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The choice of the site for inclined shaft and parameters of its stage-by-stage construction in the conditions of the Tersinsky coal region

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Abstract. The problem of the construction of inclined trunks in the conditions of coal mines in the Tersinsky geological and economic region of Kuzbass is discussed in the paper. The feasibility study for the technological option of the inclined boundary shaft construction in seam 67 in the complex mining and geological conditions of the mine was carried out. The recommendations on the monitoring of the workings state and development of measures ensuring the reduction of negative manifestations of rock pressure during the construction and operation of the inclined shaft are given taking into account the cumulative influence of the system of the previously mined workings and seasonal increased water inflow.

1. Introduction

The construction and maintenance of opening workings in difficult mining and geological conditions is a very urgent task for mine-designers [1,2]. Annually in Kuzbass the construction of more than 7 km of opening inclined workings is carried out, about 4 km of permanent mine openings need to be repaired. Strengthening of the support and repair for the entire lifetime is required in almost 35% of cases during the lifetime of the workings.

In the course of the work on the construction of the boundary inclined ventilation shaft in seam 67 of the brunch "Mine "Uvalnaya" of JSC "UK Sibirskaya" in difficult mining and geological conditions, the results of engineering geological, hydrogeological and geophysical surveys in the construction area were analyzed.

Based on the results of analysis of the mining and geological situation and the spatial location of previously mined areas the following alternative options and technologies for conducting the boundary and inclined ventilation shaft are justified (figure 1):

1) Performance of stripping works, building the frame of the boundary ventilation shaft, concreting the working and filling up it to the existing level of the earth's surface.

2) Construction of a boundary inclined ventilation shaft under the previously sealed working to the vertical shaft.

3) Construction of the boundary inclined ventilation shaft from the junction with the previously driven working at a distance of 8 m from the sealed part horizontally and 10 m vertically.

4) Construction of the boundary inclined ventilation shaft from the junction with the previously driven working at a distance of 8 m from the sealed part horizontally and 18 m vertically (below the level of seam 66).

The four options for choosing the location for the construction of the boundary ventilation shaft in seam 67 are shown in figure 1.

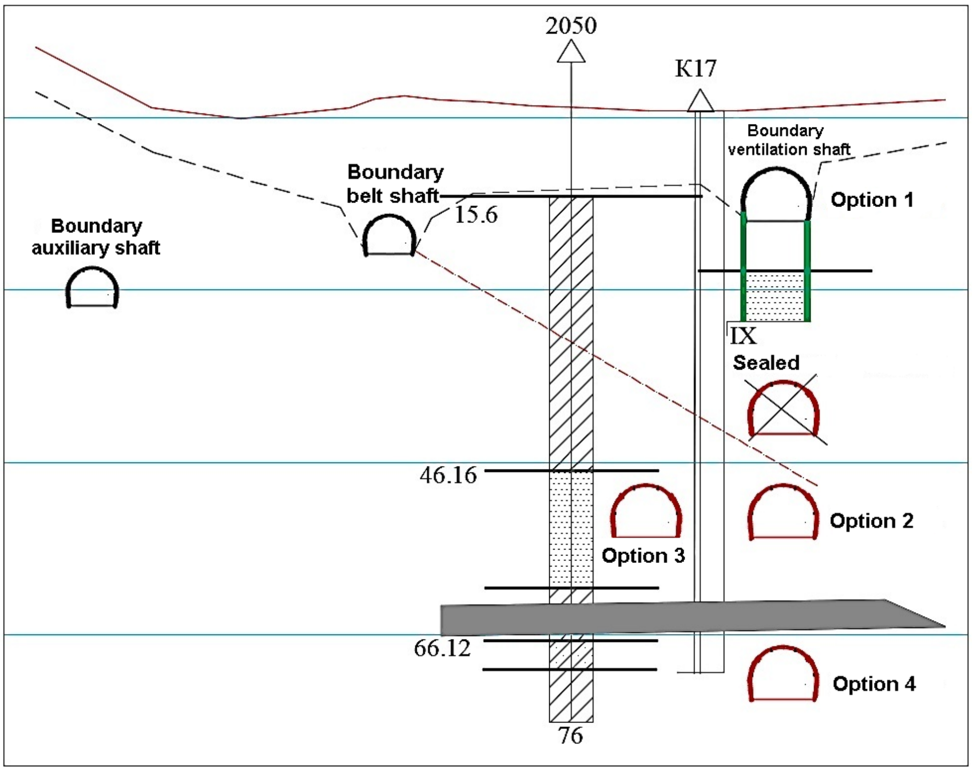

Figure 1. Spatial position of options for the boundary inclined ventilation shaft.

