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ACCOUNTING FOR THE EFFECTS OF PROPERTIES OF ROCKS ON THEIR GEOMECHANICAL PROCESSES OF DISPLACEMENT

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ABSTRACT: The paper deals with improving the accuracy of simulation results of geomechanical processes strata movement zones location of construction projects on earth surface at undermining their underground mining. An example of the determination of forecast zones dangerous displacement earth's surface and rock during the resumption of mining stocks ferruginous quartzite. Authors have developed methodological recommendations, which allow defining true physical and mechanical properties of rock massifs on the lab research results of samples and correction factors calculation eliminating properties irrelevance because of massif morphology peculiarities. The results of calculation by the proposed method differ by 6-10% from the actual. Solutions of the authors should be taken into account in the techniques of modeling subsidence and caving rock massifs by maintaining appropriate amendments to the calculated curves that allow establishing the basic parameters of the zones undermining arrays rock underground mining.

Keywords: Accounting, Properties of rocks, Displacement, Construction projects, Forecasting, Development zone of deformation.

1. INTRODUCTION

Currently, Ukraine has one of the most powerful underground mining complexes in the world. The main types of minerals that are mined enterprises of this complex are rich in iron ore and coal.

In the largest-scale mining of these minerals is carried out in the Kryvyi Rih iron ore and Donetsk coal basins. These basins are large industrial regions with a large number of enterprises, settlements, developed social and industrial infrastructure. These regions are characterized by significant areas of building structures for industrial and civil purposes, as by the presence of extended communications of various kinds. Infrastructure in these regions continues to develop rapidly.

This situation puts the underground mining industry (iron ore and coal mines) in an extremely difficult position.

The reason for its occurrence is as follows. Large-scale industrial and civil construction in these basins is carried out from the beginning of the fields and has been going on for 100-130. At the beginning of the development was not known the exact location and the geometric parameters (depth, length and power) of all fields in these pools. Many of these deposits were generally discovered only 40-60 years ago.

This led to the fact that many mining companies were located directly within the boundaries of settlements, which is constantly expanding. As a result, a large number of buildings, facilities and communications in these settlements were in the area of influence of underground mining.

The formation of such areas related to the fact that in these basins for the extraction of mineral resources are mainly used to develop the system with the collapse of the country rocks [1]. These systems are characterized by high performance and cost-effectiveness. However, their use leads to a massive disruption of the natural geo-mechanical state of large arrays of rocks located above the fields.

2. THE LATEST SOURCES' OF RESEARCH AND PUBLICATIONS OVERVIEW

As the analysis of the literature to address this problem, the currently available conventional computational methods to predict the development of zones of subsidence from mining of iron ore, do not provide sufficient accuracy and reliability of the forecast when they are used for conditions of working ferruginous quartzite. [2]

This is because the physical and mechanical properties of ferruginous quartzite and rocks that contain them are significantly different from the properties of the rocks (rich ores), for which these techniques have been developed in 60-70 years. There are some inconsistencies coefficients and deformation characteristics, brittleness, porosity, fractures, etc.

3. THE PROBLEM

The need to develop appropriate methods to predict the size and location of shifting rock bands that takes into account the working out of a modern underground mining period and opportunities for further development of densely populated areas.

4. PREDICTION OF SURFACE PROCESSING DEVELOPMENT

One of the largest and most dangerous of geo-mechanical phenomena arising as a result of the displacement is the formation of rocks on the earth surface "processing zone" (Figure 1).

Displacement processes large amounts of host rocks form a dangerous situation for both objects are located on the surface near the fields and underground mining-construction objects in the mines themselves.

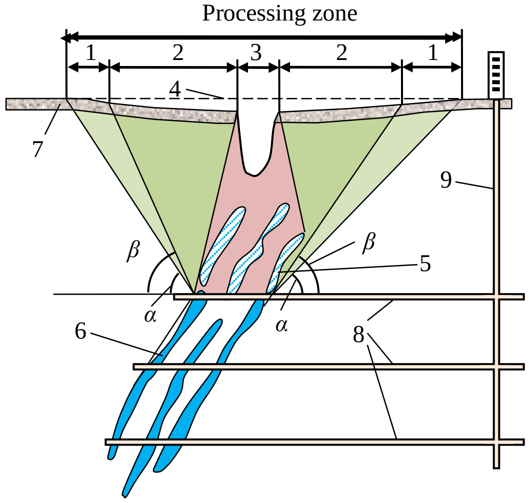

Fig.1. Scheme of ground surface's laydown zone
1 – zone of rock displacement;
2 – zone fractures and terraces;
3 – the failure zone;
4 – the initial level of the earth's surface;
5 – wasted area;
6 – area prepared for mining;
7 – sedimentary rocks;
8 – horizons of mine;
9 – mine trench.

