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Deflected mode of marginal rock massif around mine working boundaries depending on anchoring parameters

V F Demin[1], O B Fofanov[2], T V Demina[2] and V V Yavorskiy[3]

[1] Karaganda State Technical University, 56, Mira bul., Karaganda, 100027, Kazakhstan
[2] Tomsk Polytechnic University, 30, Lenina ave., Tomsk, 634050, Russia
[3] Karaganda State Industrial University, 30, Republic ave., Temirtau, 101400, Kazakhstan

E-mail: yavorskiy-v-v@mail.ru

Abstract. The deflected mode, rock pressure manifestations, conditions of maintenance of mine workings depending on geological and technological parameters have been studied. Researches have allowed establishing the degree of these parameters impact on the effectiveness of anchoring of mine workings. The paper researches such aspects of the problem as rock pressures, terms of maintenance of mine workings, technological parameters and others. The authors consider the expediency of the introduction of anchor certificates which will allow for stability of the rock mining and a reduction of the expenses on realization and maintenance of mine workings.

1. Introduction

The maintenance and the increase of the volumes of underground coal mining are possible only at the presence of highly efficient technology of realization and maintenance of development workings, which provide an increase of the volume of mining and preparatory work. The aim of the research is the creation of technology of intensive and safe mining based on identified patterns of behavior of adjacent rocks, optimization of the parameters of flow charts of preparatory work, providing the increase in the functioning efficiency of underground mining practice [1-7].

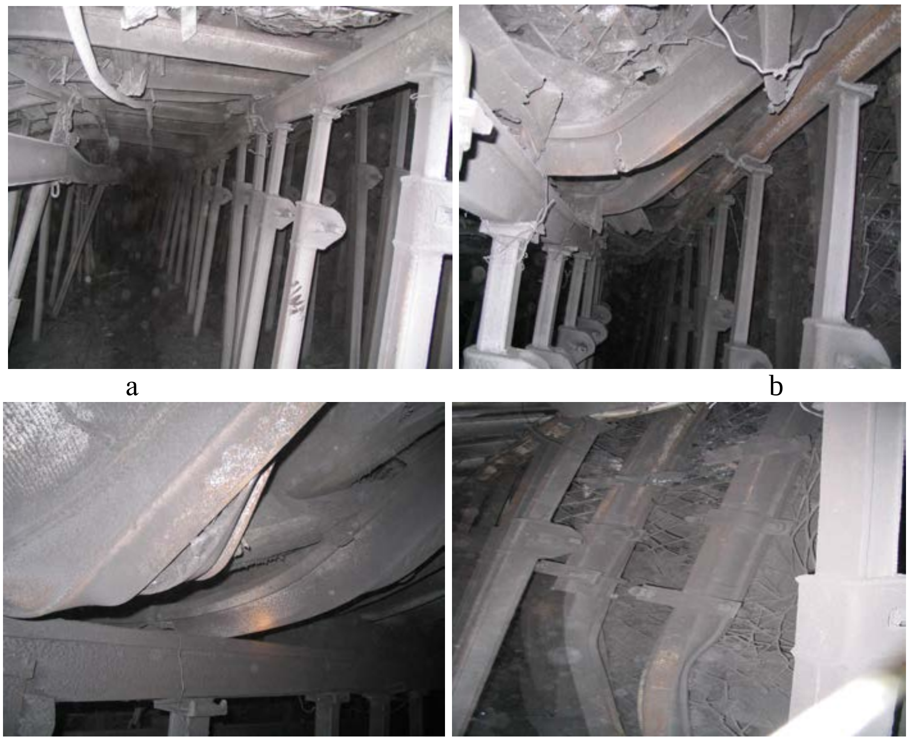
2. Ensuring the stability of mine workings

When operating mines with the increasing depth of mine working, one of the problems demanding solution is ensuring the stability of mine workings. To maintain the mine workings in the mines of Karaganda coal basin, metal yielding supports (MYS) of the arch type and the anchoring technology in the limited volume (in a pure form up to 22 %) are applied. The expenditures on realization and anchoring of 1 m of mine working amount to 13-18 thousand rubles, the consumption of the metal-roll is 0.3-1.0 t. At that, the maintenance cost is not less than 10-15 % of the mining costs. With the approved systems of mine working, it is required to perform 5.0 to 5.5 km of mine workings per 1 million tons of coal, which requires considerable expenses for the preparation of excavation sites.