2. Methods of research

The calculation of the parameters of the stress-strain state (SSS) of the coal-bearing massif near the newly driven boundary inclined ventilation shaft is presented on the basis of numerical solution by the finite element method of differential equations of continuum mechanics using a package of computer programs [3-5].

For substantiating the shape and size of the zones of coal and rocks destruction near the ventilation shaft, the results of mine observations and laboratory studies of the properties of rocks and their deformation diagrams were used. The following sources of information were used as input parameters for the mathematical model:

- geological sections along the wells;
- the sizes of the zone of rock massif movement according to the forecast;
- the height of the dome of natural equilibrium and the load-bearing capacity of the frame support elements, calculation of the support setting parameters of permanent workings with frame and concrete support in accordance with the current instructions.

The following geometric model of the coal-bearing massif is adopted for modeling:

- the length of the vertical section along the axis of the ventilation shaft in seam 67 is assumed equal to 300 m;
- the mining depth of seam 67 in the area of ventilation drift construction in seam 67 is 62 m;
- the width of the opening workings of the ventilation, belt and auxiliary shafts was adopted taking into account the design recommendations and actual side rocks sloughing according to field observations 7.0-8.0 m;

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- the height of the workings is taken equal to the maximum extracted volume of the extracted rock mass – 5.0-5.5 m;
- the origin of coordinates on the vertical section is taken at the intersection of the roof in seam 67 (vertical axis of ordinates) and the left side of the previously driven and "sealed" section of the boundary ventilation shaft in seam 67 (horizontal axis of abscissas).

3. Results and discussion

According to the analysis of the results of rock displacements distribution in the vicinity of the ventilation shaft the nature of deformation and the vector directions of rock displacement did not change significantly in comparison with the displacements during performing mining operations under the previously driven working (figure 2).

The values of the displacement of roof rocks decreased by almost 15%, in the soil of the working the probability of swelling increased by 20%. Horizontal displacements in the soil of the working increased, which indicates an increased probability of destruction of rocks at the contact of the soil and the wall of the working, especially in the case of increased water inflow in rocks highly prone to soaking.

