DOI: 10.31643/2022/6445.31

Accounting for creep of the rock mass around the sides of the quarry

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Received: *September 08, 2021*
Peer-reviewed: *February 14, 2022*
Accepted: *March 31, 2022*

ABSTRACT

Since open-pit mining operations on the elements of development systems have areas with dynamically changing stresses and deformations of the rock mass, the stress-strain state of the array around the sides of the quarry is considered. The objective of the research is to determine the parameters of the stress-strain state of the array that affect the stability of the sides of the quarry. Studies are conducted to determine the parameters of the stress-strain rock mass around the sides of the quarry. A mathematical model has been developed for determining the factors affecting the stability of the sides of the quarry. A multifactorial mathematical model of the stability of the sides of the quarry from mining geological and mining technical factors was obtained, taking into account the creep of the rock mass of the sides of the quarry. According to the formula obtained for the multidimensional model, it is possible to find a set of factors affecting the stability of the sides of the quarry. The obtained dependence makes it possible to determine the desired value from the known values of the factors.

Keywords: massif, rocks, side, ledge, berm, slope, quarry, stress-strain state, deformation, stress, stability, creep, mathematical model, strength conditions.

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Introduction

The rapid development of computer technology and its implementation in almost all spheres of life has led to the fact that today a competent specialist in any field of knowledge should be well-versed in the world of computers and possess the necessary software tools. A modern engineer is not successful without knowledge of computer-aided design and analysis systems. The introduction, in this regard, of automated calculations based on mathematical modeling allows for a comprehensive analysis and optimization of object parameters.

The experience of implementing such systems shows the need to use effective numerical methods and flexible software that implements the solution of various tasks. The most commonly used numerical method is the finite element method (FEM). The use of such programs helps project organizations to shorten the development cycle. The finite element method is used in solving a wide variety of problems of mathematical physics and engineering, in particular, in the presented work, the FEM is used to study the stress-strain state (SSS) of the rock mass around the sides of the quarry in order to predict the stability of the instrument arrays [[1], [2], [5], [6], [7], [8], [9], [10]].

Research analysis

The design scheme of the modeling object is constructed, a mathematical model and regression dependences of the studied parameters are obtained.

An array of rocks is a complex physical environment with a number of specific features that

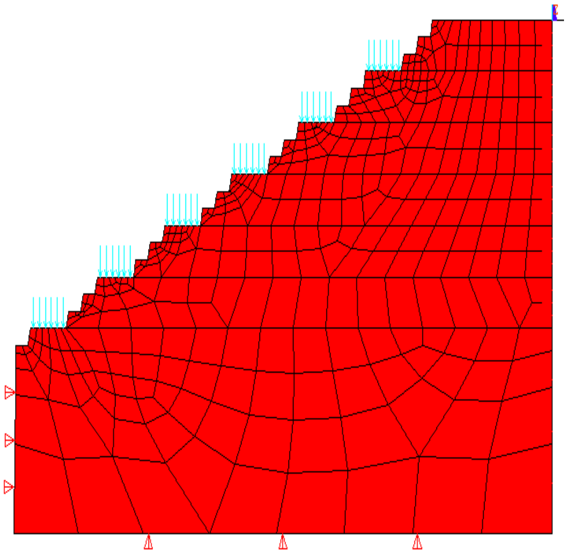

Figure 1. Calculation scheme of the problem

largely determine its mechanical state. Therefore, for a mathematical description of the processes occurring in the array, when developing methods for calculating the stability of slopes, they are forced to resort to schematization of the phenomena and properties of the rock mass under consideration. The side of the quarry, as a man-made structure, is the main supporting technological element in the open-pit development of deposits. The objective of the research is to determine the parameters of the stress-strain (SSS) array that affect the stability of the sides of the quarry. The vertical section of the array around the ledges is considered. A rectangular plane in a plane-deformed state, which is divided by a grid of triangular elements with appropriate boundary conditions, is chosen as the design scheme (Fig. 1).

In the design scheme, q is the load acting on the transport berm;

An unconventional method of constructing multidimensional mathematical models is used to process studies on determining the VAT of a rock mass, in particular, to determine the stable sizes of ledges and berms during field development [9].

