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Features of Fastening Very Unstable Rocks with Combined Support on the Basis of SZA and Shotcrete

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Abstract. The results of industrial tests of a reinforced combined support based on self-fastening anchors are presented. The approved versions of reinforced combined supports that ensure the stability of contours of mine workings in difficult mining and geological conditions of the mine "Orlovskaya" LLP "Vostoksvetmet".

1. Introduction

The mine "Orlovskaya" is characterized by complex mining and geological and mining&technical conditions. The presence of intensively disturbed sericite&chlorite carbonate metasomatites in the mine footwall and its contact areas significantly deteriorates the conditions of mining conduct and mounting in these areas. The identified metamorphosed rocks cause the development of special measures to prevent their contact with an aggressive mine atmosphere as well stipulate for the application of heavy supports and advanced fastening.

At the lower horizons of the mine "Orlovskaya" one observes the sections with higher air and massif temperatures, which facilitates the development of additional thermoelectromotive forces as well as metamorphization and other chemical processes causing rock fall. Continuous barite-polymetal, copper&zinc, continuous copper-sulphide ores and those impregnated into quartzites as well as some rock varieties (silicious siltstones) possess high strength properties. That is why at the conduct and mounting of minings for such ores and rocks one needs to take into account the possibility of the manifestation of the rock pressure dynamic forms and apply compressible supports.

At the lower sections of the deposit one can generally observe the rocks of the 3d-4th rigidity categories and the ores of the 4th-5th rigidity categories. The period of outcrop standing (with the area of up to 10 square meters) in such ores and rocks is up to three days for unstable rocks while the period for very unstable rocks - up to one day. Therefore, in case of the mine workings, conducted for very unstable and unstable ores and rocks, one needs to reduce the time required to build a temporary support.

2. Relevance, scientific significance of the issue with a brief overview of references

Combined mounting methods (anchors and shotcrete), applied in the rocks with a low stability at the national and foreign ore mines, are becoming increasingly relevant. In this connection it is rather interesting to consider the results of the research, conducted by Australian and Canadian mine companies [7-9], having an experience of mine support mounting with the help of fibrous shotcrete as well as the research [10], conducted by the scientists in the Russian Federation.



The main functions of a combined support consist in the formation of bonds between a support and a rock, which makes up a bearing rock beam as well as holds rock pieces between anchors, providing for the increase of the mass resistance towards destruction and weakening from the mine atmosphere influence [1]. Selecting support parameters and types is made on the basis of the analysis of mining and geological and mining&technical factors as well as the support cost.

The support should be rather hard, capable of bearing high loads, but also being flexible and providing for slight rock shift. To ensure an optimal operation of a combined support, anchors and a surface support should have identical deformability levels.

3. Problem statement

Today the support type and its parameters definition for the mine workings in the area of cleaning works' influence are selected in compliance with the recommendations of specialized organizations. Before choosing the support type, one needs to define the stability category of a rock mass. An engineer-geotechnician is responsible for relating a mine working to one or another stability category.

In compliance with [3] the stability of ore and rock outcrops is defined by the Barton empirical method (Q-rating), which evaluates the influence of such factors as strength and rock quality, mining depth, mining section and a stressed state in the surrounding mass, crack number and state, including the degree of their change.

Unstable areas include: 4th and 5th categories of a rock mass stability; areas of fractures and tectonic deformations; sections of metamorphosed rocks.

In case of the 4th category of a rock mass combined structures are generally applied; they consists of anchors, metal net and shotcreting or arched metal supports made of a special section SVP.

Under the conditions of the Orlovskaya mine the researchers conducted the tests for quite a large number of mine working mounting options within unstable areas. All the options provide for the stability and normal functioning of mine workings in compliance with their scope of application but significantly reduce the rate of mine development thus causing the growth in mounting costs and, in addition, do not have a universal nature.

4. Theory

In the course of the conducted analysis of the peculiarities of a combined mine working mounting [1-10] for the conditions of the mine "Orlovskaya" the authors found out that the most reasonable solution is to use the support structure based on friction anchors (SZA type) in combination with reinforcement cages and developed by UralEnergO Rus, LLC [1].

The fastening method, based on a self-fastening anchor support SZA-Reinforced support, was developed to fasten intensely fractured unstable rocks liable to inrush formation. The key feature of such structure is a reinforcement cage in addition to the anchor SZA. The reinforcement cage is a mesh grid, made of high-tensile reinforcement and installed simultaneously with an anchor, which ensures rock lagging along the mine working perimeter and excludes the danger of mass structural block inrush in intensely fractured rocks.

The anchor support with a reinforcement cage makes the mounting process completely mechanized and thus eliminate the possibility of people standing under unfastened mine working lines, which makes it safer for workers. Such support type can be applied to fasten the mine workings without a gap between the support and a bottom. Before shotcreting it prevents the danger of the rock piece fall from the mine working roof and borders.