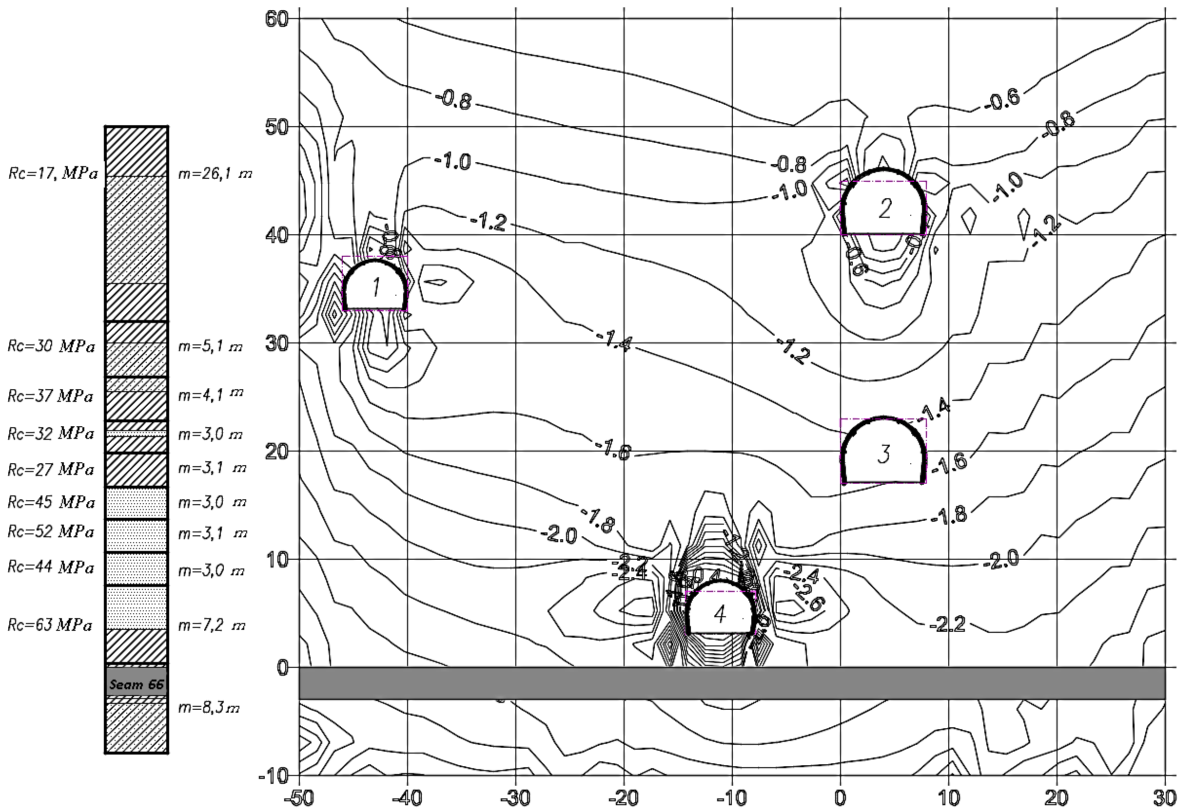

Figure 2. Isolines of vertical stress distribution (MPa) according to option 3 of boundary ventilation shaft placement with a maximum approach to seam 66.

It should be noted that when constructing the boundary ventilation shaft in the area with no contiguous previously driven working, the vertical stresses and the expected rock displacements of the roof and walls decreased significantly, on average by 25%.

The analysis of the simulation results of the options for placement of the boundary inclined ventilation shaft in relation to the previously driven workings of the technological site made it possible to draw conclusions about the advisability of adopting the third construction option.

It is necessary to take into account a number of factors to ensure the stability of the boundary inclined ventilation shaft during its construction and maintenance during the entire period of its operation.

First, it is the working support or to be more exact the stages of support setting. Obviously, when driving the boundary inclined ventilation shaft, the greatest stresses are observed in the places near the previously driven and sealed working. The stability of the wall rocks will be reduced, therefore at the stage of the boundary inclined ventilation shaft construction near the previously driven working, it is recommended to use back laths before installing the frame metal support in the right wall and roof of the working.

The *second* factor to ensure the stability of the opening working is the technology of conducting (selection of the cross-section during the driving and subsequent expansion). Simulation of different options for working driving shows a significant advantage of the working construction in two stages. Initial driving of a working of narrow cross-section with subsequent expansion to the design cross-section.

Driving the working with a narrow cross-section will reduce the probability of increased stresses on the part of the rock massif and ensure a reliable working support. Expansion of the output will be accompanied by a redistribution of the rock massif SSS and will significantly reduce the probability of soil heaving and deformation of support elements in the inclined ventilation shaft.

The revealed regularities in the isolines distribution of host rocks residual strength according to simulation results showed that when driving a working with a full cross-section, the zone of heaving rocks in the soil of the working will amount to 6 m^2 in the cross-section, that is, an active soil pressure up to 5-7 m^3 per running meter in the working should be expected. The destruction of rocks in the roof is expected at a height of more than 2 m, the greatest pressure is expected from the walls of the mine. To ensure the sustainability of the working, it is recommended to develop measures for the installation of back laths into the walls.

When driving the working with a partial cross-section, the SSS changes substantially in the vicinity of the ventilation shaft: the zone of the heaving rocks in the soil of the mine will be less than 1 m^3 of rock. Rock destruction in the roof is expected at a height up to 1.5 m, the greatest pressure is expected from the walls of the mine, which is significantly less than when driving a working with a wide cross-section. The most dangerous is the zone near the roof, in places of stress concentration. It should be noted that the choice of the domed shape of the working is correct, however, it is possible to recommend measures for the installation of back laths into the right walls of the working during driving immediately after extraction of the rock mass.

In connection with the expected large displacements and destruction of rocks in the walls of the mine, it is proposed to consider the option of a stage-by-stage mining operations. At the first stage, the working is driven with a narrow cross-section 16 m^2, at the second stage it extends to a design cross-section of 22 m^2.

In figure 3 and 4 the distribution graphs of residual rock strength isolines during driving the boundary inclined ventilation shaft in seam 67 with a full and narrow cross-section are given.

Reduction of the intensity of roof and soil rocks convergence by 30% significantly increases the stability of the working and reduces the risk of negative impact on the conditions of driving and maintenance of the boundary ventilation shaft of seam 67. The expected displacements during the driving of working with a small cross-section are compensated in full by the strength characteristics of the erected support.

From the comparison of isolines in figure 4 it follows that the vertical load by the action of the roof rocks is reduced by 30%. The rock heaving during the formation of the fracture zone in weak soil rocks with intensive water inflow in the spring period is recommended to be avoided by increasing the working cross-section due to active dinting of the working soil. The option of initial working arrangement of smaller cross-section, followed by the increase in height to the design cross-section by the method of dinting, will substantially increase the working stability during its maintenance.

