**ANNOTATION**

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# Development and substantiation of the design of the support of a vertical shaft being constructed in difficult mining and geological conditions (on the example of a DNK mine)

**The relevance of the work.**

Vertical shafts of mines are the main ones in the technological complex of workings, providing a connection between the underground part of the mining enterprise and the surface. They are of long-term use and in this regard, increased requirements are imposed on them: the shaft lining must not be damaged, which is achieved by choosing the appropriate material and lining design with an appropriate margin of safety, which is determined by research and calculation.

Shaft sinking is one of the most responsible, costly, time-consuming and costly stages of mine construction.

About 30% of the cost and 50% of the total duration of the mine construction is accounted for by vertical shafts. At the same time, up to 60% of these costs are associated with the support of workings.

One of the characteristic features of modern underground construction is an increase in the depth of deposits, and as a result, the complication of mining and geological conditions, which in turn is associated with an increase in the depth of exposure of unstable, watered and crushed rocks. Therefore, the issue of reliability and durability of the lining of vertical shafts is of particular importance.

An increase in the level of stresses in the rock mass with depth exacerbates the problem of ensuring the stability of capital mine workings under construction and in operation. At the design stage, the selected support and its characteristics should ensure the stability of the working during construction and operation, but, as practice shows, this often does not happen. The studied object, which is part of the group of Don chromite deposits in terms of its natural parameters, is unique not only in terms of volume and rich content of minerals, but also in heterogeneity and high complexity of the mining and geological conditions of occurrence of ore bodies and structural disturbance of the massif.

A characteristic feature of this deposit is the uneven stress field acting in the rock mass. Structural features are characterized by the presence of numerous tectonic faults and a strong fragmentation of the rock mass. The structural block of this environment is in a mobile state, under the influence of modern geodynamic movements. They cause uneven concentrated loading of the lining, which creates serious problems in ensuring the stability of the working both at the construction stage and subsequent operation.

Violation of the integrity of the lining of mine shafts under construction and in operation entails many negative consequences associated with serious costs for its restoration, a decrease in the rate of sinking of a shaft under construction, a violation of the efficiency of the mine, and sometimes with a complete stop of work or conservation of workings.

For example, at the DNK mine of the Donskoy Mining and Processing Plant in five shafts, starting from a depth of 500 meters, the stress level in the support reached the ultimate strength of concrete [8]. In the cage and skip- cage shafts, disturbances of the lining in the form of cracks and deformations were observed. A serious accident occurred in the cage shaft. Two hundred meters of support at a depth interval of 552 - 765 m was completely destroyed. It took more than two

years to restore the destroyed section of the trunk. The main reason for the large number of accidents that occurred at the shafts of the DNK mine is the excess of the existing stresses in the massif of its tensile strength at a depth of more than 500 m, as a result of which the massif is in conditions of inelastic deformation (excessive stress-strain state), which provokes movements blocks.

Therefore, ensuring the stability of vertical shafts is an acute and urgent problem, the result of the solution of which largely determines the efficiency of mining enterprises, as well as safety during their construction and operation.

The dissertation work devoted to the development and justification of the design of the Skipova shaft lining in the depth range of 900÷1200 m, namely at the intersection of a complex of ultrabasic rocks - serpentinites - with special properties, is an urgent task of mining .

**The object of the study** is the support of the «Skipovaya» vertical shaft and the surrounding rock mass of the DNK mine, JSC TNC Kazchrome .

**The subject of research** is: the stress-strain state of the near-contour massif and the design of the support of the "Skipova" shaft in the specific conditions of the rock massifs of the Donskoy Mining and Processing Plant.

**The aim of the work** is to develop and justify innovative designs of supports and effective technologies for fixing a vertical shaft, based on a comprehensive account of geomechanical and mining and technical factors, which ensures cost reduction during construction and operation in difficult mining and geological conditions, located in an anisotropic massif with an aquifer.

**The idea of the work** is to develop individual designs of supports for each interval of the formation (layer) of the massif intersected by the development of the shaft, taking into account the peculiarities of the interaction of the elements of the "rock mass-technology-vertical shaft" system at the drilling stage, providing an increase in the bearing capacity and operational reliability, as well as minimizing material consumption of the structure.

**Justification of the need for this research work.**

The need to perform research work is caused by the complexity of the geomechanical conditions for sinking shafts at the Decade of Independence of Kazakhstan mine (DNK mine), due to the high level of stresses of the untouched rock mass (initial stresses) with its relatively low strength.

High stresses are due to additional horizontal (tectonic) stresses, which was experimentally confirmed by field studies of the Institute of Mining Mining of the Ural Branch of the Russian Academy of Sciences during the sinking of the Auxiliary shaft and subsequent numerous and long-term instrumental observations of the stress-strain state of the mine shaft support.