In-seam workings are most subjected to the influence of the rock pressure. The loss of their cross-sectional area reaches up to 60-70 %. This leads to the fact that 20% of mine workings are annually repaired and retimbered. The share of the expenses on carrying out, anchoring and maintenance of mine workings reaches up to 15-20 % of the coal production cost. More than 10 % of the underground workers are engaged in repair of mine workings.

The conditions of maintaining the mine workings with different types of anchoring in the zone of influence of the stope were studied by the example of intermediate belt entry 49k_{10}-z of lava in the mine named after Kostenko, Karaganda coal basin. The working-bed height of a k_{10} stratum in the West wing of the mine is 3.7 m to 4.0 m. The immediate roof varies along the strike from 3 m to 7 m and is represented by mudstone. The main roof is composed of loosely crumbling sandstones with a thickness of 24-32 m. The maximum value of blowing of soil rocks after two years of maintenance of mine working amounted to 0.35-0.8 m. To ensure the necessary cross-section ahead of the lava at a distance of 50-80 m, the ripping of the soil rocks of the entry was carried to a depth of 0.5 m to 0.8 m.

Figure 1 shows the status of the studied mine working in the area influenced by the stope. The most favorable conditions of the maintenance were provided in the area of intermediate belt entry 49k_{10}-z with a length of 50 m of a semi-arched form, anchored by the composite support (anchors in combination with the MYS) with a density of 1.33 frame/RM. m (figure 1 a).



a b

c d

a – composite support; b – deformation of the roof bar;
c – impulse of the roof bar; d – deformation of the props

Figure 1. The condition of intermediate belt entry 49$_{K10}$-z of the mine named after Kostenko of Karaganda coal basin in the zone of influence of stopes.

For this area of mine working, the following changes of deformations in the support condition are typical: for the roof bar and its impulse (figure 1 b, c) along the borders of summers – 60 %; for the composite props (figure 1 d) in a vertical plane – 1.5 %; the deviation of friction props from the vertical position, preliminary along the first summer from the stope – 70 %.

3. The impact of stope

In this regard, the study of features of deformation of the rock massif around development workings with anchoring at various incidence angles of the stratum and depth of anchorage, justification of the installation of the anchor support and the definition of the rational sphere of its use are an important task of the mining industry.

In the course of studies, the authors determined the deflected mode (DM) around the mine working: of the roof, soil and sides; the strain rate, the area of delamination (cracking); stresses (compressive, tensile and shear), shifting of the service life (in progress). Relatively favorable, average and difficult conditions of mine workings have been considered.

To determine the conditional zones of inelastic deformations, the program, which allows determining the deflected mode in the considered point of the technogeneous space, and then setting the durability of an object (the time to failure) and evaluating the stability of bed outcrops for subsequent adoption of technological measures. For the geomechanical interpretation of the modeling results, belt entry 64_{K10}-z with the 16.2 m^2 cross-section of stratum K_{10} of the mine 'Abaiskaya' in Karaganda coal basin, traversed at a depth of 630-640 m (figure 2).

In the present research, the analytical modeling is performed using the numerical finite element method. The simulation is performed for the conditions of the strata conveyor working of stratum K_{10} of the mine 'Abaiskaya' in Karaganda coal basin at a mine working depth of 400 m and a bed thickness of 3.8 m. The deflected mode of the massif around the current mining working is considered. The problem is reduced to the flat working. The solution is carried out in the elastic formulation due to the relatively short time of deformation of rocks in the area of the development face during its development. In contrast to the known approaches, the sizes of the zones of deformation propagation with the analysis of their parameters are specified.

