Modern portal support for slopes

Vladimir Pershin^{1*}, Pavel Budnikov¹, and Qiao Wei-Guo²

¹T.F Gorbachev Kuzbass State Technical University, Kemerovo 650026, Russia

²Shandong University of Science and Technology, Qingdao 266590, China

Abstract. In view of the problem of the portal support of a slope, this paper summarizes four arch barrings, their main structure characteristics and disadvantages are analyzed, then a new design of in-situ reinforced concrete barring is developed for the slope mouths, the cost of barring materials and the wage of the pitmen are determined by comparing several barring structures used to support the mouths of inclined shafts.

1 Introduction

Currently, in Kuzbass constructing mines are developed by inclined shafts. The shaft collars are fixed by in-situ reinforced concrete barring.

When choosing the structure of the portal support of an inclined shaft the main factor is the method of construction (by open pit and mining), as well as the mining and geological conditions for location of the mouth of inclined shafts. In Kuzbass mines, an arch barring is the most usable.

Comparison of Support scheme

When the arch barring is used, an important structural element is a rigid reinforcement, which is used as a special interchangeable profile (SIP). Depending on the geological conditions at the mouth location, the section may vary from SIP-17 to SIP-33. The variety of arch structures is determined not only by the section number, but also by its location relatively to the barring cross-section [2].

The arch barring with one profile SIP located in the center of the cross-section of the barring (Fig. 1) is the simplest construction design of the portal support. The most important factor in the location of the special profile is the bending moment diagram.

* Corresponding author: pvv.spssh@kuzstu.ru

Fig. 1. In-situ reinforced concrete barring with rigid reinforcement

In the Fig.1: 1 – metal frame made of section SIP; 2 – in-situ concrete.

The disadvantages include the work of solid barring structures mainly in the transverse direction of the development and the insufficiency of their work in the longitudinal direction; the material intensity of the barring design while ensuring its required bearing capacity; unequal strength of the structure due to the presence of overloaded barring elements.

Having analyzed the second in-situ reinforced concrete barring with flexible internal reinforcement (Fig. 2) we came to the following conclusions. The most important structural element—rigid reinforcement—is located in such a way that it can take up load from both compressive and tensile stresses.

Fig. 2. In-situ reinforced concrete barring with flexible internal reinforcement

In the Fig. 2: 1—metal frame made of section SIP; 2—main reinforcement; 3—distribution reinforcement; 4—in-situ concrete.

The second arch barring also has some disadvantages; they include the unsatisfactory work of the barring from the development sides in the longitudinal direction; an increase in the metal consumption of barring structure, while ensuring it with required bearing capacity when flexible reinforcement is used; inequality of structure due to the presence of overloaded barring elements.

The third arch barring with taken out section SIP was proposed by open joint stock company KuzNIIshakhtostroy, while the special profile is taken out, and the mesh reinforcement remains inside (Fig.3). The analysis of the third arch barring showed that the calculations and comparisons with the previous version showed that the bearing capacity of this beam exceeds, on average, 3–4 times the bearing capacity of the beam with the central location of rigid reinforcement; it indicates the great potential of the new type of support with taken out rigid reinforcement.

Fig. 3. In-situ reinforced concrete barring with a rendered profile SIP

In the Fig. 3: 1–metal frame made of section SIP; 2–main reinforcement; 3– distribution reinforcement; 4–in-situ concrete.

The third arch barring also has some disadvantages. They include the unsatisfactory work of the barring from the development roof support in the longitudinal direction; an increase in the metal consumption of barring structure, while ensuring its required bearing capacity through the use of flexible reinforcement; unequal strength of the structure due to the presence of overloaded barring elements; susceptibility to corrosion of the taken out profile SIP.

The fourth type of arch barring with two profile SIP is used in very difficult geological conditions, when one profile SIP does not carry the load. The scheme of distribution of rigid reinforcement over the profile through cross profile is only one – in the stretched and compressed zone (Fig. 4).

Fig. 4. In-situ reinforced concrete barring with distribution of rigid reinforcement in the barring profile

In the Fig. 4: 1–metal frame made of section SIP; 2–working fittings; 3–distribution fittings; 4–in-situ concrete

The disadvantages of the fourth type of arch barring are the unsatisfactory work of the barring from the development roof support in the longitudinal direction; a significant increase of metal consumption of barring structure, while providing it with the necessary carrying capacity due to the use of the second profile SIP and flexible reinforcement; unequal strength of the structure due to the presence of overloaded support elements; increase in labour intensity, when a barring is being constructed.

In-situ reinforced concrete barring

We started our investigation in 2006, we carried out the series of experiments on the experimental plant and get the following results [1].

When bearing capacity and the choice of elements of frame supports of mine developments are calculated, it is necessary to determine internal force factors (longitudinal and transverse forces, bending moments), build corresponding diagrams of their distribution in the structural elements, identify dangerous sections to each of the force factors. According to calculation of the limiting values of the forces in dangerous cross sections of the elements, their sizes are selected, or their limiting bearing capacity is determined depending on the type of actual loads for the known parameters of the structure.

Calculations and selection of durable dimensions of frame support elements are carried out by stresses arising in the most dangerous cross-section, while the parameters of the bearing profile are taken to be the same for the whole structure; it leads to inefficient use of metal, as part of the frame contour, depending on the type of external load, is overloaded.

