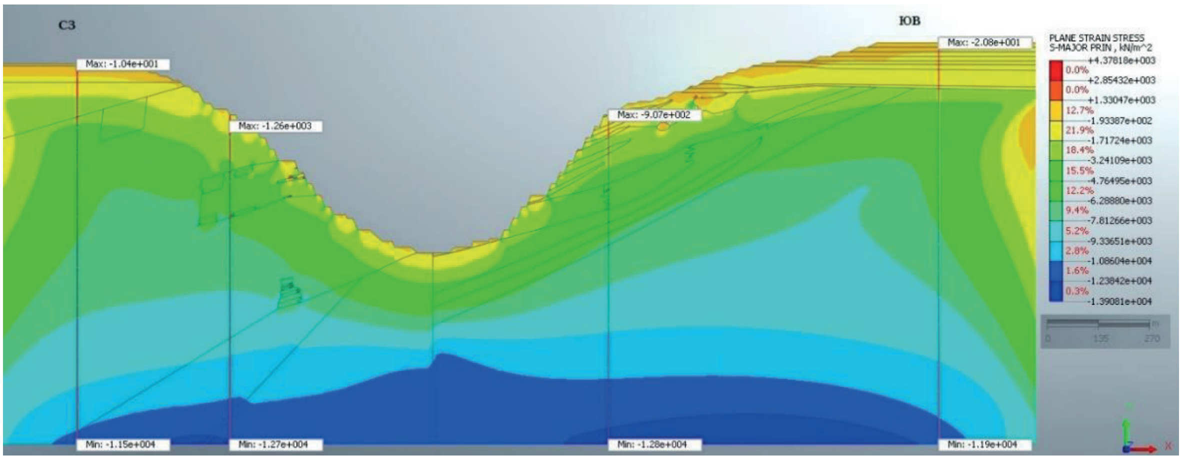

Figure 1. Distribution of maximum stresses σ_{max} in the SE and NW directions of the sides of the Kurzhunkul mine in the intact near-edge rock mass and borrow excavation

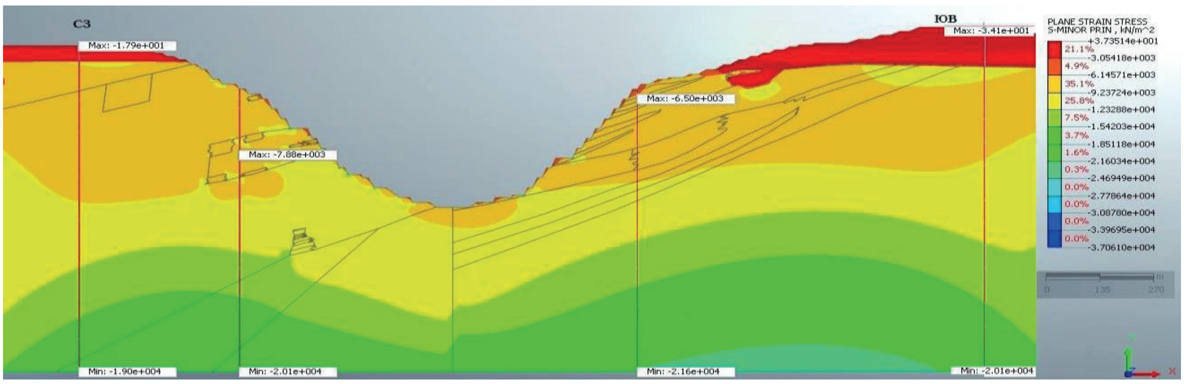

Figure 2. Distribution of minimum stresses й σ_{min} in the SE and NW direction of the sides of the Kurzhunkul mine in the intact near-edge rock masses and borrow excavation