To achieve this goal, the following **research tasks are considered in the dissertation**:

- Study, generalization and analysis of geomechanical and mining-geological conditions for sinking the shaft of the "Skip" mine of DNK.
- Study of the features of the geological-structural model, physical-mechanical and hydrogeological characteristics of the complex of ultrabasic rocks - serpentinites in the range of 900÷1200m, at the intersection of the Skipova shaft working, in order to establish the most characteristic features of the behavior of the massif and determine the optimal types and parameters of supports.
- In order to select the type and parameters of the lining for the extended part of the shaft, it is necessary to determine the categories of rock stability, taking into account the complexity of the geomechanical conditions of shaft sinking, by two alternative methods.

– determination of the rating of the rock mass according to the multifunctional geomechanical classification of D.Lobshir (MRMR – Mining Rock Mass Rating );

– determination of rock mass stability categories according to the traditional method of designing underground mine workings (SNiP II-94-80, SN RK 2.03-04, SP RK 2.03.106-2013).

Determine the load on the shaft support:

- calculation method based on the theory of calculation of the retaining wall, where the magnitude of the load is determined at the contacts in the overlying and underlying layers of the reservoir.

To do this, of course, it is necessary to determine the values of the lateral pressure coefficient ($\lambda$)in the natural stress field in the enclosing rock mass.

Study and selection of new progressive fastening materials, taking into account the diversity of mining, geological and geomechanical conditions for driving a shaft;

Selection of the type and design of the lining based on physical models, taking into account the interaction of the lining deforming together with the surrounding rock mass for each layer (formation) individually;

Analysis of the material consumption of the design of the shaft supports in the investigated interval of the depth of the shaft.

**Scientific novelty of the work:**

– In the process of studying the structural features of the investigated interval of the massif around the working under construction, the presence of six fine-grained rock blocks with different strength and deformation characteristics was revealed, and the boundaries of tectonic disturbances of the "slip mirror" were also established. Therefore, this interval is divided into layers in accordance with the physical-mechanical and water properties of the rocks. In the fourth layer, layers are separately identified, which differ from each other in physical and mechanical characteristics.

– To assess the stability categories of the rock mass in the area of the construction of the Skipovaya shaft, in addition to traditional methods of assessment, for the first time the multifunctional geomechanical classification of D. Lobshir (MRMR – Mining Rock Mass rating ).

Based on the analysis and generalization of the results of studying the stability of the massif according to D. Lobshir and SNiP II-94-80, the boundaries of the same type of rock layers were determined, which later allows determining the calculated parameters of horizontal (radial) pressure of rocks on the lining layer by layer.

– It has been established that the heterogeneity of the natural stress field is due to the presence of tectonic zones. Therefore, the values of the lateral pressure coefficient ($\lambda$)in the natural stress field are determined by alternative three methods, so that, as a result of their generalization and analysis, the most reliable value ($\lambda$)for determining the rock pressure at the level of the roof and soil of the reservoir.

– New technological solutions were proposed for the creation of a rock waterproof structure in the section of the shaft with aquifers. The essence of the work of rock structures created around workings is to maximize the use of the bearing capacity of the rock mass.

– Based on research, analysis and generalization of the geomechanical state of the massif containing the shaft working, and the study of progressive materials and the design of modern supports, the design and parameters of the support for each interval of the structural layer (formation) are proposed and substantiated by calculations.

**Scientific provisions and results** submitted for defense:

1. Studies of the structural features of the massif around the working under construction have established the presence, in the investigated depth interval, of six fine-structured fractured rock blocks with different strength strength and deformation characteristics, the boundaries of tectonic disturbances of the "slip mirror" have been clarified, and the physical-mechanical and hydrogeological properties of each individual layer have been studied ( layer) in order to develop and justify an individual type of support for each layer (layer) on the basis of these specific data.

2. Based on the definitions of massif stability categories, in the interval of intersection of the trunk ( $H_C = 900 \div 1200$ м) by two independent alternative methods (D. Lobshir and traditional empirical - SNiP II-94-80), clear boundaries of the same type of rock layers are established in terms of their physical, mechanical and water properties, which in the future made

it possible to calculate the values of horizontal (radial) rock pressures on the lining layer by layer, individually.

3. The determination of the value of the coefficient of lateral pressure on the rock support, due to the heterogeneity of the natural stress field, was carried out by three alternative methods: depending on the depth of the layer and the deformation modulus; only from the depth of the layer (formation); taking into account the Poisson's ratio and the volumetric weight of rocks, taking into account the depth of the layer (formation).

