Numerical study of the effect of console length of the main roof hanging on the geomechanical parameters of the mine face

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Numerical study of the effect of console length of the main roof hanging on the geomechanical parameters of the mine face

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Abstract. This article presents the results of scientific research aimed at establishing the effect of console length of the main roof hanging above the gob on geomechanical parameters in the vicinity of the mining face. According to the results of numerical modeling of the stress-strain state of the rock massif, the nature of the distribution of vertical displacements and stresses in the vicinity of the face was established with a consistent increase in the console length of the hanging main roof, the dynamic loads on the roof support sections, the hydraulic props settlement, the inrush area of roof rocks and the coal sloughing from the seam surface in the face. The results of the conducted research allow the preventive measures to be developed, the implementation of which will ensure the stable and safe operation of the working faces during underground coal mining in difficult mining and geological conditions.

1. Introduction

The extraction area of a modern coal mine includes a complex of expensive high-performance equipment. To select such equipment at the stage of development of project documentation, it is necessary to take into account a variety of geological, mining and technical factors. One of these factors is the type of roof [1-3], which determines the step length of the periodic collapse of rock slabs, the load on the powered support unit and the parameters of the reference rock pressure in the mined coal seam. With a depth of development up to 300 m and a working resistance of the support sections 6000-8000 kN, the influence of the frequency of hanging and collapse of the roof was secondary. With the increase in the depth of development to 600-700 and a working resistance of the support sections of 10000 kN, there were problems in controlling the powered roof support and the roof, as evidenced by the “dry” installation of the support sections, the necessity of the coal-cutting with stone, roof rock inrushes, destruction of the edge part of the seam to a depth of the more extracted seam thickness. These facts lead to the need for unscheduled stoppings of faces for special arrangements to be done, as a result, there is a decrease in coal production.

The nature of the rock collapse of the active roof into the gob has been repeatedly studied by many authors on the basis of hypotheses, the results of analytical, numerical and field studies [1-8, etc.].

In article [9], according to the results of continuous automated monitoring of the convergence of the seam roof and the soil using sensors installed in support props, the distribution pattern of precursors of rock bursts based on the dynamics of the support sections convergence was revealed. The novelty of the pattern is the underworked roof rocks collapse not along the entire length of the face, but in wave like manner. The high pressure areas in the hydraulic props move along the length of the face successively along the positive and negative dip of the seam. However, the 10-30 sections closest to the face and drifts are always loaded more than the sections in the middle part of the face. The revealed regularity of the collapse of the roof rocks in a wave along the length of the lava, apparently, manifests itself in long lavas. In short lavas, there is a massive collapse of rocks over the entire area of the excavated space, with the hanging of rock slabs in the marginal areas of the lava.

The wave-like nature of the roof rocks collapse along the length of the face and along the length of the extraction panel was proved in the works of A.A. Borisov [10]. The wave character of the roof collapse is confirmed by the results of seismic monitoring (GITS) of the state of the rock massis within the mining allotment of the mine “Osinnikovskaya” [11].

The dynamics of the distribution of seismic events in time and space of the working area confirms the presence of waves and the frequency of loading and unloading of the seam edge sections. The recorded seismic tremors are positioned not only in the development works in the working area, but also within the previously worked out extraction column, which indicates the intensification of the process of shifting the underworked rocks to the adjacent working areas.

In this regard, studies of the effect of the console length of the main roof hanging on the geomechanical parameters of the mine face are relevant to the development of preventive measures, the implementation of which will ensure the stable and safe operation of the mine faces in difficult geological conditions.

2. Methods of research

The mathematical model for studying the deformation of the rock massif in the zone of face influence was formulated as a boundary problem of the elasticity theory by boundary conditions of the second type. The numerical modeling was carried out by the finite element method using the author’s complex of programs [12, 13]. The discretization scheme of the rock massif model into finite elements is presented in figure 1.