Negative manifestations of increased watering of the field, intensive pressure of coal and rocks from the walls and roof of the mine, and rock heaving were the objective prerequisites for the development of a set of measures to monitor the condition of the support and surrounding rocks around the inclined workings.

To ensure the safety and effectiveness of mining operations, as well as reduce the risk of rock inrushes and collapses while driving inclined shafts, a comprehensive methodology for studying the state of the rock massif and the support elements has been developed.

The *methodology* considers the following provisions:

- visual inspection of the contour massif of mine workings;
- visual inspection of the condition of the roof support and the walls of workings;
- visual and instrumental survey of the roof rocks for the presence of rock lamination processes;
- instrumental control of the host rocks convergence in the vicinity of mine workings;
- observation over the movement of rocks and the earth surface;
- physical modeling on equivalent materials;
- numerical finite element modeling (FEM).

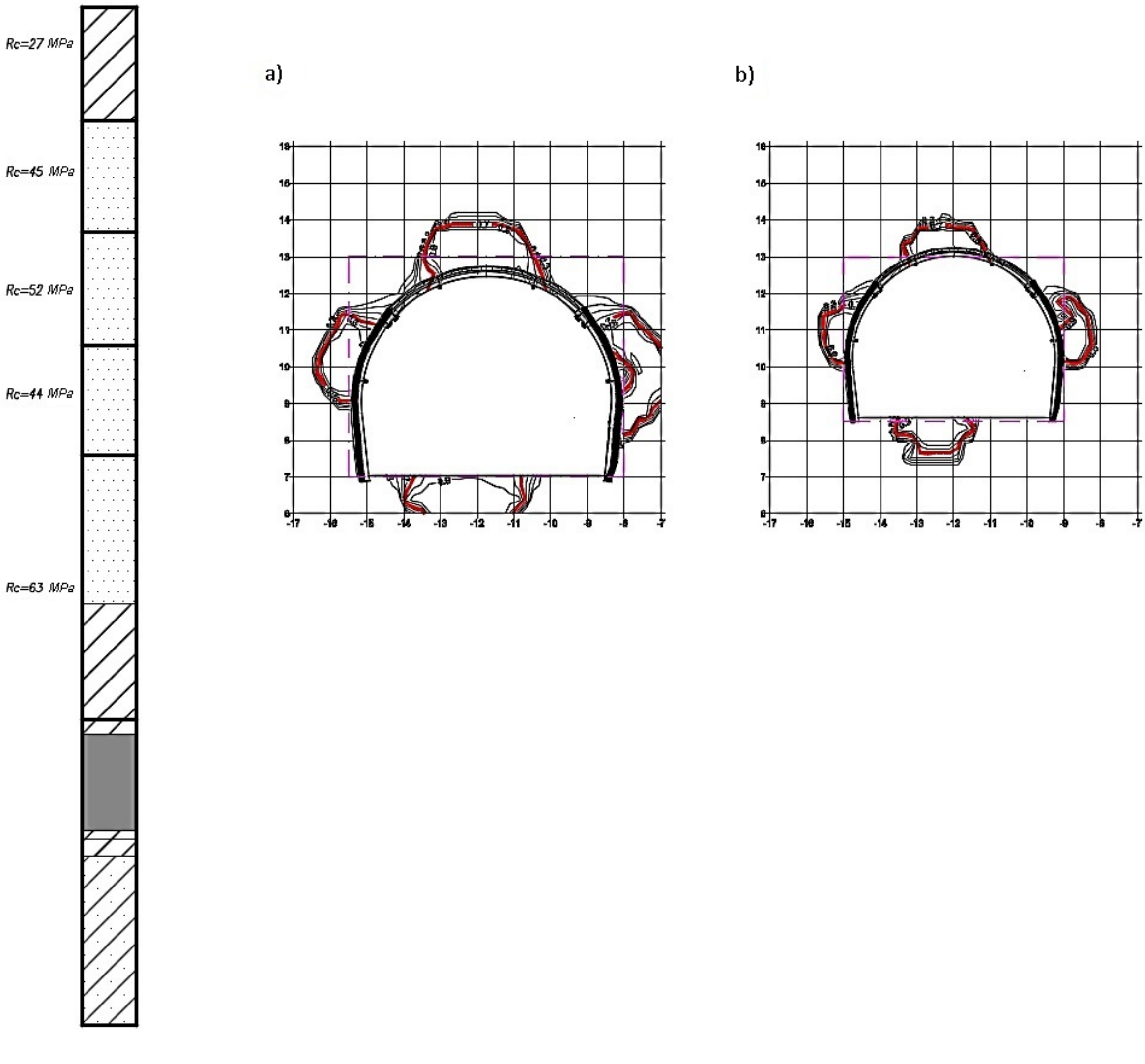

Figure 3. The distribution isolines of the ratio of residual rock strength to the initial one when driving the boundary inclined ventilation shaft with a full cross-section (a) and narrow cross-section (b).

