Analysis and Generalization of Experience in the Application of Technologies for Supporting Mine Workings in Difficult Mining and Geological Conditions

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Abstract. An analysis of the technologies for securing mine workings in difficult mining and geological conditions has been conducted. The options for fastening with the use of self-fastening roof bolting in combination with reinforced cages and metal meshes are considered; sprayed concrete, applied according to the technologies of "dry" and "wet" sprayed concrete; fiberglass and basalt-plastic roof bolting; plugging of rocks in difficult hydrogeological conditions.

1. Introduction
According to domestic and foreign publications, ensuring the stability of mine workings by combined methods of fastening is becoming increasingly widespread. This fact is due to an increase in the strength of the sprayed concrete lining through reinforcement with metal meshes and the use of fiber fibers, a significant increase in the productivity of the tunneling cycle due to the mechanization of the fastening process and reducing costs compared to the use of heavy types of lining such as monolithic concrete and metal arch support. The existing disadvantages of traditional fastening methods can be reduced and, in some cases, eliminated through the use of modern technologies and materials.

The increasing complexity of mining and geological conditions associated with great depths, low stability of rocks, the presence of high stresses in the rock mass determined the need to improve the design of supports, revise the features of their work in such conditions and methods for calculating the parameters of the support. The conducted research is aimed at generalizing the experience of the process of fixing mine workings.

2. Relevance, scientific significance of the issue with a brief overview of references
Over the past 10 years, friction roof bolting to ensure the stability of mine workings in underground mines in Russia, the Republic of Kazakhstan, Uzbekistan, Kyrgyzstan has become widespread [1,2]. This is due to the high manufacturability and safety of work when using these types of support.

Under the operating conditions of several mines in the Southern Urals and Yakutia, laboratory and pilot-industrial tests of the following fastening methods were carried out:
1. Anchor methods of fastening - non-metallic composite and self-fastening anchor support;
2. Injection hardening;
3. Spray concreting using "wet" and "dry" technology with the addition of various additives to the
composition of the sprayed concrete mixture.

One of the promising areas in civil construction, as well as in several coal and salt mines, is the use of composite reinforcement, based on glass and basalt fiber, instead of metal reinforcement. Thus, in the conditions of copper-pyrite mines, tests of fiberglass (ASP) and basalt-plastic (ABP) roof bolting were carried out. The fastening technology is similar to the traditional type of reinforced concrete rods (RCB), with the exception of the use of composite reinforcement rather than metal reinforcement as a reinforcing element.

The defining parameter of the quality of rock anchorage is the bearing capacity [1]. As a result of research, the bearing capacity of non-metallic reinforcing rods was 360 kN, reinforced concrete - 288 kN. The adhesion of the standard mortar to the fiberglass reinforcement during the tests exceeded the adhesion to the metal reinforcement by 15% already for 1 day.

Improvement of the anchoring technology made it possible to develop a new design of anchor rods - self-anchored roof bolting (SZA), which is an analogue of the well-known frictional roof bolting of the "Split-Set" type, intended for fastening the roof and sides of workings.

Industrial tests of the self-fastening support structure began in 2009. In the process of carrying out large-scale tests at the mines of the Southern Urals, Yakutia, Kemerovo Region, the support design and the technology of its installation were improved, and positive technical and economic indicators were obtained. At present, SZA support is widely used at large mining enterprises UGMK-Holding, AK Alrosa, OJSC EVRAZRUDA, and others.

The productivity of sprayed concrete works significantly increases with the transition from "dry" machines to robotic installations using "wet" technology. The average 8-hour productivity in the "wet" method usually exceeds the productivity in the "dry" method by 4-5 times [3].

Backfill is an effective way to strengthen the rock mass. The injection method, as an independent hardening method, is characterized by the fact that in the process of injecting cement slurries into the rock mass, it is necessary at the initial stage to ensure the fastening of mine workings by traditional methods, which is characterized by an increase in the volume of work [2]. Analysis of the injection technology revealed the possibility of using self-anchored roof bolting as a device for supplying the components of the cement slurry to the area of the rocks to be hardened through boreholes with anchors installed in them.

