

Abstract

**of the dissertation for the degree of Doctor of Philosophy (PhD) in the specialty: 6D070700-"Mining"
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Substantiation of the parameters of rational and safe open-pit mining using digital technologies

Relevance of the work. The economic potential of the leading countries of the world, including Kazakhstan, is closely connected with the development of the mining industry, which provides states with energy resources, metals, building materials and various types of minerals, without which the modern economy cannot develop. Therefore, at present, much attention is paid to the open way of development of mineral deposits as the most economical and safe. At the same time, their efficiency is ensured by reliable justification and ensuring the stability of the tool massifs of quarries, and the safety of mining operations is guaranteed by the quality of setting the slopes of the ledges on the design contours and instrumental observations with the introduction of laser-digital measurement technologies. Now, more thorough study of the structural features of the massif is required than ever by determining the quality index of the massif, taking into account the identification of patterns of changes in the size of structural blocks with the depth of occurrence in the sides and the strength properties of rocks along the entire depth of the tool massifs of the quarry, that increases reliability of evaluation of stability of slopes of ledges and sides of quarries and requires development of technology for setting slopes of ledges on design circuits using technological schemes of backfilling. The condition of the slopes of the ledges and sides of the quarry is controlled by modern laser-digital technologies.

The purpose of the work is to develop a reliable assessment of the stability of the slopes of the benches and sides of the quarry to solve the technological problems of mining with the provision of safe and rational development of the field.

The main idea of the work is to increase the stability of the stationary slopes of the ledges and sides of the quarry on the basis of improving the methods of studying the structure of instrument massifs and the strength properties of rocks and to ensure high-quality performance of offshoot work and control of their condition.

To achieve this goal, the following tasks have been identified:

- examine the structure of instrument massifs and the physical and mechanical properties of rocks taking into account the depth of their occurrence;
- study the values of structural weakening factors of the mass and the rock quality index taking into account the depth of occurrence of the instrument masses.
- substantiate the stability parameters of the sides of the Koktaszhal open pit taking into account the revealed regularities of the structural features of the instrument massifs and the obtained design strength properties of the rocks;

- study the process flow diagrams of offshoot operations during drilling and blasting operations.

Research methods include:

- analyze literature sources by methods of calculation of stability of quarry slopes by methods of fracturing, study of physical and mechanical properties of rocks and technological diagrams of bench retraction on design contours;
- laboratory tests for obtaining physical and mechanical properties of rocks;
- mathematical substantiation of results of structural elements change with depth of their occurrence;
- pilot industrial explosions when setting slopes of ledges at the Koktaszhal quarry.

The scientific provisions defended in the dissertation and the novelty:

- a scientific and methodological basis for substantiation of rock strength properties for assessment of slope stability of benches and sides of quarries was created, which consists in carrying out special studies on cores taken from drilled geotechnical wells in instrument massifs, characterizing their geological structure and clarification of the structure of the mountain massif of the sides for detailed study of rock strength properties along the entire height of the side.

- detected $\lambda_0 = -0,016 \ln(H) + 0,1272$ logarithmic regularity between the coefficient of structural weakening, the quality of rocks by the depth of occurrence of the main types of rocks (porphyrites), which approximates the value of $R^2 = 0,978$ shows the presence of a reliable relationship between the considered indicators, allowing you to quickly justify the amount of adhesion in the array for a reliable assessment of the stability of the slopes of ledges and sides of the quarry;

- the dependence of the effect of explosions on the deformation of the contour array is established to substantiate the parameters of technological schemes for cutting ledges that increase the stability of stationary quarry slopes.

The scientific novelty of the study consists in:

- study of on-board engineering and geological cores at an angle of 60^0 for physical and mechanical properties according to the depth of their occurrence at the Koktaszhal quarry;

- study of the values of structural attenuation coefficients of the massif and the quality index of rocks, taking into account the depth of their occurrence of on-board arrays at the Koktaszhal quarry.

- substantiation of the stability parameters of the sides of the Koktaszhal quarry, taking into account the revealed patterns $\lambda_0 = -0,016 \ln(H) + 0,1272$ structural features of the instrument arrays and the calculated strength properties of rocks obtained, an approximation of $R^2 = 0,978$ shows a reliable assessment of the stability of the slopes of ledges and sides;

- studying the stability margin coefficients in the Slide, Phase2 geomechanical programs to assess the technological parameters of the stability of the boards at the Koktaszhal quarry;

- research of the technological scheme during preliminary crevice formation, drilling and blasting operations during the design of ledges, study of the deformation zone, mowing operations during preliminary crevice formation

Personal contribution as an applicant consists in direct participation in all stages of the research process: search for independently established scientific tasks and methods for solving research tasks, obtaining, processing the data obtained, statistical analysis, development, implementation and testing of research results, as well as preparation of major scientific publications on the work performed in collaboration.