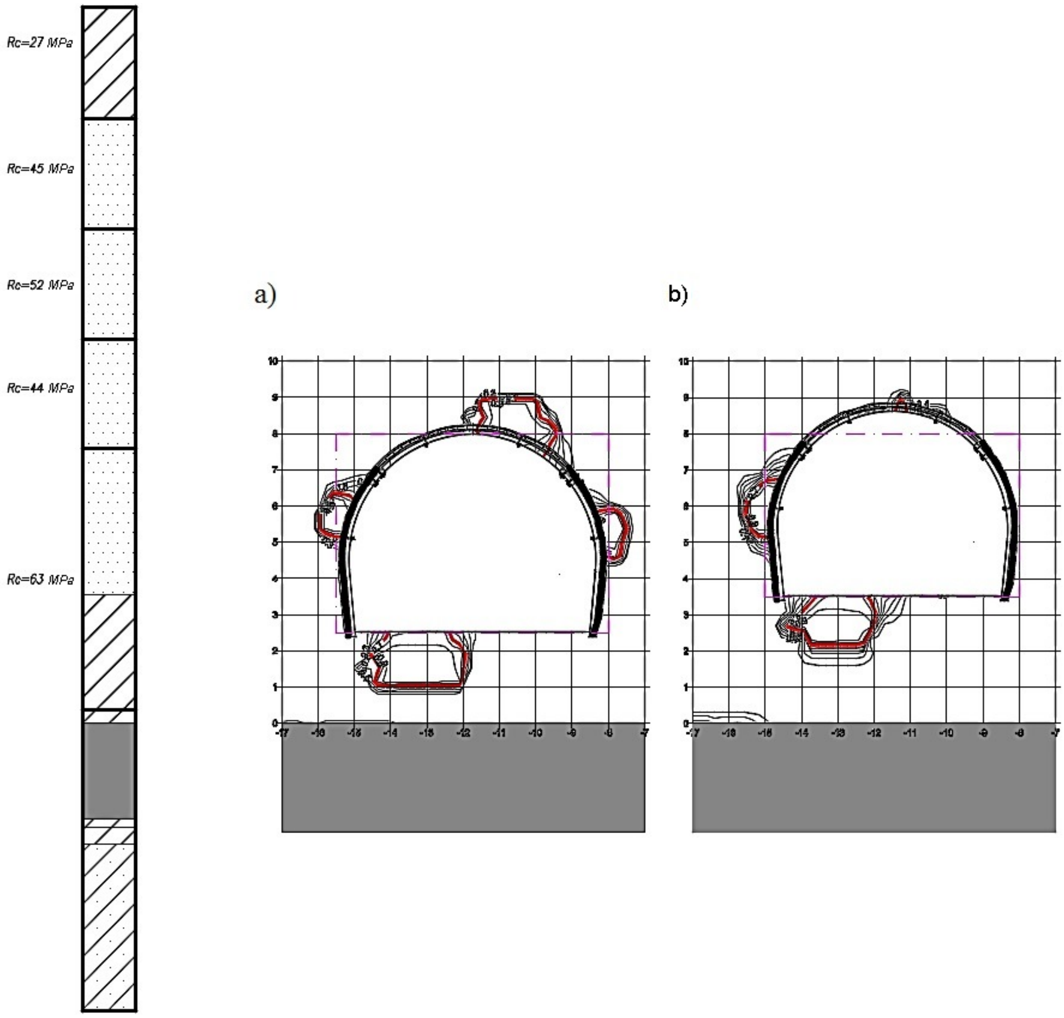

Figure 4. The distribution isolines of the ratio of the residual rock strength to the initial one during driving the boundary inclined ventilation shaft in the area maximally close to seam 66; a) with a full cross-section; b) with a narrow cross-section.

4. Conclusions

Thus, the developed technological solutions for choosing the location of the inclined shaft and the technology of its step-by-step driving and supporting with the use of observations over the condition of the support and the surrounding rocks in the maintained working allowed the costs for the working support while driving to be significantly reduced. The monitoring of the state of the opening inclined working carried out over the period of two years showed a satisfactory condition and the absence of the necessity for any additional repair works in the working.

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