This area represents a surface portion which sags after mineral extraction. At the same time, the size of the processing zone significantly higher than the horizontal dimensions of the cleaning space, from which it was extracted minerals. During the constant increase in the depth of exploitation there is a corresponding extension of the processing zone.

Currently, underground mining is carried out in these basins at depths up to 1400-1600 m. This resulted to the formation of the surface processing zone over each deposit ranging from 2 to 6 km^2.

All of the above applies to projects of the mining companies' development. The need to ensure the continued functioning of these enterprises requires constant development projects of mining operations at certain times with increasing depth development. Such projects include the need for the construction of underground technological objects (mining blocks, panels, capital mining, underground technology cameras, etc.). With their construction is necessary to determine the permissible location of such facilities in the underground space, the sequence and intensity of their construction, commissioning, and other protective measures. This requires consideration the situation prevailing in the interior and on the surface as a result of the impact on them of earlier and planned to carry out mining operations.

4.1 Detailing of method

One of the main measures to eliminate the possibility of dangerous situations on the surface and in the interior for the reasons stated, is the prediction of the parameters of the surface area as a part-time job in the process of development at existing mines, and in the preparation of projects for the construction of new mines.

Undermining earth surface area divided by the amount of deformation of rocks into three components such zones.

The first zone (Figure 1, item 1), is part of the surface on which there is a smooth rock ground movements on the value of not more than 5 mm / m, without violating their solidity. The width of this zone depends on the extent of bowels violations may be from 10-20 m to 100-500 m and more. There are cases when deposits debugging formed only area without displacement of more hazardous areas, which are described below.

The second zone (pos. 2) - Land caving (zone cracking and terraces). In this zone, the deformation of rocks leads to their breaks to form a network of cracks. At sites close to the location of the cleaning space formed terraces in the form of steps, separated by large faults. The width of this zone reaches 100-1000 m.

The third zone - a site failure (pos. 3). Within this area occurs caving into the bowels. As a result, formed on the surface with steep sided funnel. Dimensions of the width of this zone reach 50-200 and a depth of 100 m.

Undermined territories, suitability for building-governmental, are considered parts of the earth surface, are located outside the zones to potential failures; possible flooding of precipitation and groundwater; outputs faults and the axial surfaces synclinoria folds; possible landslide [3].

When planning and building of residential districts and neighborhoods of housing construction at sites with different combinations of groups in magnitude of ground deformation, rational distribution of functional areas and individual buildings can be provided by structural measures passed under natural conditions and construction practice.

In order to predict the coordinates of the boundaries of the zone of smooth displacement, its size and resizing in time, as well as determine the amount of deformation of the surface of the rock is necessary to know the angles α and displacement angles caving β (Figure 1). It is to determine the values of these angles and the modeling process of undermining the country rocks all of the above methods.

4.2 Shortcomings

However, as practice shows, the accuracy of such modeling is extremely low. This leads to the prediction that this does not preclude the formation of dangerous unforeseen situations. In this regard, it is necessary to improve the accuracy of modeling the processes of shifting rocks.

Authors have conducted special studies in this area and have developed a number of recommendations to address this problem. The results of the studies are provided below.

5. SIMULATION OF ROCKS DISPLACEMENT

Analysis of the modeling techniques and the study of processes of rocks' displacement showed that one of the most significant factors that most affect the accuracy of the simulation results is a set of physical and mechanical rock's properties. These properties include: the proportion of species γ; volumetric weight ν; humidity ω; strength σ, Young's modulus E.

These properties must be considered when determining the displacement angles α and β species collapse, since they are functionally related.

$$\alpha = f(k_\gamma \gamma, k_\nu \nu, k_\omega \omega, k_\sigma \sigma)$$
$$\beta = f(\varepsilon_\gamma \gamma, \varepsilon_\nu \nu, \varepsilon_\omega \omega, \varepsilon_\sigma \sigma), \quad (1)$$

where *k*, *ε* – rates that determine the nature of the functional relationship between *α*, *β* and influencing parameters.

The numerical values of the parameters characterizing the properties of the rocks are determined by laboratory tests of samples of rocks collected during the geological exploration and their plots.