The reinforcement cage is put onto the anchor rod and installed simultaneously with the anchor introduction into a drill hole retaining with a foundation base against the mine working line. Therefore, along the mine working perimeter, after applying a shotcrete layer of a necessary thickness the structure works as a monolithic reinforced concrete.

For a shotcrete support material the authors suggest using ready dry mixes to be the most reasonable in terms of technology. It significantly enhances the labour performance. An average shift performance of a team at the application of ready dry mixes is 1.5-3 times higher if compared with the

team performance in case such mixes are prepared on-site. Using ready mixes combined with shotcrete application complexes reduces the part of manual labour comparing with a traditional method and makes the mine working process faster.

5. Practical significance, offers and introduction results, results of experimental research

The field research were conducted in mine workings at the deposit "Orlovskoye", layers 10 and 14. As a result of the conducted field research the authors visually inspected the state of mine working borders, support parts, evaluated the roof and borders' stability, carried out the preliminary analysis of the direction of main stress activity.

The visual inspection demonstrated that the rocks subject to mine workings are broken. One can observe the mass indentation with cracks, the rock structure weakening factor is equal to 0.4-0.1 at the inspected sites.

The crack bedding angle, their orientation towards the working axis as well as the general rock state make it possible to draw a conclusion that unfavorable conditions for the conduct of anchor works with standard anchor systems (ZhBSh, SPA).

The rocks after outcrop entered into an active reaction with a mine atmosphere, changed their initial physical&mechanical properties and passed into the stage of active inrush formation.

To analyze the processes, passing in a rock mass at the interaction with an aggressive mine atmosphere, the authors conducted the tests under GOST 8269.0-97 and GOST 24816-2014.

The content of a sorption humidity in the samples, kept in the environment with a 100% humidity for 48 hours, approximates to 50% of the water sorption for the same 48 hours. It should be noted that after 48 hours the rocks stop absorbing moisture from the air.

The key metamorphization processes in rocks take place in the period of 0-24 hours. In the period of 6-18 hours after outcrop rocks absorb moisture, their weight increases, the adhesive capacity reduces which triggers rockfall.

In the period of 24-48 hours the processes in the area up to 0.6 m from mine working lines stop and, in case of a partial or full rockfall in the area, the processes pass into deeper layers.

To fasten the rocks of a medium and low stability under the conditions of the development of the Orlovskaya mine, one needs to test the support structures with the use of SZA anchors (48 mm diameter) with a length of 2.2 m as part of the following reinforced combined support types.

1. In the unstable (category IV) rocks

- SZA–reinforced support – shotcrete.
- SZA–reinforced support – shotcrete - UKK - shotcrete.

2. In the very unstable rocks (category V), subject to the intense change of strength properties and loss of stability in the course of time

- Shotcrete – SZA–Reinforced support– UKK – shotcrete – Metal support frames – outrunning injection.

As a main site for pilot industrial tests' conduct by the committee, including the specialists of the underground mine "Orlovskiy", a cross cut No.2, located on the top 15, block 1, layer 15

The cross cut No.2 is made in copper-sulphide ore in sericite chloritic metasomatites. The mass is intensely fractured with the presence of fracture systems 1,2,3. The rock hardness factor according to the scale of professor M.M. Protodiakonov $f=3$, Q-rating – D, weak.

The results of industrial tests show that the bearing capacity of the SZA anchor support does not deteriorate over time and is more than 8.5 tons.

For the moment of inspection a fastened mine working site has been under operation for 2 months. The site state is satisfactory. No damages of the support identified.

Taking into account the pilot tests' results as well as the conducted evaluation of a load-bearing capacity of a surface shotcrete support, the authors suggests using the following support types to fasten the rocks of various stability in the mine "Orlovskaya", Vostoksvetmet, LLP:

1. Anchor support SZA.
2. Anchor support SZA + shotcrete.

3. Anchor support SZA, reinforced with a reinforcement cage (SZA-Anchor support) with shotcrete.

5. Combined support shotcrete - SZA-Reinforced support-UKK-shotcrete.

6. Conclusions

The analysis of design solutions on the mine working mounting in complex mining&geological solutions showed that today we have quite a vast legal framework. Both national and well-tried foreign methods are applied to define the stability of rock masses for selecting support type and parameters. Modern materials for mine working mounting were developed and tested in the industrial conditions.

According to the outcomes of the conducted research it was established that the anchor support SZA corresponds to the characteristics, stated by the manufacturer, and complies with the requirements of the international standard GOST 31559-2012 (Revision No.1 of 01.06.2016) "Anchor Supports. General Specifications".

The technology of mine working mounting in the rocks of a medium/low stability with the use of a reinforced combined support on the basis of SZA-Anchor support and shotcrete MasterRocSTS1510 can be possibly applied under the conditions of the Orlovskaya mine without significant changing of the variety of the existing process equipment for short-hole drilling and shotcrete build up by the "dry" method, which facilitates the transition to this support type application.

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