The practical significance of the work Results of the dissertation work was carried out within the framework of contractual work between NAO KarTU and Altai Polymetals LLP on the topic: "Study of the stability of the sides of the Koktaszhal quarry in connection with the adjustment of the mining and geological situation" - (under contract No. NIC-1803/2020 dated 03/18/2020).

1. A methodological basis has been developed for reliable preparation and substantiation of initial information for assessing the stability of the slopes of ledges and sides of quarries, which consists in conducting special studies on rock cores obtained from drilled engineering-geological wells in instrument arrays for a detailed study of the structure of the array, strength and physical properties of rocks at all heights of the sides.

2. The parameters of the slopes of ledges and sides are justified, recommended and accepted into the technical project of the development of the Koktaszhal quarry on the basis of a detailed study of the condition of the instrument arrays, taking into account the study of the size of structural blocks and strength properties of rocks by cores from specially drilled engineering-geological wells in the sides. The coefficients of structural weakening over the entire depth of the instrument arrays are reliably substantiated, taking into account the revealed regularity of the sizes of structural blocks with their depth in the logarithmic spiral by the function $\lambda_0 = -0,016\ln(H) + 0,1272$ with the approximation value $R^2 = 0,978$.

3. The method of assessing the stability of the sides of the quarry based on the use of the limit equilibrium method, taking into account the numerical and analytical solution, showing the possibility of its use in the production of calculations for assessing the stability of the sides of the Koktaszhal quarry.

4. The maximum steep parameters of the slopes of the ledges and sides of the quarry are proposed, which range from: for the slopes of the ledges with a height of 30 m, the angles of inclination are from 50° to 75° , and the general angles of inclination of the sides are from 46° to 52° with their height from 250 to 315 m. At the same time, the coefficients of the stability margin range from 1,19-1,37, which meets the requirements of the existing methodological guidelines of the Ministry of Emergency Situations of the Republic of Kazakhstan

5. To determine the fracturing coefficient of rocks $J_{cond_{99}} = 15.8$, the properties of mining and geological cores were initially studied taking into account the structural features and quality of rocks. Based on these data, the average numerical calculation of the $GSI = 63.5$ index for drilled mining and geological wells and the calculation of the strength characteristics of rocks for the Koktaszhal deposit in the RocLab software package were determined

6. A method of instrumental observations of the deformation of the rock mass during drilling and blasting operations in the contour zone is proposed, based on

the use of an electronic total station, which allows to obtain the values of the displacements of the array with high accuracy in cramped conditions from a ledge to another ledge.

7. Technological schemes for cutting slopes of ledges with justification of the parameters of explosives are proposed on the basis of the revealed empirical dependences of the size of the stabbing zone on the specific consumption of explosives and displacements of the array from conducting mass explosions to improve the quality of mowing operations.

8. When forming the stability of the sides of quarries, it is necessary to take into account the height of the ledge, which directly affects the quality of the extracted mineral, the rate of advance of the front, the rate of deepening of mining operations, the volume of mining and capital works, the total length of the work front, intra-quarry paths and roads, etc..

9. Effective parameters of contour blasting have been developed that allow the use of special methods of conducting BVR in the design of ledge slopes. It has been shown that the most effective way to limit the deformation zone behind the design surface of separation is the use of pre-crevice formation..

Testing work. The results of the work were presented and discussed at the conference: international forum of surveyors "digital technologies in Geodesy, surveying and geomechanics", Karaganda, 2019; International Scientific Conference "Interexpo-Geographic-2020", Novosibirsk, 2020, "innovative technologies in Geoinformation digital engineering" NAS RK Proceedings of the international scientific and practical conference dedicated to the 115th anniversary of Coor-member A. zh.mashanov and the 100th anniversary of Academician of Nas RK Zh.s.Yerzhanov, Almaty, 2022.

The results of scientific research obtained in the dissertation have been introduced into the educational process in the profile disciplines of the bachelor's degree 6B07202 "Surveying".

The research practice took place at the enterprise "Scientific and Engineering Center "Geoanalytka" LLP and "Altaypolymetal" LLP, scientific internship at the Tashkent State Technical University named after I.Karimov, mining and geotechnology of coal and reservoir deposits (Tashkent).

Publications. The main provisions of the dissertation work are reflected in 9 scientific papers, including 2 articles in peer-reviewed scientific publications on the scientific direction of the dissertation topic indexed in CiteScore in the Scopus database (Elsevier) is included in quartile Q3 (quartile 35), 2 articles in publications recommended by the Committee for Control in the Field of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan and 2 Patent for a utility model in the National Institute of Intellectual Property, 4 (four) articles in the collections of International and Republican scientific and practical conferences.

Structure and scope of work. The structure of the dissertation consists of an introduction, 4 sections, a conclusion, A list of references, 74 figures and 16 tables, and 150 pages of computer-printed text.