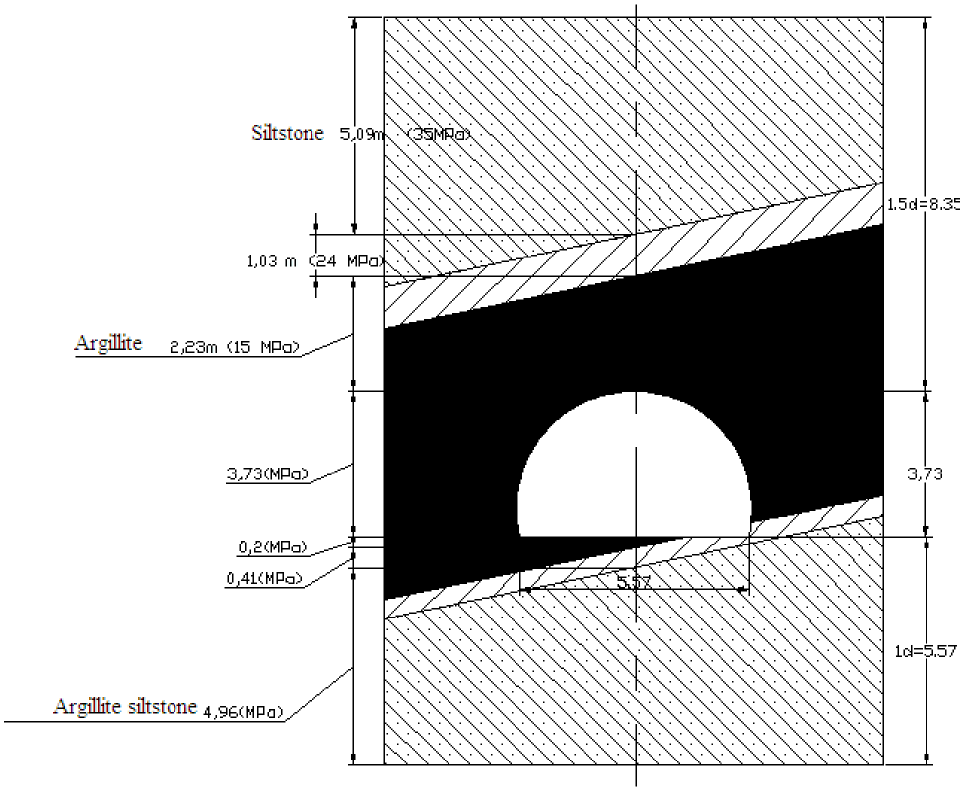


Figure 2. The section structure of host rocks according to belt entry 21_{K12}-s from the mine 'Abaiskaya' in Karaganda coal basin.

The study produced mathematical models using ANSYS software allowing us to determine the influence of geological factors on the operating conditions of the powered roof support of mine workings.

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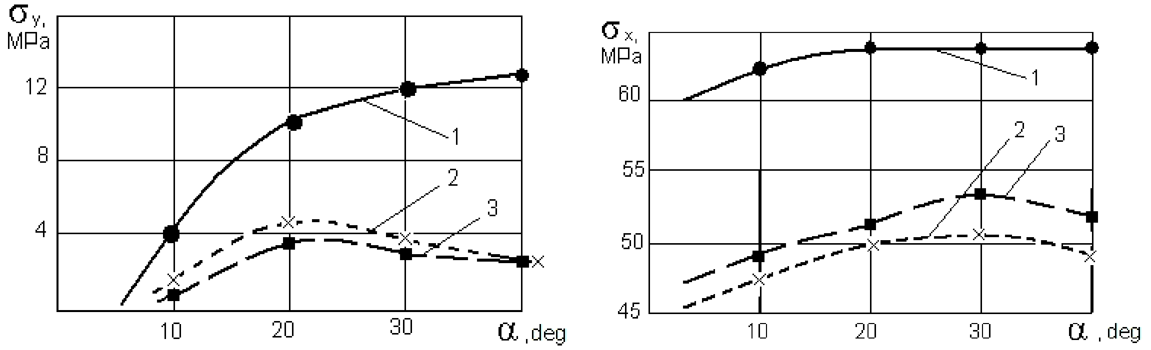
The ANSYS model was built to the massif of enclosing rocks, corresponding to the conditions of occurrence of stratum K_{10}.

At the first stage, we studied the influence of the shape of the cross section of the mine working and the incidence angle of the coal seam on the value of the occurring maximum stresses in the rock massif when mounting the working with the anchor support.

In case of a vaulted (arched) shape of the cross section of extraction production, normal stresses (σ_y) grow with the increase of the incidence angle (α) of the stratum from 10° to 40° according to the exponential function in the range from 10 to 13.5 MPa (figure 3 a). Longitudinal stresses (σ_x) are increased at angle α from 10° to 20° in the range of 63.2 to 64.1 MPa, and then the influence of the incidence angle is not seen (figure 3 b). Shear stresses (τ_{xy}) decrease from 50 to 33 MPa proportionally in the range of incidence angles $\alpha = 10^\circ - 30^\circ$ of the stratum, and at $\alpha = 30^\circ - 40^\circ$ – increase from 33 to 37 MPa (figure 3 c).