Determination of rock and hydrogeological pressure at the level of the roof and soil of each layer (layer) of rock based on theoretical studies $\lambda -$ of the lateral pressure coefficient allows the adoption of technical and technological solutions to determine the design and materials individually.

- In order to minimize the influence of rock and hydrostatic pressure on the lining structure in the section of the shaft with aquifers, a technology for preliminary chemical compaction of the massif around the shaft by creating a protective layer from the rock structure with the maximum use of the bearing capacity of the rock massif is proposed.
- Based on the study of geomechanical and mining-geological conditions for the construction of the shaft, innovative designs of supports were developed and justified using the latest materials in the interval of the depth of the shaft ( $H_C = 900 \div 1200$ м).
- The technical and economic indicators of various designs of the support of the "Skipova" shaft have been studied in detail.

**The practical significance of the work** lies in the development of lining by the method of multifactorial examination of underground structures, the development of a methodology for predicting changes in the stress-strain state (SSS) taking into account real rock pressure, the use of specialized adapted programs that will improve the accuracy of the results of multifactorial measurements.

The versatility of the developed design of the combined support of a vertical mine shaft will prevent emergency situations that may occur during construction and operation, increase the bearing capacity and service life of the working, control the hydrostatic pressure of groundwater, when erecting a permanent support using innovative building geomaterials .

The results of the research of the author of the thesis will be used in the development of recommendations for the effective strengthening of the structures of a vertical mine shaft constructed in difficult mining and geological conditions, aquifers and in the calculations for the construction of the “Skipovaya” shaft of JSC TNC “Kazchrome”, which is confirmed in the act of implementation.

The calculation method can also be used in the educational process, for educational purposes when modeling dynamic processes for underground structures for various purposes.

**The author's personal contribution** consists in setting research objectives, directly summarizing the results obtained in all sections of the dissertation, namely in selecting materials for the development of a combined lining, conducting a comprehensive multifactorial analytical survey of the skip shaft, modeling the shaft under construction using modern software and performing calculations to determine the SSS a complex system of underground structures and analysis of their results, drawing up recommendations on the technology of erecting the developed lining and preliminary decisions for future repairs.

The validity and reliability of scientific results and conclusions of the work are based on the use of special calculation methods and data for comparison with previously obtained results.

**Research methods:** analytical- geomechanical and mechanical-mathematical modeling of the processes of SSS change based on the theory of elasticity of anisotropic media and the processes of determining the beginning of destruction based on conservation laws.

**Economic significance of the obtained results**. The developed design of the lining of the vertical mine shaft and the established patterns of the formation of the area of plastic pre- fracture in the design of the permanent lining of the “Skipovaya” shaft make it possible to develop

recommendations for additional strengthening in advance, which makes it possible to prevent destruction and stop the production process in a timely manner. It will also ensure the uninterrupted operation of production and industrial facilities of the national economy and the preservation of the parameters originally set by the project for the entire period of operation.

The effective combined support offered by us reduces the consumption of materials by 1.5 - 3 times and is economically beneficial when carrying out capital mining.

**Approbation of work.**

The results of the research were reported at international scientific symposiums and conferences: IX International Conference "Efficient use of resources and environmental protection - key issues in the development of the mining and metallurgical complex" (May 20-22, 2015, Ust-Kamenogorsk, RK); Science and technologies in geology , exploration and mining conference proceedings (30 June - 6 July , 2016 Albena , Bulgaria ), "Problems of subsoil use" (19 - 21 April 2017, St. Petersburg State University, St. Petersburg, RF).

**Publications.** The main results of the dissertation are reflected in 12 scientific articles. Of these, 6 recommended by the Committee for Control in the field of education of the Ministry of Education and Science of the Republic of Kazakhstan, 4 International conferences; 3 in ranking international journals.

**Implementation of work results.** The results of the research will be recommended in the development of recommendations for sinking and fastening vertical shafts constructed in difficult mining and geological conditions, designing vertical shafts of mines, with preliminary plugging of rocks and waterproofing of the permanent shaft lining being erected, an act of implementation of the research results was received from GSK Shakhtproekt LLP ", as well as the use of individual results of the dissertation research will be used to prepare students in the form of materials for lecture courses and practical work in the disciplines: MIN4691 "Technology for the construction of vertical mine workings" and MIN4721 "Calculation of the design of underground structures" for bachelors of the specialty 6B07205 - "Mining Engineering" , there is an act of introducing results into the educational process.

**Structure and scope of work.** The dissertation consists of an introduction, 4 sections, main results and conclusions, contains 180 pages of typewritten text, 30 tables, 36 figures, as well as a list of references from 86 titles and 8 appendices.