Solution to this problem and the basis of the proposed method are described for example, one of the largest, previously closed, mining companies in Ukraine, which was the development of ferruginous quartzite, and restore production capacity is planned in the first place - is the "May Day iron ore plant".

Plant said of the deposit of ferruginous quartzite, located in the northern part of the Kryvyi Rih iron ore basin, which is one of the largest of these pools in the world. General layout of the ore bodies and the situation around them in this plant, shown in Figure 2.

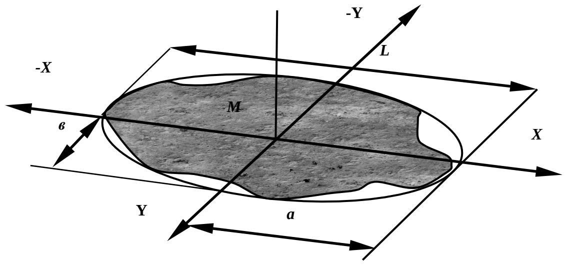

Fig. 2. The calculation scheme for determining the size of the zone of active deformation.

5.1 Encountered difficulties

Explored reserves of ferruginous quartzites in the mine field of the plant is at the depth H = 920 m and extend to a depth H = 1500 m, the coefficient of the fortress and quartzite rocks, their host, is f = 12-20. The deposit consists of a complex ore bodies columnar shape with an angle of incidence α = 80 °. The size of the deposit along strike L = 550 m and cross wiping M = 300 m.

In the zone of displacement of rocks from underground mining of quartzite misses acting career May Day Northern Mining and Processing Plant as well as part of the production facilities located on board the quarry and at the earth's surface.

Studies have shown that the development of shear zones from the previously carried out the development of ferruginous quartzites close to elliptical shape in the horizontal plane (see Fig. 3). Size large and minor axes of the ellipse are: a = L / 2 m; a = M / m^2.

With the gradual extraction of reserves and lowering the level of mining operations contour ellipse shifts. On the contour of the ellipse is observed to achieve a balance between the mechanical stresses acting in a mountain range that arise in his part-time job and mechanical stresses resulting from pressure on an array of caving, located in the loop of the ellipse. The magnitude of these stresses is determined by the expression:

$$\sigma_X = \lambda \cdot \gamma \cdot H \, ; \quad \sigma_{XX} = \lambda_1 \cdot \gamma_1 \cdot H \, , \quad (2)$$

where σ_x is the horizontal stress acting in the rock mass, MPa; σ_{xx} is the horizontal surface pressure caving goaf per circuit, MPa; γ, γ_1 is the respectively, the density of the surrounding and caving, t / m^3; λ is the coefficient of lateral thrust in caving $\lambda = (1 - \sin\rho)/(1 + \sin\rho)$; ρ is the internal friction angle of rocks.

From this we can determine the value of the distributed load applied to the contour of the shear zones $P = \sigma_X - \sigma_{XX} = \lambda \cdot \gamma \cdot H - \lambda_1 \cdot \gamma_1 \cdot H$.

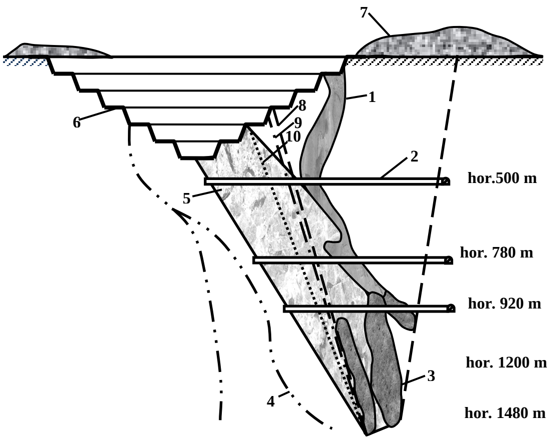

Fig.3. Diagram ferruginous quartzite May Day iron plant.

1 - loop waste of rich iron ore;
2 - development of basic horizons;
3 - circuit ferruginous quartzite deposits, some of which worked by underground methods, and planned renewal of their mining;
4 - tectonic faults;
5 - ferruginous quartzite deposits, which are processed quarry Northern Mining and Processing Plant (NorMPP);
6 - circuit May Day career Northern Mining and Processing Plant (NorMPP);
7 - waste rock quarry;
8 - Current loop displacement zone rocks by the proposed method;
9 - the actual outline of the displacement of rocks;
10 - contour displacement, calculated by the method Scientific and Research institute of Mining and Surveying (SRIMS).