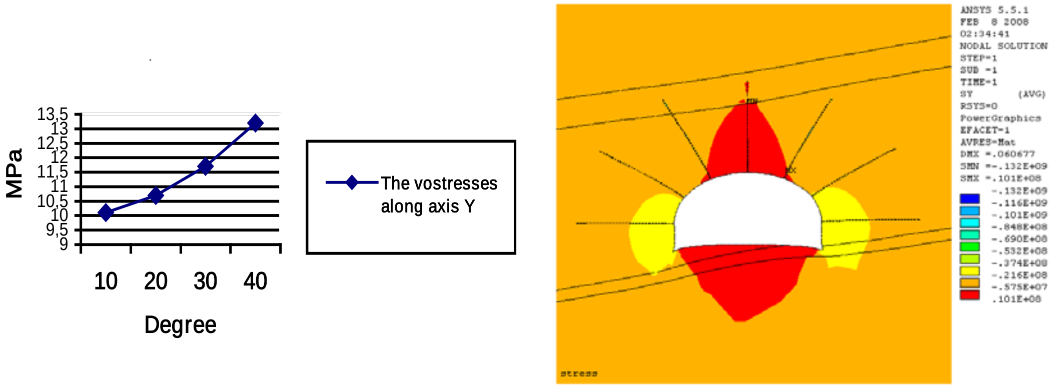


a b

1 – arched; 2 – polygonal; 3 – rectangular

Figure 3. The influence of the type of the cross-sectional shape and the incidence angle of the stratum on the value of the maximum normal (a) and longitudinal (b) stresses in the rock massif in case of anchoring of mine workings.

Moreover, large stresses occur along the coal seam rise. The distribution of stresses in the zones of country wall rocks surrounding the mine working is presented in figures 4 a and 4 b.

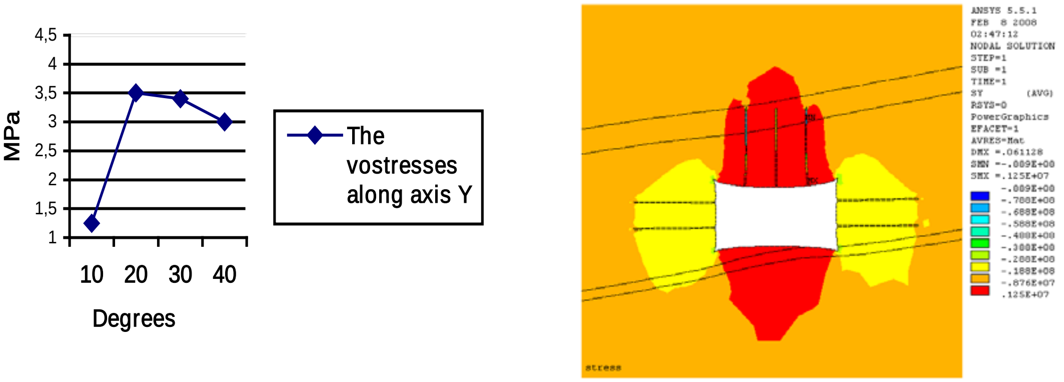


a b

a and b – the nature of changes and the plot (when $\alpha = 10^\circ$) of maximum normal stresses

Figure 4. The change and distribution of the maximum stresses in the zones surrounding mine working.

For a rectangular shape of the cross-section of excavation mine working, maximum normal stresses σ_y grow at $\alpha = 10^\circ - 20^\circ$ from 1.2 to 3.5 MPa, and then slightly decrease when $\alpha = 20^\circ - 40^\circ$ from 3.5 to 3.0 MPa. Longitudinal stresses (σ_x) increase from 49 to 53.4 MPa when $\alpha = 10^\circ - 30^\circ$, and then sharply decrease to 52 MPa during angle shifting $\alpha = 40^\circ$. Shear stresses (τ_{xy}) grow according to the mild exponential function from 18 to 38 MPa at angle change $\alpha = 10^\circ - 40^\circ$. Stress values in the areas surrounding the mine working, are presented in figures 5 a, b.