In order to obtain a mathematical model of the type y = f (x_1, x_2, x_3, x_4, x_5, x_6), where y is the maximum main tensile stress; $x_1 = h_1$, $x_2 = h_2$, $x_3 = h_3$, $x_4 = \gamma_1$, $x_5 = \gamma_2$, $x_6 = E$. 25 variants of the VAT array have been investigated. In each variant, the problem of determining the SSS of the FEM array was solved.

When solving the planar FEM problem, the parameters (geotechnical factors) changed within the following limits:

$h_1 = 10 \div 30$(m) – the height of the ledge with an interval of 5 m;

$h_2 = 10 \div 18$ (m) - is the width of the berm with an interval of 2 m;

$h_3 = 2 \div 10$ (m) is the width of the slope projection with an interval of 2 m;

$\gamma_1 = 1200 \div 2000$ (кг/м^3) - density with an interval of 200;

$\gamma_2 = 2000 \div 3600$ (кг/м^3) - density with an interval of 400;

$E = 10^4 \div 6 \bullet 10^4$ (МПа) - is the modulus of elasticity of rocks with an interval of $1,5 \bullet 10^4$

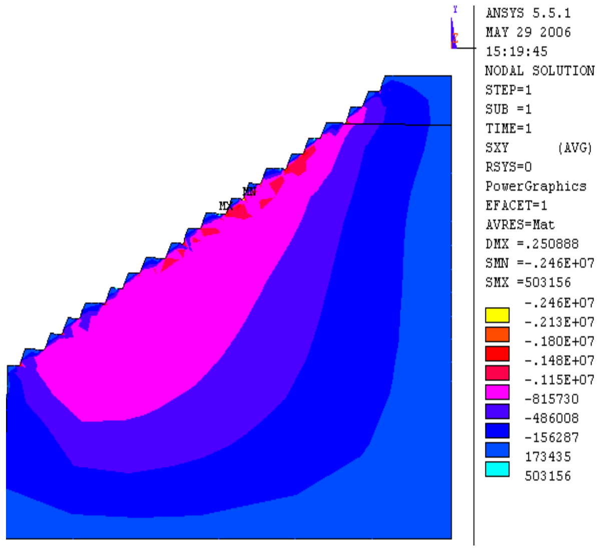

Figure 2. Tangential stress isolines

Figure 2 shows the tangential stress isolines for one of the options.

According to the above program, a mathematical model has been obtained that takes into account a complex of factors:

$$\sigma_1^{max} = f(x_1, x_2, x_3, x_4, x_5, x_6).$$

The maximum main voltage is selected as the function.

With a correlation coefficient R = 0.965, a generalized equation of the following form is obtained:

$$Y(\sigma_1^{max}) = Y(h_1)*Y(h_3)*Y(\gamma_2)*Y(h_2) + Y(E) + Y(\gamma_1) \quad (1)$$

where h_1 - is the height of the ledge, E – is the modulus of elasticity, γ_1 – is the volume weight of the upper layer, h_2 is the berm width, γ_2 – is the volume weight of the lower layer, h_3 – is the projection of the slope.

According to the formula (1) obtained for the multidimensional model, it is possible to find a set of factors affecting the stability of the sides of the quarry.

According to this dependence, the desired value is determined from the known values of the factors from the following rock strength condition:

$$\sigma_1^{max} \leq \sigma^p_{adm},$$

where σ^p_{adm} – is the allowable tensile stress

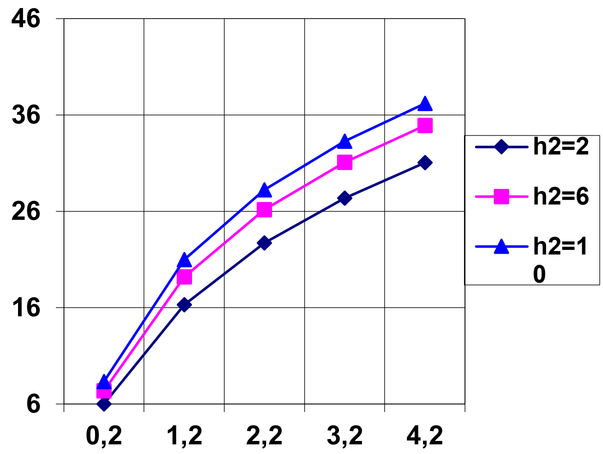

Figure 3. The dependence of the height of the ledge on σ^p_{adm}

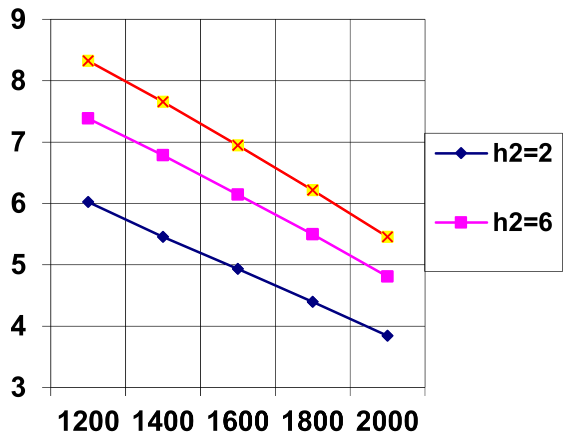

Figure 4. The dependence of the height of the ledge on γ_1

Figures 3-5 show graphs of the distribution of the dependence of the height of the ledge on various factors. When one of these values was changed, the values of the others were fixed. The quarry side, as a man-made structure, is "in operation" for a long time (more than 1 year), therefore, the conditions for the development of the array can be attributed to a viscoelastic environment with small deformations in time of the elements of the development systems.

To solve viscoelastic problems with small deformations, an effective calculation method using variable modules has been developed. It is known [10] that the solution of linear hereditary creep is reduced to the replacement of elastic constants by integral operators. In mining geomechanics, the Abel kernel $\delta(t-\tau)^{-\alpha}$. Is most often used as the creep core (operator). When using the method of variable modules, the solution of the linear-hereditary creep problem under constant boundary conditions is reduced to the formulation of the elasticity theory problem in the corresponding solution, no longer an operator, but a function of time.

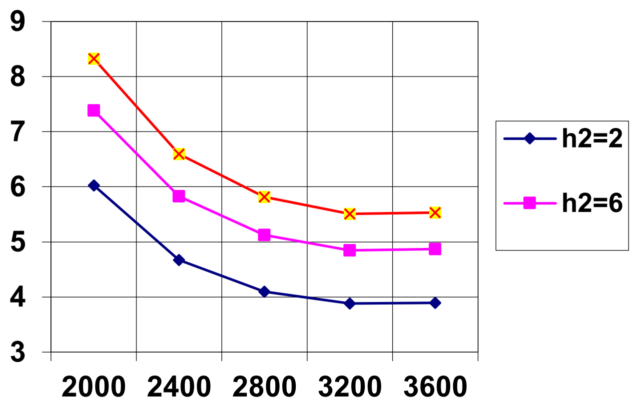

Figure 5. The dependence of the height of the ledge on γ_2

To solve viscoelastic problems with small deformations, an effective calculation method using variable modules has been developed. It is known [10] that the solution of linear hereditary creep is reduced to the replacement of elastic constants by integral operators. In mining geomechanics, the Abel kernel $\delta(t-\tau)^{-\alpha}$. Is most often used as the creep core (operator). When using the method of variable modules, the solution of the linear-hereditary creep problem under constant boundary conditions is reduced to the formulation of the elasticity theory problem in the corresponding solution, no longer an operator, but a function of time.

The work uses a time operator of the following form:

$$E_t = E / (1+F_t), \quad (2)$$

where $F_t = \delta t^{1-\alpha} / (1-\alpha)$, α, δ – are creep parameters, t is time.

The objective of the research is to determine the parameters of the stress-strain state (SSS) of the array, which affect the stability taking into account creep.

Formula (1) using the method of variable modules has the following form:

$$Y(\sigma_1^{max}) = Y(h_1) * Y(h_3) * Y(\gamma_2) * Y(h_2) + Y(E / (1+ \delta t^{1-\alpha} / (1-\alpha)) + Y(\gamma_1) \quad (3)$$

According to the formula (3) obtained for the multidimensional model, it is possible to find a set of factors affecting the stability of the sides of the quarry.

According to this dependence, the desired value is determined by known values from the following rock strength condition:

$$\sigma_1^{max} \le \sigma^p_{adm}, \quad (4)$$

where σ^p_{adm} – is the allowable tensile stress.