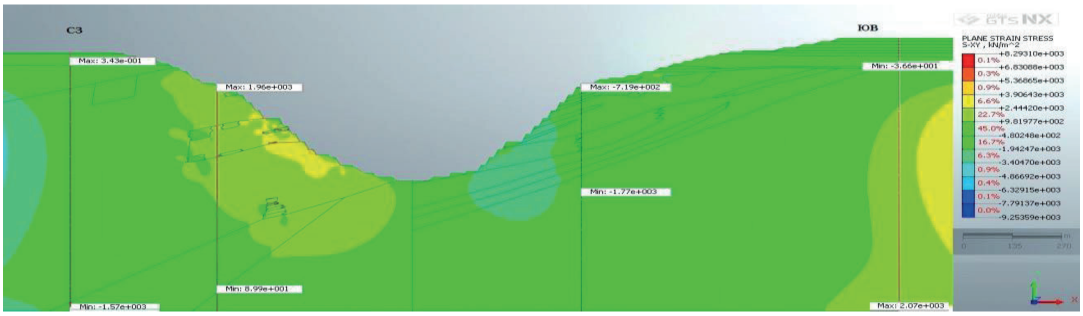

Figure 3. Distribution of maximum shear stresses τ_{xy} in the SE and NW direction of the sides of the Kurzhunkul open-pit mine in the intact near-edge rock masses and borrow excavation

Figure 4 illustrates the model used to predict the maximum horizontal stress gradient with depth. For the NW side, the values of the maximum stress component σ_{max} of stresses first decrease to the mark (-100) - (-130) m in an absolute value from 9.07 to 7.04 MPa due to the loading by an external blade. Then increase uniformly to 9.42 ÷ 9.51 MPa and at the mark (-400) m the maximum component of horizontal stresses is compared with the gravitational stress, $\sigma_{max} = \sigma_{верт}(YY)$ (Figure 4). The value of the lateral pressure coefficient (λ) of the near-rock mass of the Kurzhunkul quarry, defined as the ratio of the maximum horizontal stresses to γH up to a depth of 600 m is λ = 1.1 ÷ 3.42, below - λ = 1.01 (Figure 5).

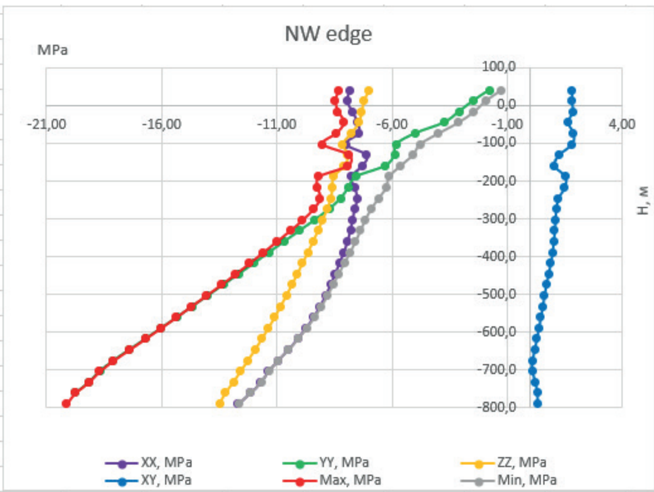

Figure 4. Diagrams of distribution of σ_{max}, σ_{min}, τ_{xy} (XY) NW edge

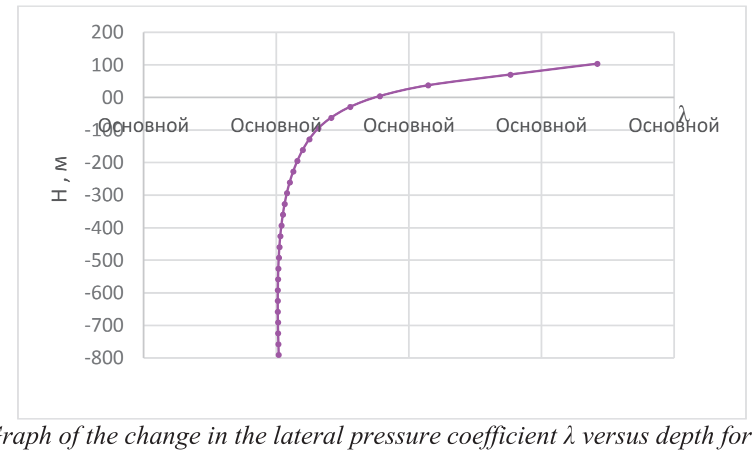

Figure 5. Graph of the change in the lateral pressure coefficient λ versus depth for the NW side

Tensile minimum stresses σ_{min} (Figure 1) in the pit walls are observed at the points of contacts of geological layers with different deformation properties (at the base of the external dump No. 4) and at the surface of the slope benches. The values of the tensile minimum stresses σ_{min} are 0.37 MPa, which is much less than the calculated values of tensile stresses σ_p in the sample and, in general, they do not affect the stability of the walls.