The known method of plugging rocks using special designs - packers for supplying solutions to boreholes.

The advantage of the proposed technology for the construction of mine workings in deteriorated mining and geological conditions using the SZA - Injector is in the exclusion of additional drilling of boreholes for placement of special devices for supplying solution - packers, as well as the need to use the packers themselves. The use of this design allows at the same time to ensure the stability of rocks at the initial stage of construction of workings, as well as to perform injection for the purpose of strengthening and waterproofing. Injection work is carried out under a fixed space.

3. Problem statement

During pilot tests of fiberglass and basalt-plastic lining at the pilot sites of the Gaysky, Uchalinsky, Uzelginsky underground mines of the Southern Urals, a non-metallic composite roof bolting was installed using a standard hardening composition based on sand and cement. On the fourth day, random tests of the bearing capacity of composite anchors were carried out using the PKA-1 device. As a result of tests on the tested sections, the bearing capacity of the anchors was more than 70 kN.

To assess the economic and technological efficiency of the use of composite materials after pilot tests, the material and labor costs were calculated using the example of driving a mine with a cross section of 14.7 m² in rocks with a stability category of IV b in the conditions of the Uchalinsky mine.

Compared to the use of metal reinforcement in the construction of reinforced concrete rods, the transition to composite materials will reduce the cost of fixing 1 running meter. by 17%.
4. Theory
Since in the world practice of supporting mine workings there is a tendency to abandon heavy types of support and the transition to combined supports, it was expedient to conduct research on improving the sprayed concrete support by introducing various additives into the composition to eliminate the disadvantages that it possesses.

Despite the significant advantages of using mechanized installations for the erection of sprayed concrete lining and improved performance of the resulting layer with the "wet" technology, the use of the "dry" method at most mines remains the most rational and economically profitable.

During research work in this direction, the strength characteristics of the sprayed concrete lining were determined, the quality of rock fastening of mine workings was assessed using fiber-optic fibers and a hardening accelerator. The support was carried out using the Spraymec 1050WP wet sprinkler.

As a result of the studies carried out in the conditions of deposits developed by the underground method in the South Urals, the conditions for the effective use of self-fixing anchors were clarified and the structures of combined supports based on them were developed.

The specified support structures were tested in workings driven in rocks below the average stability category, where, according to the fastening passport, it was planned to use heavy types of arch support. As a result of testing the technology of fastening underground mine workings with reinforced types of support based on SZA, no disturbances in rock stability were revealed.

5. Practical significance, offers and introduction results, results of experimental research
As a result of these studies, it was found that non-metallic composite roof bolting meets the requirements of GOST 31559-2012 “Anchor roof supports. General technical conditions , can be used as a support for underground mine workings and allows you to reduce the cost of fastening.

The use of fiberglass and basalt-plastic rods makes it possible to abandon the use of metal reinforcement and achieve an economic effect of 945 rubles / r.m. for the main materials in classes II-III. in the case of using fiberglass-based roof bolting, and up to 647 rubles / running meter. - basalt fiber.

The studies carried out show the possibility in difficult mining and geological conditions to avoid the use of arched metal lining from the special profile of the SVP and reinforced combined lining from reinforced concrete anchors and sprayed concrete reinforced with a metal mesh and replace them with combined and reinforced combined lining using self-fastening anchors, as well as to reduce the cost of mount 1 rm output by 48 and 11%, respectively.

6. Conclusions
Thus, combined roof supports based on SZA can be used in a wide range, which is confirmed by the results of their successful application during their own experimental-industrial tests, and according to data from foreign literary sources.

In conditions of driving workings with significant water inflow and low stability, it is necessary to use the technology of strengthening and waterproofing the massif using a distinctive design of the SZA.

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