Thus, the mutual influence of the size of the quarry ledge varies over time.

When one of the factors changes, the values of the others are fixed.

Thus, the research methodology makes it possible to establish technologically necessary

ratios of elements of development systems depending on specific conditions

Conclusions

According to the formula obtained for the multidimensional model, it is possible to find a set of factors affecting the stability of the sides of the quarry. The resulting dependence makes it possible to determine the desired value from known values.

As we can see from the results, the methodology gives adequate answers to the tasks set.

The research methodology makes it possible to establish technologically necessary ratios of elements of development systems depending on specific conditions

Optimization of parameters will affect the level of regulatory losses and ensure stability during the extraction of reserves.

Conflicts of interest

On behalf of all authors, the author declares that there is no conflict of interest.

Cite this article as: Tutanov SK, Tutanova MS. Accounting for creep of the rock mass around the sides of the quarry. Kompleksnoe Ispol'zovanie Mineral'nogo Syr'a = Complex Use of Mineral Resources. 2022;322(3):74-78. https://doi.org/10.31643/2022/6445.31

Карьер ернеулерінің айналасындағы тау жыныстары массивінің жылжуын есепке алу

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Мақала келді: *08 қыркүйек 2021*
Сараптамадан өтті: *14 ақпан 2022*
Қабылданды: *31 наурыз, 2022*

ТҮЙІНДЕМЕ
Игеру жүйелерінің элементтері бойынша ашық тау-кен жұмыстары тау жыныстары массивінің динамикалық өзгеретін кернеулері мен деформациялары бар учаскелерге ие болғандықтан, карьердің ернеулері айналасындағы массивтің кернеулі-деформацияланған күйі қарастырылады. Зерттеудің міндеті карьердің борттарының тұрақтылығына әсер ететін массивтің кернеулі-деформацияланған күйінің параметрлерін анықтау болып табылады. Карьердің ернеулері айналасындағы тау жыныстарының кернеулі-деформацияланған массивінің параметрлерін анықтау бойынша зерттеулер келтірілген. Карьер ернеулерінің тұрақтылығына әсер ететін факторларды анықтаудың математикалық моделі әзірленді. Тау-кен және геологиялық және тау-кен техникалық факторлардан карьер қабырғаларының тұрақтылығының көпфакторлы математикалық моделі карьер қабырғаларының айналасындағы тау жыныстарының массасының сусылуын ескере отырып алынған. Көп өлшемді модель үшін алынған формула бойынша карьердің бүйірлерінің тұрақтылығына әсер ететін факторлар жиынтығын табуға болады. Алынған тәуелділік факторлардың белгілі мәндерімен қажетті мәнді анықтауға мүмкіндік береді.
Түйін сөздер: массив, тау жыныстары, борт, Кемер, берма, көлбеу, карьер, кернеулі-деформацияланған күй, деформация, кернеу, орнықтылық, жылжу, математикалық модель, беріктік шарттары.

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Учет ползучести массива горных пород вокруг бортов карьера

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Поступила: *08 сентября 2021*
Рецензирование: *14 февраля 2022*
Принята в печать: *31 марта 2022*

АННОТАЦИЯ

Так как открытые горные работы по элементам систем разработки имеют участки с динамически изменяющимися напряжениями и деформациями массива горных пород, рассматривается напряженно-деформированное состояние массива вокруг бортов карьера. Задачей исследований является определение параметров напряженно-деформированного состояние массива, влияющие на устойчивость бортов карьера. Приводятся исследования по определению параметров напряженно-деформированного массива горных пород вокруг бортов карьера. Разработана математическая модель определения факторов, влияющих на устойчивость бортов карьера. Получена многофакторная математическая модель устойчивости бортов карьера от горногеологических и горнотехнических факторов с учетом ползучести массива горных пород вокруг бортов карьера. По формуле, полученной для многомерной модели, можно найти комплекс факторов, влияющих на устойчивость бортов карьера. Полученная зависимость дает возможность определить по известным значениям факторов искомую величину.

Ключевые слова. массив, горные породы, борт, уступ, берма, откос, карьер, напряженно-деформированное состояние, деформация, напряжение, устойчивость, ползучесть, математическая модель, условия прочности.

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