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The Impact of Mining Technology on Stability of Open Cast Mine

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Abstract

The article describes the aspects of mine workings when there are cracks in the rock massif of several systems. The research is intended to determine the massif stability around rocks. A methodology to determine strength parameters of rocks in the presence of cracks was proposed. The undertaken studies allowed developing reasonable data sheets for supporting mine workings in various mining and geological conditions. Processing of mathematical modeling results by using statistical methods allows significantly facilitating the calculation of maximum load acting on the support without resorting to direct modeling within the specified range of rock strength parameters. In this manner, it becomes possible to use this approach in a mining company without complex preparation of initial data to accompany the mathematic modeling.

Keywords: rock strength, rock cracking, stresses, destruction zone, mine opening, mathematic modeling, support load, analytical dependence, chart

INTRODUCTION

When mine workings are made by drilling and blasting, rocks are fully destructed and mechanical properties of the peripheral massif are distorted as a result of radial and spherical cracks.

The studies have shown that reducing destructive stresses and increasing the number of cycles of pulsating loadings is natural for all type of rocks. Along with that, the reduction intensity with increasing the number of cycles of pulsating loadings to the cyclic strength limit is different.

It has been established for many types of rocks studied that the ultimate fatigue compression strength is about 50% of the ultimate static strength.

Rocks have their own structural features that affect the nature of destruction in case of pulsating loads. The rocks structure includes porousness, defects and cracking. Pulsating loads substantially change the rock destruction process. Secondary stress fields, which are caused by the inhomogeneity of the structure, change cycle-wise. The strength of rock samples changes from the initial value and blasting loads cause the rock strength to decrease and their porosity and water absorption to increase.

When reaching the rock tensile strength (in terms of mineral grains and intergranular bonds), these tensile stresses cause cracks oriented towards the external compressing load and finally resulting in the destruction of the rock volume affected by loading. This *mechanism of rocks brittle fracture* accompanied by the formation of cracks oriented towards the maximum compression loading is often observed in reality (destruction of rocks around workings, in the peripheral part of pillars, etc.).

The data obtained by multiple measurements taken in the Federal Government Budgetary Institution "Mining Institute" of the Kolskiy Scientific Center of the Russian Academy of Science show that the thickness of the destructed zone in case of ordinary mining can vary from 0.3 m to 1.5 m.

When the drilling and blasting mining is used, the stope is 1.0-2.0 m in most cases.

Consequently, it is required to additionally take into account the rock massif cracking caused by blasting when forecasting the stability of the peripheral massif of the mine working made by drilling and blasting.

METHODS

The primary method to study this issue is the mathematic modeling method based on the boundary integral equation method. This method allows significantly reducing the amount of initial data to be prepared and scanning the rock massif in more details in the close vicinity to the working. Furthermore, the program algorithm is integrated with a module to take into account the massif cracking with a capability of applying strength properties along crack directions.

The research is intended to determine the massif stability around mine workings.

Objectives:

1. Study and analyze the rock massif cracking;
2. Mathematically model the stresses and deformations of rocks around the mine working;
3. Determine the possible dimensions of the destruction area around the working.

In this case, the rock massif is divided by several primary crack systems.

RESULTS

As a calculation model of a fractured rock massif, a continuous, uniform, isotropic environment can be used taking into account the systems of attenuation surfaces. Attenuation surfaces can be modeled as directions where shear and tensile strengths are attenuated. For mathematic modeling of this environment, physical and mechanical parameters of the massif itself and strength parameters on attenuation surfaces should be well known.

The possibility to take into account the effect of drilling and blasting on the strength of the peripheral massif has several specific features. The difference having the strongest effect upon the results discrepancy is associated with various approaches to assign residual rock strength at the working's cross-section periphery in the area of non-elastic deformations. The residual strength is introduced in an effort to implement a Coulomb-Mohr strength condition that is fulfilled when rocks assume the limiting state in the event of extreme deformations. This approach is acceptable to describe the qualitative nature of the phenomena, but the freedom to assign the residual strength (from zero to the rock massif strength) may not yield satisfactory results for all conditions. Multiple approximations of reduction functions for strength characteristics by using various analytical functions prevent from obtaining unambiguous numerical results, though they describe experimental data with an equal degree of satisfaction. To reduce cracking in the massif, the perimeter blasting technique is applied, which implies reduced blast energy and efficient positioning of periphery holes. The perimeter blasting technique reduces the crack depth in the rock massif 4-7 times.

Experimental data used to determine the physical and mechanical properties of rocks on attenuation surfaces can be found in many studies. As primary strength parameters of attenuation surfaces, these studies consider bonding over the attenuation surface K_a, internal friction coefficient over the attenuation surface $n_a = tg\varphi$ and the tensile strength limit over the attenuation surface σ_t^a.

The bonding over the attenuation surface is not an independent mechanical characteristic, since it is secondary and depends on the extent to which the processes being secondary in the genesis have impaired the rock strength. So, when the bonding values change, it is reasonable to represent it not as an absolute value, but as a relation of bonding over the attenuation surface K_a to the bonding in the massif itself K.

The internal friction coefficient n defined by the internal friction angle φ over the attenuation surface is a rather weak value. When assessing strength on the attenuation surface, this allows not to consider possible change of the internal friction angle and treat it as constant.