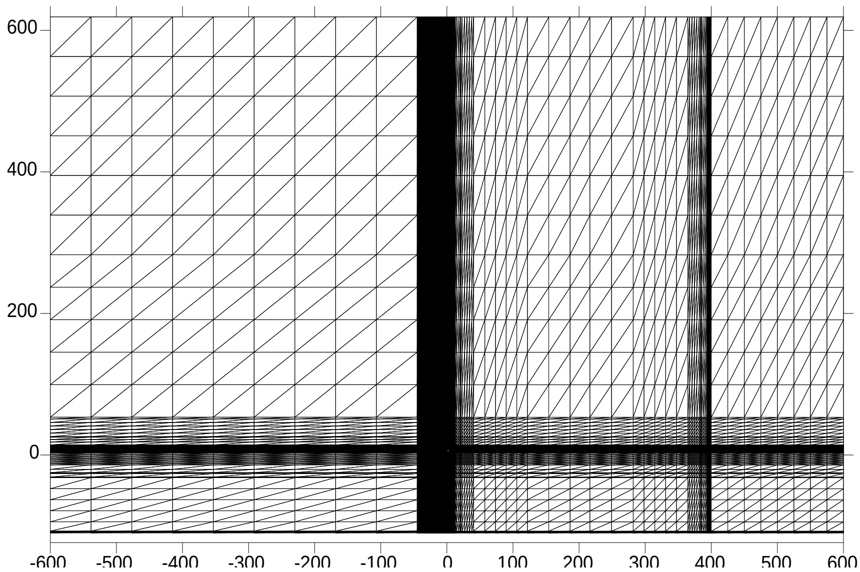

Figure 1. The discrete model of rock massif along the vertical section of the axis of the extraction panel 4-1-5-6 in E-5 seam.

To study the effect of the active roof collapse and the console length of its hanging on the parameters of rock pressure in the vicinity of the face, a vertical section along the axis of the extraction panel 4-1-5-6 in E-5 seam of the mine “Osinnikovskaya” in Kuzbass was considered. The section height is assumed to be 619 m from the roof of E-5 seam; the overworking zone below the seam is 120 m thick.

The total height of the model is 739 m. The length of the model along the strike of the seam is 1200 m. The basic initial values of the models for the options are presented in the table. Mining and geological parameters of the coal seam and enclosing rocks are taken in accordance with the sections of exploration wells. The console length of the active roof hanging varied from 0 to 25 m at 5 m intervals. The abscissa (horizontal axis in figure 1) of the seam edge in the development face in all options changed according to the position of the face from X=0 to -25 m at 5 m intervals. The position of the mounting chamber corresponds to the abscissa X = 400 m. The underworked roof rocks between the mounting chamber and the collapse boundary of the previous active roof slab are taken as destroyed. The boundaries and angles of the collapse line of the underworked roof rocks were taken in accordance with the Rules of Protection [14].

On the model, the roof of E-5 seam is located on the vertical axis with a mark of 0 m, the face on the horizontal axis at the abscissa mark X = 0 m, and the mounting chamber on the abscissa X = 400 m. The initial data and the obtained geomechanical parameters are presented in table 1.

Table 1. Baseline data and simulation results of the stress-strain state of the massif rocks with different console lengths for the active roof hanging over the gob.

Parameter	Numbers of options of rock console length					
	6	7	8	9	10	11
Rock console length L_c, m	0	5	10	15	20	25
The width of the pre-destruction zone of the coal seam ahead of fully-mechanized longwall (FML)	3.8	4.8	5.2	5.4	5.5	5.5
Depth of the pre-destruction zone of soil rocks under the conveyor, m	0.1	0.2	0.4	0.5	0.5	0.5
Area of roof rocks inrush in the FML, m^2	0.2	0.4	0.5	0.6	1.0	1.2
Convergence of the roof and soil of the seam along the face line, mm	110	125	150	160	160	160
Convergence of the roof and soil of the seam along the axis of the hydraulic prop, mm	170	210	220	230	240	250
Minimum fluid pressure in hydraulic system of FML, MPa	29	34	36	37	39	40
The concentration ratio of vertical stresses in the edge part of the seam	3.0	3.1	3.2	3.4	3.6	3.8
The width of the zone of intensive methane release in the edge part of the seam, m	1.8	1.2	1.0	1.0	1.0	1.1
Load on the mechanized roof support, kN	7290	8551	9054	9305	9808	10060