Taken into consideration all the above, the department of underground mines constructions has developed a new design of in-situ reinforced concrete barring for the slope mouths. The patent of the utility model is received.

Our type of arch barring has the following structural elements. Installed at a large distance from each other the elements of metal barring in the middle (vertical) part as reinforcing elements are less effective in comparison with a large number of rods of a small cross-section in the mesh and the outer surface of the barring.

The development support (Fig. 5, *b*) consists of the metal arch support from a section with interface nodes 1 between the legs 2 and the head block 3, located respectively at the inner surface of the vertical curved part of the concrete support 4 [1, 3].

Additional reinforcing meshes 5 and 6, which are not connected with each other, are installed respectively at the inner surface of the curvilinear part and at the outer surface of the vertical part of the concrete barring 4 in the stretched zone according to the diagram (see Fig. 5, *a*).

The barring is installed in the following way. In the development with a certain clearance from the sides and close to the top point, the frames of the metal arch support with the interface nodes 1 between the legs 2 and the head block 3 are installed and the mesh-wire lagging 1 is fixed on them.

Fig. 5. In-situ reinforced concrete barring with flexible reinforcement in the barring profile

In the Fig. 5: 1 – interface node; 2 – legs; 3 – head block; 4 – in-situ concrete; 5 – lower reinforcement mesh; 6 – upper reinforcing mesh; 7 – layer of armour stone; 8 – pinning; 9 – layer of "lean concrete"; 10 – reinforced concrete floor; 11 – starter bars.

Then, at some distance from the face, on the frames of the arch support, additional reinforcing meshes 6 are installed at the edge of the excavation and additional reinforcement meshes 5 are installed under the head block 3.

In this case, the upper ends of the meshes 6 are located above the lower ends of the meshes 5 (almost above and below the interface nodes 1).

The form work (is not shown in the picture) for the construction of concrete barring 4 is installed in such a way that its surface is located at the insignificant distance from legs 2 and the suspended mesh 5.

In accordance with the stress diagram in the barring of the mine developments, maximum bending moments M_b occur in the middle of the vertical and curvilinear upper parts of the barring with zero values in the zone between the ends of the reinforcing meshes 5 and 7 and the nodes 1 of elements 2 and 3 arise of the metal arch barring; maximum stretched stresses occur only in the reinforcing meshes 6 and 6, this allows to reduce the size of the special section and the number of support frames.

The final stage of our experiment was devoted to calculations of the economic effect from labour inputs reducing while constructing the reinforced concrete barring of the mouth, as well as the cost of barring materials and the wage of the pitmen is determined by comparing several barring structures used to support the mouths of inclined shafts for the same geological conditions.

2 Conclusion

Comparison of the complexity parameters of the reinforced concrete barring construction of the mouth in the inclined shafts shows a decrease in the number of man-hours to 31.6 % (Fig.6, a). When calculate the basic wage of pitmen of the V category, the savings are to 30.1 % (Fig.6, b).

Fig. 6. The economic effect in the construction of reinforced concrete barring of the inclined shaft mouth

(2)The diagram of materials costs for the construction of the reinforced concrete barring of the mouth of the inclined shaft shows a decrease in costs up to 41.7 % (Fig. 6, c). Comparison of the planned cost during the construction of the supports of the mouth of an inclined shaft allows to save up to 36.6 % of funds (Fig. 6, d).

References

1. Rock support, Patent 59726 RU, Bul. No. 36, M. D. Voitov, V. V. Pershin, K. V. Sadykov, P. M. Budnikov (2006)
2. Vladimir V. Pershin, Michail D. Vojtov, Pavel M. Budnikov, Coal in the 21st Century: Mining, Processing and Safety: The 8th Russian-Chinese Symposium. – Kemerovo, Russia, 27 (2016)
3. V. V. Pershin, M. D. Voitov, P. M. Budnikov, *Construction of the mouths of inclined shafts* (Nauka, Novosibirsk, 2018)

4. A. Khoreshok, L. Kantovich, V. Kuznetsov, E. Preis, E3S Web Of Conferences, 03004 (2017)
5. A.M. Keropyan, L.I. Kantovich, B.V. Voronin, V.V. Zotov, IOP Conf. Series: Earth and Environmental Science, **87** (2017)
6. B. Gerike, Y. Drozdenko, E. Kuzin, I. Ananyin, D. Kuziev, E3S Web of onferences, **41**, 03011 (2018)
7. A.M. Keropyan, D.A. Kuziev, A.E. Krivenko, Springer Nature Switzerland AG 2020 Proceedings of the 5th International Conference on Industrial Engineering (ICIE 2019), Lecture Notes in Mechanical Engineering (2019)
8. D. Kouziyev, A. Krivenko, D. Chezganova, B. Valeriy, E3S Web of onferences, **105**, 03014 (2019)
9. M.V. Pavlenko, N.G. Barnov, D.A. Kuziev, K.N. Kenzhabaev, M.V. Monzoev, Ugol, **1**, 36 (2020)
10. A. Khoreshok, K. Ananyev, A. Ermakov, A. Babarykin, Acta Montanistica Slovaca, **25:1**, 70 (2020)