The ledges of the SE side up to the projected depth of 500 m are under the action of low compressive stresses in the absolute value σ_{max} = 6.5 ÷ 10.64 MPa. In the SE board at marks (-400) - (-450) m, the maximum component of horizontal stresses is compared with the gravitational stress, $\sigma_{max} = \sigma_{vert}(YY)$. There are no tensile minimum stresses σ_{min}. The value of the lateral pressure coefficient (λ) of the near-edge rock mass of the Kurzhunkul pit, defined as the ratio of the maximum horizontal stresses to γH up to a depth of 600-650 m is λ = 1.1 ÷ 3.39, below - λ = 1.01

Based on the results of modeling the SE-NW sides were identified areas, where there is an unfavorable effect of the maximum shear stresses on the side rock mass and the maximum shear stresses τ_{max} may exceed the shear strength (Table 3). For these areas, the condition of non-destruction according to Mohr-Coulomb (1) and the calculation of the safety factor (SF) for τ_{max} according to (2) were calculated. [9-12]

$$\tau_{max} < \sigma_n \, tg\, \varphi + C \qquad (1)$$

where τ_{max} - effective maximum shear stresses;

C, φ - adhesion and angle of internal friction of the destroyed material;

σ_n- normal stress component acting on the slip area.

In equation (1), the left side τ_{max} is a shear force, and the right side ($\sigma_n \, tg\, \varphi + C$) — is a holding force, their ratio determines the safety factor n:

$$n = \frac{(\sigma max + \sigma min) tg\varphi + 2C}{2\tau_{max}} \qquad (2)$$

Discussion. In the NW side at marks (-20) ÷ (-230) m and in the SE side at marks (-20) ÷ (-250) m, the effective maximum shear stresses τ_{max} exceed the shear strength. On these horizons, a shift of rock blocks along natural and mining-induced queres is possible. The failure mode of open pit slopes will largely depend on the orientation of the fractures in the rock mass in relation to the orientation of the slope and the angle of the slope. The direction and nature of the main surfaces of weakening in this part of the open pit have not been sufficiently studied to date for their use in the kinematic analysis of the NW side of the open pit [6].

Table 3. Impact analysis of shear stresses τ_{max} on the near-edge rock mass of the Kurzhunkul pit in the SE and NW direction of the sides based on the results of numerical modelling

Calculation scheme	Dangerous areas for the development of deformations, horizons m	Fulfillment of the condition of non-destruction		Estimated SF site	Predicted site condition
		Effective maximum shear stresses τ_{xy}, MPa	Design shear strength, MPa		
NW	130 м÷(-20) m (-230) м ÷ (-290) m	0,48-2,44	3,31	1,25	Mass is stable
	(-20) ÷ (-230) m	3,9	3,31	0,76	At these horizons, when the shear stresses exceed the shear strength, shear queres appear and shear blocks of rocks along natural and mining-induced queres are likely
SE	(-250) м ÷ (-290) m	1,94	3,04÷3,07	1,41	Mass is stable
	(-20) ÷ (-250) m	3,4	3,04÷3,07	1,16	Mass is stable

Conclusions. Based on the results of numerical modeling, the assessment of the influence of the principal components of normal and maximum shear stresses on the stability of the near-edge rock mass showed:

- the predicted stress values are within reasonable limits in accordance with the measured data.

- the geomechanical state of the sides of the Kurzhunkul mine is characterized by the action of low compressive stresses. The values of the maximum compressive stresses in the absolute value σ_{max} in the open pit and intact rock mass vary from 5.52 MPa to 14.25 MPa, increasing from the surface to the bottom of the open pit. Zones of compressive stress concentrations σ_{max} are confined to the bottom of the open pit (11.2-14.25 MPa), which is no more than 0,1-0,35 σ_{co}, i.e. stresses acting in the mass do not destroy the rock and are compressive.

- the minimum component of the principal stresses σ_{min} varies in absolute value from 0.70 to 9.4 MPa. Zones of tensile stresses σ_{min} with a value of 0.37 MPa are observed in the NW and SE sides at the points of contacts of geological layers with different deformation properties (at the base of the external dump No. 4) and at the surface of the slope benches. The values of tensile minimum stresses σ_{min} are much less than the calculated values of tensile stresses σ_p in the sample and do not affect the stability of the pit walls.