3. Results and discussion

The ratio of the residual strength of coal and rocks to the original one is most representative for assessing the stability of the edge part of the coal seam and roof rocks in the vicinity of the face. Figure 2 contains the comparison of the graphs of the residual and initial strength ratio of coal and rock with a console length of 0 m (figure 2 a) and 25 m (figure 2 b). According to the nature of the distribution of coal and rocks residual strength to the original one and table data, with the increase in the console length of the roof rocks hanging behind the sections of the powered support from 0 to 25 m the area of destruction of the edge part of the seam increases by 1.8 times, cracks and blocks occur in the roof rocks and soil.

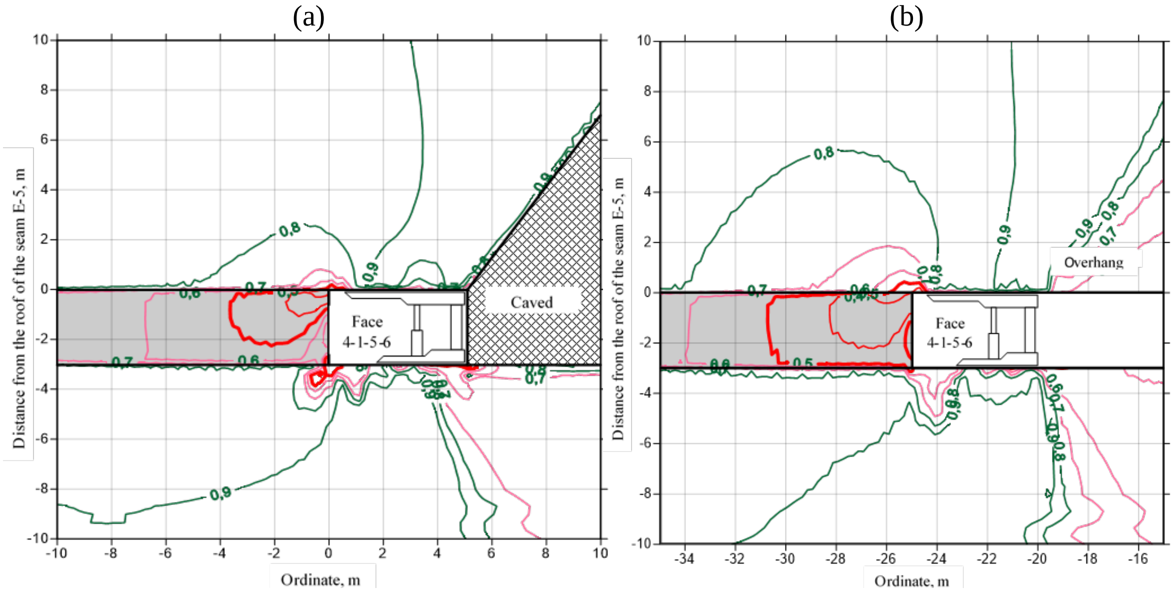

Figure 2. The ratio of residual strength of coal and rocks to the original one with the console length of the main roof hanging: a) 0 m; b) 25 m.

The magnitudes of the vertical displacements (figure 3) increases significantly with the increase in the console length of the roof rocks hanging. The incline of the roof rocks in the direction of the gob and the hydraulic props settlement increase 1.4 times.