Measuring the ultimate tensile strength σ_t^a over the attenuation surface can be done with the assumption that the bonding of rocks is associated with the ultimate tensile strength (with straight line enveloping Mohr's limit circles) by a linear dependence:

$$p = A \cdot K$$

where A = proportion coefficient. The coefficient A equals as follows:

$$A = 2\cos\varphi \div (1 - \sin\varphi)$$

On the assumption that the internal friction angle over the attenuation surface is unchanged, the ultimate tensile strength over the attenuation surface can be measured using the following formula:

$$\sigma_t^a = A \cdot K_a$$

where K_a = bonding over the attenuation surface. In this case, it can be recorded as follows, provided the internal fiction angle is unchanged:

$$\sigma_t^a \div \sigma_t = K_a \div K$$

In this manner, the strength properties of rocks in the area of well-ordered cracking (ultimate tensile strength and bonding) can be adopted as being equal to the properties in their samples taking into account the changes in strength characteristics (σ_t and K) on the surfaces coinciding with crack directions.

To model the geomechanical processes in the fractured massif, the mining conditions at the Ushkatyn 3 mine of Zhayremskiy GOK OJSC have been selected. Mathematic modeling was done using Kolokolov's methodology by the boundary integral equation method. In this case, the rock tensile strength changes from 1 MPa to 9 MPa. Calculation results are summarized in Table 1. Figure 1 shows the fracture zone around the working with the rock tensile strength of 2.4 MPa and the crack inclination angle of 45 degrees.

This zone embraces the mining perimeter rather irregularly. Crack systems with the inclination angle of 45 degrees have a strong effect on the destruction zone shape. In the following calculations, we will adopt maximum destruction zone dimensions.

Table 1: Initial data and modeling results with respect to crack systems of rocks

Ultimate tensile strength, MPa	Bonding coefficient, fractions of γN	Ultimate tensile strength fractions of γN	Fracture zone height in the roof	Vertical load on the support, t
0	0	0	3.7	49.3
1	0.375	0.125	2.2	28.7
2.4	0.9	0.3	1.0	13.6
4	1.5	0.5	0.4	5.8
5	1.875	0.625	0.2	2.7
6	2.25	0.75	0	0
9	3.375	1.25	0	0

The graph of the destruction zone height variance in the roof is given in Figure 2.

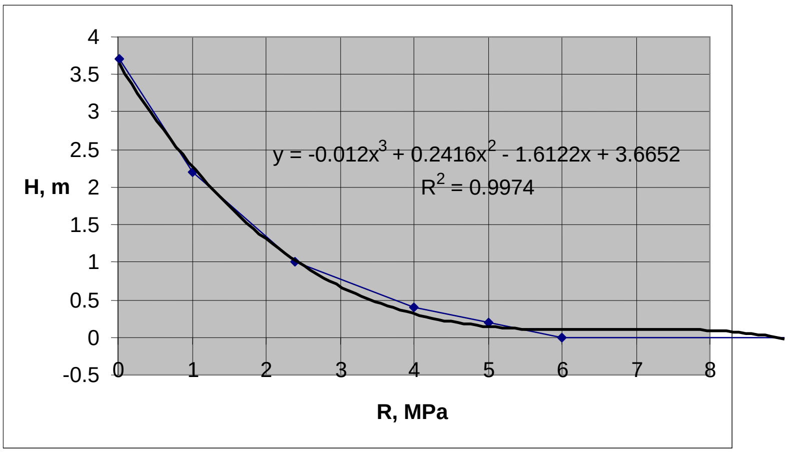

Figure 2: The change of the height of fracture zone in the roof of the strength of rocks in tension and three systems of cracks

The increase of the tensile strength results in an abrupt decrease of the fracture zone dimensions around the mining and a respective decrease of the support loading (Table 1). As Table 1 shows, the destruction zone in the roof for the compression strength of rocks being 50 MPa is below 0.2 m, and that for the strength of 60 MPa almost disappears.

DISCUSSION

Currently, there are many studies intended to determine the strength characteristics of a fractured rock massif, but:

1. There are no recommendations on how to reduce the strength properties of the massif depending on the massif itself and the number and direction of cracks;

2. No methodologies are developed to consider the direction of cracking and number of crack systems during the massif numerical modeling.

For this reason, we currently carry out studies intended to determine the fracture zone around the mine working located in a fissured massif. The study's practical value is that the destruction zone dimensions around the mine working vary significantly depending on the degree of cracking. In its turn, it requires various process approaches to be applied when preparing data sheets for roadway supports.

There is vast experience accumulated globally for measuring the stability of mine workings in various conditions of their mining. One of the most perspective and modern methods to solve this issue is using numerical methods for solving the task. This approach allows considering various mountain and geological conditions of mining to the highest extent.

The stability issues of man-made outcroppings are reflected in the studies of foreign scientists, such as.

In the national science, many renowned scientists studied the stability of mine workings in theory and practice.

The issues of mine working stability play a great, if not exceptional, role in the operation of any mining company. This issue is associated with human safety and normal functioning of the entire pit or mine. For this reason, the mine working stability shall be properly assessed with respect to all specifics of its location. For this purpose, we deem it necessary to use the numerical modeling of processes taking place in the rock massif.

CONCLUSIONS

The mathematical modeling shows that:

1. For the tensile strength of rocks enveloping the mine working above 50-60 MPa, the destruction zone around the working and the vertical loading on the support is low. In its turn, it means that enclosing supports can be used to prevent insignificant inrush at the perimeter of the working.
2. For the tensile strength of rocks enveloping the mine working above 30-50 MPa, the destruction zone around the working is significant and the anchor support must act as a bearing structure.
3. Further decrease of the rock strength may require application of pile supports or special combined supports.
4. Analytical dependencies and graphs built upon the calculation results allow measuring the height of the destruction zone around the working for the compression strength of 0 to 90 MPa without modeling.

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