- zones of concentration of tangential stresses τ_{max} affecting the stability of the sides are confined to: in the NW side at elevations (-20) ÷ (-230) m, in the SE side at elevations (-20) ÷ (-250) m. At these horizons, the operating maximum shear stresses exceed the ultimate shear strength and shear of rock blocks along natural and mining-induced queres is probable.

The stress state of the near-edge rock mass of the Kurzhunkul pit to a depth of 600-700 m refers to the gravitational-tectonic form, with horizontal stresses exceeding vertical ones. At a depth of 600-700 m, the vectors σ_{max} are reoriented, which are equalized with the vertical $\sigma_{max}=\sigma_{vert}$ (YY).

From a depth of 600 m - 700 m, the stress state of the near-edge rock mass of the Kurzhunkul pit is hydrostatic. Due to this feature, a change in the nature of the destruction of the rock mass is likely.

The article was written within the framework of grant funding under the project №. AP08053358 "Rock mass management to ensure the safe development of a deposit based on an integrated geomechanical model".

Съедина С.А.[1]*, Бердинова Н.О.[1], Абдыкаримова Г.[1], Алтаева А.А.[1], Токсаров В.Н.[2]

[1]«Д. А. Қонаев атындағы Тау-кен институты» «ҚР МШҚҚӨЖ ҰО» РМК, Алматы,Қазақстан;
[2]Ресей Ғылым Академиясының Орал филиалының тау-кен институты, Пермь, Ресей.
E-mail: *SSA2704@mail.ru*

КУРЖУНКУЛЬ КАРЬЕРІНІҢ КЕРНЕУЛІ-ДЕФОРМАЦИЯЛАНҒАН КҮЙІН САНДЫҚ МОДЕЛЬДЕУ

Аннотация. Тау жыныстарының кернеулі-деформацияланған күйі терең карьерлерді игеру қауіпсіздігіне байланысты тау қысымының мөлшері мен сипатын анықтайтын негізгі факторлардың бірі болып табылады. Тау-кен жұмыстарын жүргізу кезінде қалыпты және максималды жанама кернеулерінің жоғары компоненттерінің аймақтары қай жерде қалыптасатынын түсіну қажет.

Мақалада MIDAS GTS NX бағдарламалық жасақтамасында шекті элементтер әдісімен екі өлшемді қойылымда Куржункуль карьерінің кернеулі-деформацияланған күйін сандық модельдеудің нәтижелері көрсетілген. Математикалық модельдеу кезінде далалық өлшеулермен анықталған массивте іс жүзінде әсер ететін кернеулер ескерілді. Куржункуль карьерін өңдеу тереңдігін арттыра отырып, көлденең кернеудің максималды градиентінің өзгеруін болжау үшін қолдануға болатын модельдеу нәтижелеріне негізделген модель келтірілген. Оңтүстік-шығыс солтүстік-батыс бағыттардағы борттарын модельдеу қорытындылары бойынша ең жоғары жанама кернеулерінің борт маңы массивіне қолайсыз әсері байқалатын және ығысу беріктігінің ең жоғары жанама кернеулерінен (τ_{max}) асып кетуі мүмкін учаскелері анықталды.

Сонымен қатар, қалыпты және максималды жанама кернеулерінің негізгі компоненттерінің карьердің борттық массивінің тұрақтылығына әсерін бағалау келтірілген. Куржункуль карьерінің борттарының геомеханикалық күйі төмен қысатын кернеулердің әсерімен сипатталатыны анықталды. Ең жоғары қысу кернеулерінің мәндері 5,52 МПа -дан 14,25 МПа-ға дейін өзгереді, бұл карьердің бетінен түбіне дейін артады. Негізгі кернеулердің минималды компоненті 0,70-тен 9,4 МПа-ға дейін өзгереді. Созылу минималды кернеулерінің мәндері σ_{min} үлгідегі созылу кернеулерінің есептелген мәндерінен σ_pәлдеқайда аз және карьер борттарының тұрақтылығына әсер етпейді.

Түйінді сөздер: кернеулі-деформацияланған күй, карьер, негізгі кернеулердің таралуы, массивтың тұрақтылығы, екі өлшемді сандық модель.