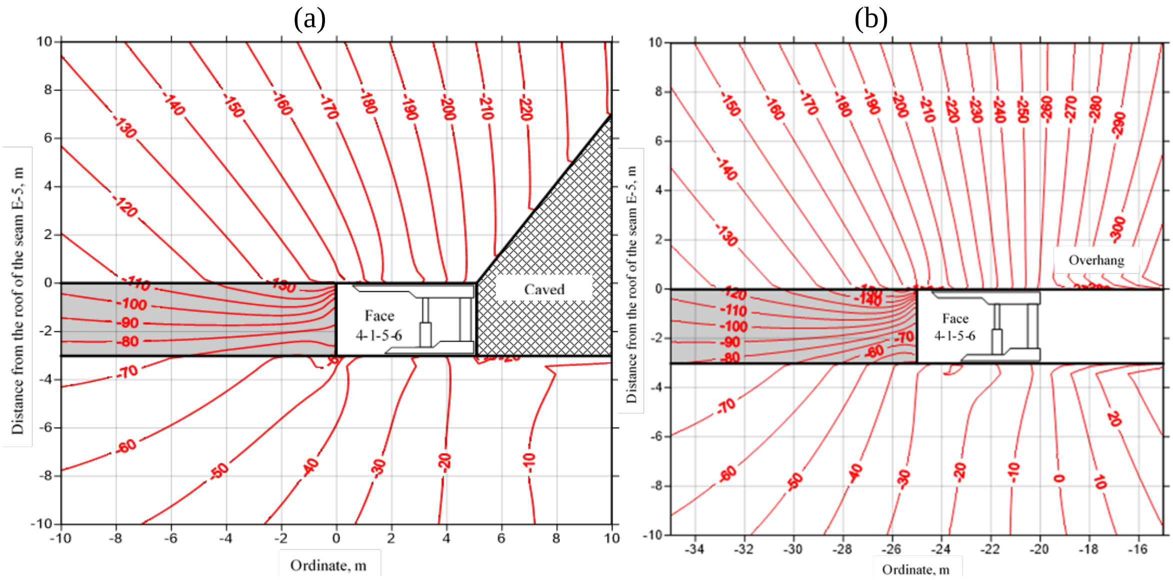

Figure 3. Vertical displacements (mm) of the coal seam and enclosing rocks in the vicinity of the face with the console length of the main roof hanging: a) 0 m; b) 25 m.

The console length of the roof rocks hanging significantly affects the pressure on the section of the powered support. Figure 4 shows the isolines of the concentration distribution ratio of the vertical

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stresses in the rock massif in the vicinity of the face. When changing the console length from 0 to 25 m, the concentration ratio increases by 1.25 times, and the pressure on the support sections by 1.38 times.

(a) (b)