5.2 Problem solving

During excavation of minerals, with a gradual decrease in the level of mining rock mass are constantly changing shape with its shift towards the goaf.

Determine the magnitude of this shift can be the method of conformal mapping of the plane with a circular hole | ε |> 1 with the help of an analytic function [4]:

$$\omega(\varepsilon) = R(\varepsilon) + m(\varepsilon), \tag{3}$$

where $\omega(\varepsilon)$ is the function which maps the considered plane with an elliptical hole on the plane with a circular hole; ε is the variable plane; $R = L + M/4$ is the reduced radius openings, m; $m = L - M/4 + M$ is the parameter that determines the size and shape of an ellipse.

From this we can determine the stress function, resulting unloading surrounding massif in the excavation of minerals:

$$\varphi(\varepsilon) = \frac{P \cdot Rm}{\varepsilon}; \qquad \psi(\varepsilon) = \frac{P \cdot R}{\varepsilon} + \frac{P \cdot R}{\varepsilon \cdot (1 + m \cdot \varepsilon^2)} + m \tag{4}$$

Displacements around the elliptical hole are determined from the following equation:

$$2 \cdot G \cdot (v_p + v_\Theta) = \frac{\varepsilon \cdot \sqrt{P \cdot \omega(\varepsilon)}}{\omega'(\varepsilon)} \left[\chi \cdot \varphi(\varepsilon) - \frac{\omega(\varepsilon)}{\omega'(\varepsilon) \cdot \varphi'(\varepsilon)} - \psi(\varepsilon) \right], \tag{5}$$

where $G = E_n / 2 \cdot (1 + \mu)$ is the shear modulus, MPa; n is the index indicating membership in the host rocks; v_p, v_Θ is the respectively radial and tangential displacement, m; p is the dimensionless radius vector; ω' is the derivative of ω; E is the modulus of elasticity of the surrounding rocks, MPa; $\chi = 3 - 4 \cdot \mu$ is the coefficient of plane deformation; μ is the Poisson's ratio of the host rocks.

Substituting the values of the functions φ (ε) and ψ (ε) in the expression Eq. (5) and sharing their real and imaginary numbers, we obtain the equation:

$$v_p = \frac{P \cdot R}{2 \cdot G} \left\{ (\chi + 1)^2 \rho^2 \cdot m \cdot \cos 2\Theta + m^2 \cdot (\chi + 1) - \frac{(1 + m^2) \cdot \rho^2}{\sqrt{\rho^4 - 2 \cdot \rho^2 \cdot m \cdot \cos 2\Theta + m^2}} \right\}$$

(6)

$$v_\Theta = -\frac{P \cdot R}{2 \cdot G} \left\{ \frac{(\chi - 1)^2 \rho^2 \cdot m \cdot \sin 2\Theta}{\sqrt{\rho^4 - 2 \cdot \rho^2 \cdot m \cdot \cos 2\Theta + m^2}} \right\}$$

Full movement in the axial direction (-Y) -0-Y is obtained from the expression:

$$v_y = v_p \cdot \sin \Theta + v_\Theta \cdot \sin \Theta \tag{7}$$

Given the fact that the tangential displacement in this case negligible radial movement of the hole contour, for example, when ρ = 1, and in its central part will be:

$$V_y = \frac{P \cdot R}{2 \cdot G} \cdot (\chi \cdot m + 1) \tag{8}$$

5.3 Inference

Mineral extraction down mining operations constantly causes deformation of rocks before reaching the earth's surface. On the stability of these species affect the voltage developing around the goaf. Depending on the magnitude of these stresses resulting displacement can lead to critical values that exceed the strength of the rocks on the gap [5].

To determine the size of the zone discontinuities array used the theory of maximum allowable elongations [6], in which conditionally allocated in the rock mass is long and thin cylindrical rod with dimensions of faces 1x1, stretchable longitudinal force applied at the end of the bar, near the goaf.

Assuming that the force that is applied to the body, causing tensile stress and strain - characterized by elongation Δl rod, according to Hook's law gives the allowable limit extension:

$$\Delta l = l \cdot \xi \qquad (9)$$

where l is the initial length of the rod, m; $\xi = \sigma_p / E$ is the maximum allowable relative deformation of the rod; $\sigma_p = 0{,}1 \cdot \sigma_t$ is the tensile strength of rocks in tension; E is the modulus rocks MPa.