Съедина С.А.[1]*, Бердинова Н.О.[1], Абдыкаримова Г.[1], Алтаева А.А.[1], Токсаров В.Н.[2]

[1]РГП «НЦ КПМС МИР РК» Институт горного дела им. Д.А. Кунаева, Алматы, Казахстан;
[2]Горный институт Уральского отделения Российской академии наук, Пермь, Россия.
E-mail: *SSA2704@mail.ru*

ЧИСЛЕННОЕ МОДЕЛИРОВАНИЕ НАПРЯЖЕННО-ДЕФОРМИРОВАННОГО СОСТОЯНИЯ КУРЖУНКУЛЬСКОГО КАРЬЕРА

Аннотация. Напряженно-деформированное состояние горных пород является одним из главных факторов, определяющих величину и характер горного давления, от которого зависит безопасность разработки глубоких карьеров. При ведении горных работ необходимо понимание, где будут формироваться зоны повышенных главных компонент нормальных и максимальных касательных напряжений.

В статье приведены результаты численного моделирования напряженно-деформированного состояния Куржункульского карьера в двухмерной постановке методом конечных элементов в программном комплексе MIDAS GTS NX. При математическом моделировании были учтены реально действующие в массиве напряжения, определенные натурными измерениями. Приведена модель, основанная на результатах моделирования, которую возможно применять для прогнозирования изменения максимального градиента горизонтального напряжения с увеличением глубины отработки Куржункульского карьера. По итогам моделирования бортов в юго-восточном северо-западном направлениях были определены участки, где наблюдается неблагоприятное воздействие максимальных касательных напряжений на прибортовой массив и возможно превышение максимальными касательными напряжениями (τ_{max}) предела прочности на сдвиг.

Также приведена оценка влияния главных компонент нормальных и максимальных касательных напряжений на устойчивость прибортового массива карьера. Определено, что геомеханическое состояние бортов Куржункульского карьера характеризуется действием невысоких сжимающих напряжений. Величины максимальных сжимающих напряжений изменяются в пределах от 5,52 МПа до 14.25 МПа, увеличиваясь от дневной поверхности к дну карьера. Минимальная компонента главных напряжений меняется от 0,70 до 9,4 МПа. Значения растягивающих минимальных напряжений σ значительно меньше расчетных значений напряжений на растяжение σ_p в образце и не оказывают влияния на устойчивость бортов карьера.

Ключевые слова: напряжённо-деформированное состояние, карьер, распределение главных напряжений, устойчивость массива, двухмерная численная модель.

Information about the authors:

Sedina S.A. – PhD, research assistant of Laboratory "Control of Geomechanical Processes" D.A. Kunayev Institute of mining, Almaty, Kazakhstan; ssa2704@mail.ru; https://orcid.org/0000-0003-0664-9057;

Berdinova N.O. – research assistant of Laboratory "Rock pressure laboratory" D.A. Kunayev Institute of mining, Almaty, Kazakhstan; bno0204@mail.ru; https://orcid.org/0000-0001-8752-9406;

Abdikarimova G.B. – junior research assistant of Laboratory "Control of Geomechanical Processes" D.A. Kunayev Institute of mining, Almaty, Kazakhstan; abdykarimovagulnur@gmail.com; *https://orcid.org/0000-0002-0767-7538*;

Altayeva A.A. – junior research assistant of Laboratory "Rock pressure laboratory" D.A. Kunayev Institute of mining, Almaty, Kazakhstan; a.aselya_92@mail.ru; https://orcid.org/0000-0002-1675-6828;

Toksarov V.N. – candidate of technical sciences, senior researcher, laboratory for physical processes of georesources development Mining Institute of the Ural Branch of the Russian Academy of Sciences, Perm, Russia; *toksarov67@mail.ru*; https://orcid.org/0000-0003-0006-105X.

REFERENCES

[1] Read J., Stacey P. (2009) Guidelines for open pit slope design. Australia: CSIRO. P. 496. ISBN 9780415874410.

[2] Kaspar'jan Je.V., Fedotova Ju.V. (2015) Naprjazhenno-deformirovannoe sostojanie massiva porod Hibinskih mestorozhdenij i zadachi geomehanicheskogo rajonirovanija. GIAB. P. 97- 107. (in Russ.).