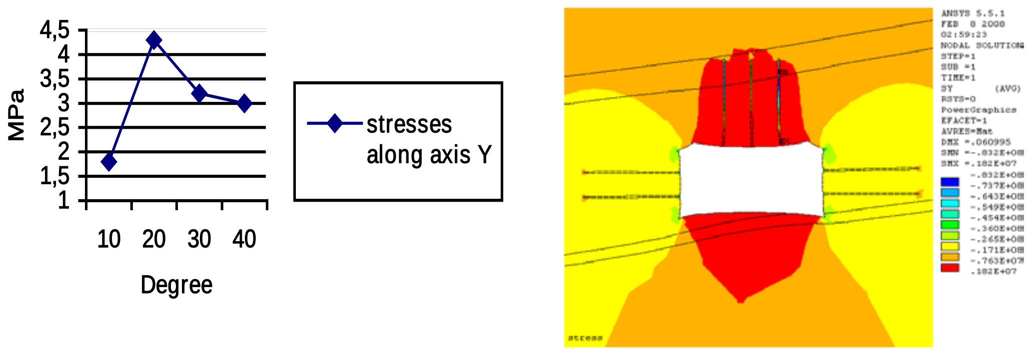


a b

a and b – the nature of changes and the plot (when $\alpha = 10^\circ$) of maximum normal stress

Figure 5. The maximum stresses in the areas surrounding the mine working of a rectangular cross-sectional shape.

In case of a polygonal shape of the cross section of mine working, the trends of the change in the deflected mode roughly resemble the nature of the change of dependencies in case of a rectangular shape of the cross-section mine working. There are stresses σ_y that are 1.5 times greater in magnitude, and, on the contrary, stresses σ_x that are less by 2-3 MPa, and τ_{xy} that are 1.5 – 2.0 times greater. Change and distribution of stresses in the areas surrounding the mine working are presented in figures 6 a and 6 b.



a b

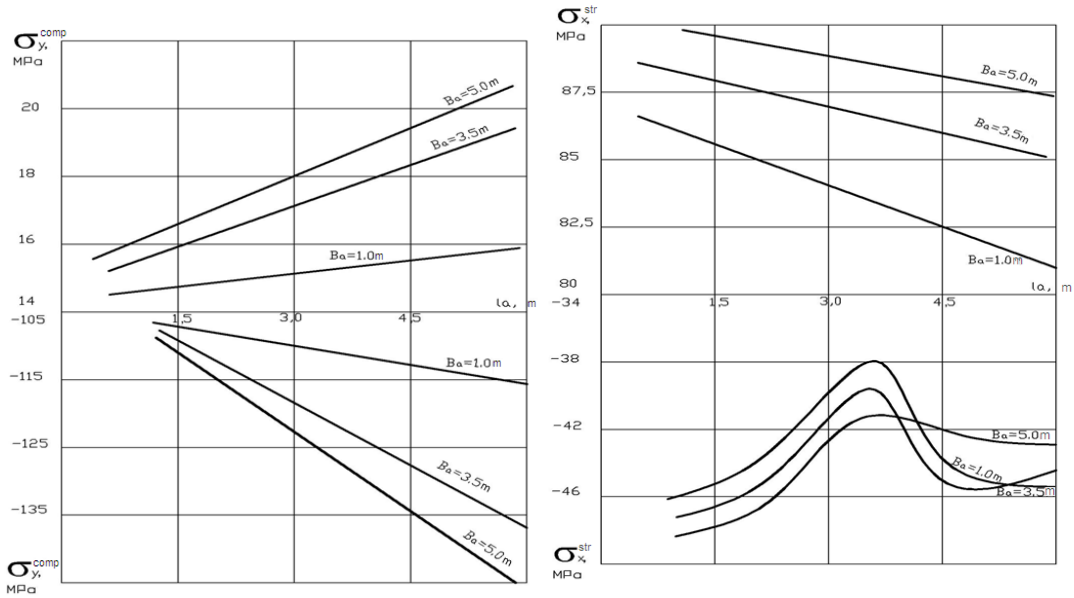
a and b – the nature of changes and the plot (when $\alpha = 10^\circ$) of maximum normal stress

Figure 6. The change and distribution of the maximum stresses in the areas surrounding the mine working.

The conducted research allows making a conclusion on the preference of applying a rectangular shape of the cross-section of excavation workings with the anchoring of country rocks for conditions of stratum K_{10} exploitation of the mine 'Abaiskaya', MD JSC 'ArcelorMittal Temirtau' [8-10].

The deflection mode of country rocks depending on the layer thickness of free caving rocks in case of different lengths of anchoring is studied. The studies were performed by the example of the mine working of the trapezoidal cross-sectional shape with following parameters of the design diagram: the incidence angle of the stratum is 15°, the stratum thickness is 3.8 m; the dredging depth is 400 m; the cross section of the mine working is 15.5 m^2; the anchor diameter is 0.022 m.