Comparing Δl with V_y, we obtain an expression for determining the size of the zone of rock mass discontinuities:

$$l = \frac{\lambda \cdot \gamma \cdot H \cdot (1-\mu^2) - \dfrac{\lambda_1 \cdot \gamma_1}{\lambda \cdot \gamma}}{0{,}1 \cdot \sigma_t \cdot L \cdot \left[\dfrac{1 - M \cdot (1-\mu^2)}{2 \cdot L} \cdot (1-\mu^2) \right]}. \qquad (10)$$

As an example, determines the size of the zone discontinuities array magnetite quartzite with $\mu = 0{,}3$; $\sigma_t = 120$ MPa; $\gamma = 2{,}8$ t / m ^{3}; $\lambda = 0{,}5$. The calculation results are shown in Table 1.

Table 1 Comparison of the calculated and actual parameters displacement of rocks

Horizon, m	The length of the deposit along strike L, m	Horizontal reservoir thickness M, m	l_p/l_f	Ratio $(l_f - l_p)/l_p$, %
500	350	80	68,3/73	6,8
570	340	200	69/76	10,1
640	320	170	78,3/85	8,9

The comparison of the sizes of zones offset by the proposed procedure, as well as by the method of the All-Russian Research Institute for the special Mining and Surveyor (ARRIMS) business data surveying shooting at depths of 500, 570 and 640 m.

The results of calculation by the proposed method differ by 6-10% from the actual, whereas the data obtained by the method of the All-Russian Research Institute for the special mining and surveyor (ARRIMS) case showed a deviation from the actual 30%.

The calculated results by the proposed method is within the permissible degree of accuracy.

6. CONCLUSION

Based on research conducted by the authors and completed development to the following conclusions:

1. The problem of determining the true physical and mechanical properties of the rock mass is one of the most important in the solution of problems of prediction of geomechanical processes in the earth caused by man-made breach of their natural state mining.

2. These properties are one of the main factors in forming of geometrical parameters of laydown zones' development and the rate of damaged rocks in these zones

3. Obtaining true information about the nature of these zones and the processes that lead to their further expansion, is an important task, which allows you to make the right decisions for the implementation of construction projects for infrastructure development of settlements, within which operate underground mining operations, attacks on the same mining projects themselves these enterprises.

4. Obtaining accurate information about the behavior undermined rock mass is complicated by the fact that there is a mismatch between the properties of the rocks composing these arrays are determined by examining the properties of their samples and arrays of them having complex structure.

5. Authors of the study made it possible to develop an approach and mathematical tools to determine the actual values of the physical parameters of rock mass based on laboratory tests of samples of these rocks, which take into account the differences in the state of rocks in the samples and the morphology of the array, which is composed of these rocks.

6. Solutions of the authors should be taken into account in the techniques of modeling subsidence and caving rock massifs by maintaining appropriate amendments to the calculated curves that allow to establish the basic parameters of the zones undermining arrays rock underground mining. The development of such techniques is in full view to the later stages of the authors in this direction.

7. Theoretically, certain dimensions of the zone of displacement made by the method suggested by the authors, showed sufficient accuracy coincide with industrial measurement data. This allows you to continue to use the methodology developed to predict changes in the size of the zone of

displacement to a depth of reserves in ferruginous quartzite 1480 m main direction for further research is the adaptation of the proposed technique to perform predictive calculations for the conditions of underground mining deposits that have were not involved in the development.

7. REFERENCES

[1] Mikhailov U.V. Underground mining, Moscow: Academy, 2008, 389 p.
[2] Viktorov S.D. Displacement and destruction of rocks, Moscow: Nauka, 2005, 280 p.
[3] Guidelines for the design of buildings and structures on undermined territories. Charles II. Industrial and civil buildings, Moscow: Stroyizdat, 1986, 304 p.
[4] Baklashov I.V., Kartosia B.A. Rock mechanics Moscow: Nedra, 1975, 264 p.
[5] Timchenko R.A., Popov S.O. "The study of the deformation of underground workings and forecasting parameters of dangerous rock pressure". Building construction: Composite steel and concrete structures: advances, design, construction and operation, Kyiv, 2012, Iss. 75, Vol. 1, pp. 187-194.
[6] Muskhelishvili N.I. Some basic problems of mathematical theory of elasticity, Moscow: Publishing House of the USSR Academy of Sciences, 1989, p.640.

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