[3] Asanov V.A., Toksarov V.N., Evseev A.V., Bel'tjukov N.L. (2016) Naturnye issledovanija

naprjazhennogo sostojanija porod prikonturnogo massiva. Vestnik PNIPU. Geologija. Neftegazovoe i gornoe delo. T.15, №20. P.270–276. (in Russ.).

[4] MIDAS GTS Manual (2017. MIDAS information Technology Co., Ltd.: Gyeonggi-do, Korea.

[5] Shamganova L.S., Syedina S.A., Berdinova N.O. (2021) Geomechanical substantiation of the northeastern pit wall stability in Kurzhunkul mine. Eurasian mining, №1, 2021. Pp.30-33. DOI: 10.17580/em.2021.01.06.

[6] Sedina S.A., Abdykarimova G.B., Altaeva A.A., Rahimov N.D. Primenenie analiza kinematicheskoi ustoichivosti pri opredelenii rasionalnyh proektnyh parametrov ustupov karera. NEWS of the Academy of Sciences of the Republic of Kazakhstan, Series of geology and technical sciences. Volume 1, Number 445 (2021), 135 – 143. https://doi.org/10.32014/2021.2518-170X.19.

[7] Toksarov V.N. (2015) Ispol'zovanie akusticheskogo jeffekta pamjati dlja ocenki naprjazhennogo sostojanija treshhinovatyh skal'nyh porod. Novosibirsk: IGD SO RAN. № 2. P. 353-357. (in Russ.).

[8] Toksarov V.N. (2017) Jeksperimental'noe opredelenie naprjazhenij v massive gornyh porod Sarbajskogo kar'era. Novosibirsk: IGD SO RAN. T. 4, № 2. P. 286-289. (in Russ.).

[9] Kazikaev Z.D., Kozyrev A., Kaspar'jan Je., Iofis M. (2016) Upravlenie geomehanicheskimi processami pri razrabotke mestorozhdenij poleznyh iskopaemyh. ISBN: 978-5-98672-441-6. (in Russ.).

[10] Rybin V.M. (2016) Razvitie teorii geomehanicheskogo obosnovanija racional'nyh konstrukcij bortov kar'erov v skal'nyh tektonicheski naprjazhennyh porodah. Dissertacija na soiskanie uchenoj stepeni doktora tehnicheskih nauk. GI KNC RAN, Apatity. (in Russ.).

[11] Kozyrev A.A., Rybin V.V., Semenova I.Je., Avetisjan I.M. (2009) Issledovanie osobennostej naprjazhenno-deformirovannogo sostojanija massiva porod v okrestnosti krupnoj kar'ernoj vyemki. Vestnik MGTU, tom 12, №4, 2009 g. str.661-669. (in Russ.).

[12] Kozyrev A.A., Semenova I.E., Rybin V.V., Avetisyan I.M. (2015) Stress redistribution in deep open pit mine Zhelezny at Kovdor iron ore deposit // Journal of Mining Science. Vol. 51. Iss. 4. P. 659– 665. DOI: 10.1134/S1062739115040015.

CONTENTS

Publication Ethics and Publication Malpractice in the journals of the National Academy of Sciences of the Republic of Kazakhstan

For information on Ethics in publishing and Ethical guidelines for journal publication see http://www.elsevier.com/publishingethics and http://www.elsevier.com/journal-authors/ethics.

Submission of an article to the National Academy of Sciences of the Republic of Kazakhstan implies that the described work has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see http://www.elsevier.com/postingpolicy), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The National Academy of Sciences of the Republic of Kazakhstan follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct (http://publicationethics.org/files/u2/New_Code.pdf). To verify originality, your article may be checked by the Cross Check originality detection service http://www.elsevier.com/editors/plagdetect.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will only accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the National Academy of Sciences of the Republic of Kazakhstan.

The Editorial Board of the National Academy of Sciences of the Republic of Kazakhstan will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайтах:

www:nauka-nanrk.kz

http://www.geolog-technical.kz/index.php/en/

ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Редакторы: *М.С. Ахметова, А. Ботанқызы, Д.С. Аленов, Р.Ж. Мрзабаева*
Верстка на компьютере *Г.Д.Жадыранова*

Подписано в печать 15.12.2021.
Формат 60х881/8. Бумага офсетная. Печать – ризограф.
4,6 п.л. Тираж 300. Заказ 6.

Национальная академия наук РК
050010, Алматы, ул. Шевченко, 28, т. 272-13-19