The nature of change and distribution of stresses in the roof, soil and sides of the mine working. When the value of the layer of free caving rocks is from 1.03 m to 6.0 m and the length of the anchor is from 2.4 m to 5.0 m, the following changes of stresses around the mine working take place. The maximum and minimum normal stresses grow in a proportional linear dependence in case of the increase of the anchor length (from 1.5 to 6 m) and of the layer thickness of free caving rocks, for example, composed of claystone, (from 1 to 6 m) (figure 7 a). The changes of stresses in the considered range in the longitudinal plane with the increase of the anchor length and the thickness growth of the free caving rocks layer have the following tendencies: stretching stresses are reduced, and compressive ones have a skip when the anchor length is 3.0 – 3.5 m and are generally in the narrow range (42-48 MPa) – figure 7 b.

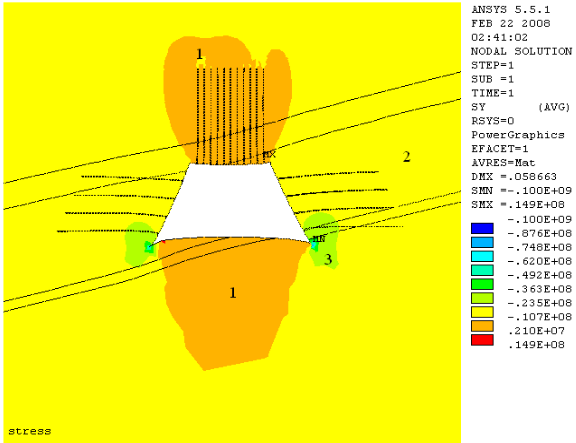


a b

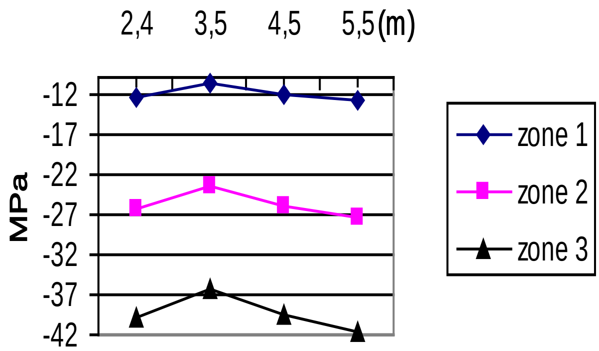
Figure 7. The change of the normal and lateral stresses in the marginal rocks of the development working, depending on the anchoring length and the layer thickness of the failed rocks.

The patterns of the tangential stresses change are presented in figure 5. They tend to rise when the mudstone layer thickness is 5 m and the claystone layer thickness is 1.0 to 3.5 m. They increase when the anchor length changes from 1.5 to 3.0 (3.5) m, and then decrease. At that, the increase in the diameter of blast holes (up to 0.05 m) has a negative impact on emerging stresses and leads to their twofold growth over the entire range.

The conducted research of the deflected mode of country rocks depending on the layer thickness of free caving rocks when the anchoring length varies allowed us to establish the following behavior of the lateral rocks by zones of their location (figure 8 a, b).



a



b

Claystone layer is 1 m, anchor length is *l*=3.5 m

Figure 8. The distribution plot (a) and dependence of the change of normal stresses (b) in country rocks on the depth of their anchoring.

4. Conclusion

Analysis of stress distribution shows that the areas of unstable rocks appear around the mine working. To a greater extent, this applies to the roof and soil of mine working, as well as its sides in the lower part of the lateral sides of the mine working boundaries. The maximum value of the normal stresses occurs in the anchor located on the roof of the mine working in the rightmost anchor in a place of its anchoring. The maximum value of the longitudinal stress arises in the anchor located on the right lateral surface of the mine working (the first one from the bottom).

The established regularities of the change of the deflected mode of the coal in rock massifs (displacements, stresses, zones of cracking), depending on the basic geological and mining factors, will allow establishing the optimal parameters of the anchoring in order to increase the stability of development mine workings under specific conditions, which will allow one to develop new and improve the existing technologies of the efficient and safe anchoring of the marginal rocks, when conducting mine workings on steep and inclined coal seams, which will be adaptive to changing geological and mining conditions.

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