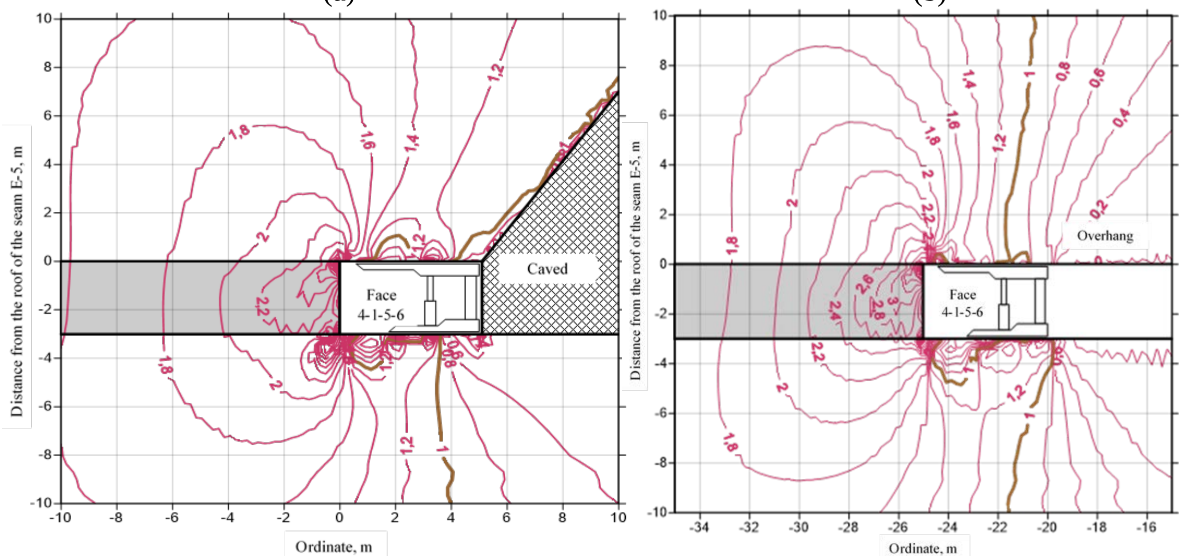

Figure 4. The concentration ratio of vertical stresses in the vicinity of the face at the console length of the main roof hanging: a) 0 m; b) 25 m.

Figure 5 shows the graphs reflecting the dynamics of geomechanical parameters in the vicinity of the face, with a consistent increase in the console length of the main roof hanging behind the sections of powered support. It follows from the graphs that the most intensively the convergence of the roof and the seam soil increases in the initial period of console formation in the range from 0 to 5 m (figure 5a). Accordingly, the area of rocks destruction of the immediate roof also increases intensively during this period (figure 5b). It is explained by the fact that when the console length is small, the deformation of the rocks occurs mainly in the vicinity of the face. As the console length increases, its weight is transferred to the coal seam, coal pre-destruction occurs in the edge part, the support area increases when the roof rocks are jammed as a beam above the coal seam and the destruction intensity of the immediate roof rocks decreases.

(a) (b)

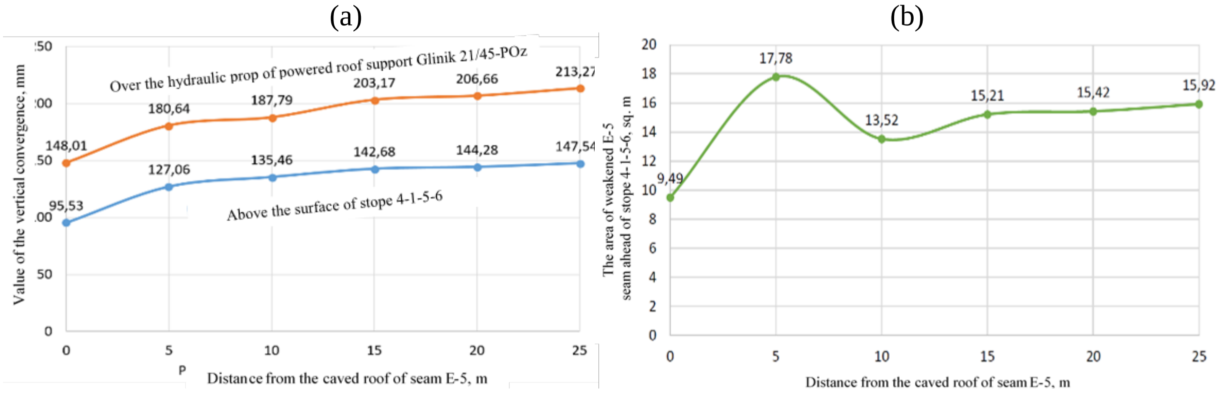

Figure 5. Graphs of changes in the geomechanical parameters in the vicinity of face: a) the convergence of the roof and soil of the seam, mm; b) the area of the destroyed roof in the vertical section of the face, m^2.

4. Conclusions

According to the results of numerical simulation, it was established that an increase in the console length of the roof rocks hanging behind the support sections within 0-25 m leads to the following changes in geomechanical parameters:

- the width of the coal pre-destruction zone in front of the face increases by 1.4 times;
- the area of the roof rocks inrush in the face increases by 6 times;
- the convergence of roof rocks and bottom along the axis of hydro-props increases by 1.5 times;
- coefficient of concentration of vertical stress in the edge part of the seam increases by 1.25 times;
- the width of the zone of intensive methane release in the edge part of the seam is reduced by 1.6 times.

Acknowledgments
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