DOI: 10.31643/2023/6445.21

Anchor bolt of rock massif in coal mines to decrease soil rock heaving of the workings

Demin V.F., *Zhurov V.V.

Non-profit joint-stock company «Abylkas Saginov Karaganda Technical University», Karaganda, Kazakhstan

** Corresponding author email: zhurvitv@yandex.ru*

Received: *April 18, 2022*
Peer-reviewed: *July 4, 2022*
Accepted: *October 10, 2022*

ABSTRACT

During the maintenance of workings, the effects of soil rock heaving, caused by plastic deformation and extrusion into the excavation cavity under the action of the rock pressure, are usually eliminated. The identified patterns of change in the stress-strain state of coal-rock massifs (displacements, stresses, cracking zones), depending on the main mining-geological and mining-technical factors will allow to establish the optimal parameters of soil anchoring, technological schemes for decreasing soil rock heaving of mine workings to increase the stability of preparatory mine workings have been developed. The development and improvement of existing technologies of effective and safe stiffening of near-soil rocks at conducting mine workings on flat and inclined coal seams were substantiated. The modelling of the SSS shows that both side-rock and ground deformations are predominantly influenced by side anchorage which results in reduction of the effective deformations in the rocks surrounding the working and in a decrease of gas release from the coal massif. It is established that the deformations and stresses both side and in-soil rocks in the excavation are influenced by side anchors rather than near-soil ones.

Keywords: mine workings, study of deformation processes, anchor parameters, geomechanical processes, anchor bolt, manifestations of rock pressure.

Information about authors:

Demin Vladimir Fedorovich — *Doctor of Technical Sciences, Professor, Non-profit joint-stock company «Abylkas Saginov Karaganda Technical University», Karaganda, Kazakhstan. E-mail: vladfdemin@mail.ru*

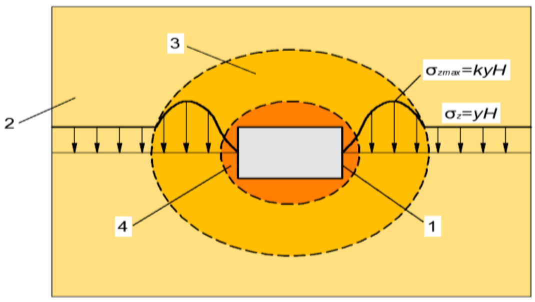
Zhurov Vitaliy Vladimirovich — *Candidate of Engineering Sciences, acting associate professor of Higher Mathematics department, Non-profit joint-stock company «Abylkas Saginov Karaganda Technical University», Karaganda, Kazakhstan. E-mail: zhurvitv@yandex.ru*

Introduction

In coal mines, the rocks in the immediate vicinity of the workings are weakened by cracking and plastic deformation, which leads to the formation of inelastic deformations around the workings, in which one can observe the restribution of the stresses, and the stress zone is moved into the rock mass [[1], [2], [3]]. Zones of increased and decreased stresses (support pressure zone) are formed in the rock mass surrounding the preparatory working (Figure 1).

For different mining conditions, mining development schemes and stages of working existence, rock heaving processes are different and this determines ways to control this phenomenon. The most often used is periodic undermining of soil rocks, which leads to disturbance of the equilibrium state of the system "bolt - zone of destroyed rocks", growth of rocks deformation intensity on the contours of workings and increase of soil rocks displacement.

The extraction of swelled rock reduces the passive back pressure on the ground by only 50-60 kN/m of the working. It is necessary to compensate



1 - preparatory working; 2 - natural stress zone; 3 - support pressure zone; 4 - decreased stress zone

Figure 1 - Stress distribution around the preparatory working

the back pressure of the excavated rock after undermining in order to ensure a stable condition of the working soil [3]. It is known that the higher the rock back pressure, the lower the rock displacement value, and the mechanical back pressure value is three orders of magnitude below the forces acting on the undermined zone perimeter. The mechanical support in mine workings at "Yuzhnodonbasskaya" mine No. 3, where the power train was located, was provided with the metal ropes with the help of which a distributed load of 0,03 MPa was set between the legs of the bolt and the soil of the mine working; this helped to reduce by 57 % the squeezing of the working ground [[3], [4]].

In order to compensate the back pressure of the extracted rocks, progressive technological solutions using dispersed purposeful load to increase the effect of counteracting the extrusion of soil rocks are required. One of them is conducting preparatory workings with strengthening of host rocks by the system of rod and cable (rope) anchoring bolts which are set for a particular working taking into account mining and geological conditions of development, character of interaction with rock massif at given loads and deformation rates.

In case of insignificant difference in strength parameters of the top, sides and soil, the deformation of rocks along the whole working perimeter occurs in conditions of full compression, while the tangential component of the stress tensor grows with its size increasing, and the shifts of contours increase. It is necessary to distinguish soil heaving, which is caused by the stress-strain state (SSS) of the whole rock mass around the working, from rock squeezing from under the pillars, which play the role of dies.

Heaving is most intense on the soil side of coal seams in preparatory workings. Soil layers covered by heavings are 2 - 5 m thick, and the thicker the weak rock layers, the more intense the heavings are [[5], [6], [7], [8], [9], [10]].

In preparatory workings, which are in the zone of cleaning operations influence (80 - 100 m), as the longwall face approaches the studied area, the growth of heaving intensity is noted up to a certain maximum. As the longwall face moves away (100 - 120 m), the intensity of heaving gradually decreases, asymptotically approaching to a certain constant value. In single workings, the heaving intensity tends to be monotonic and fades with time.

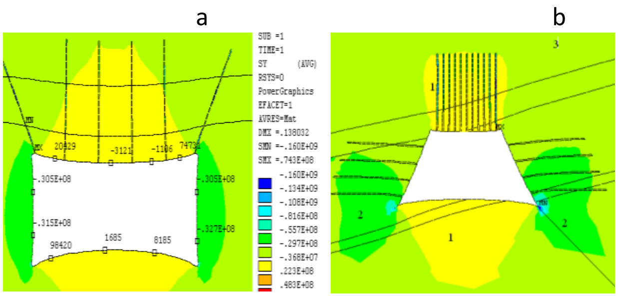
The sizes of coal pillars have a significant influence on the heaving: the smaller the pillar, the higher the heaving intensity. Increasing the width of pillars and protecting preparatory workings with rock strips reduces the heaving intensity, which lasts for 1 or 3 months. This regularity is widely used for wide workings with one-sided or two-sided rocking [5].

The classification criteria for heaving are rather subjective, due to the multifactorial nature of the phenomenon and are based on the intensity of its manifestation: "weak", "medium", "strong".

The experimental part

The decreasing of soil heaving in mine workings can be achieved by creating zones of decreased stress in the sides, by anchoring the top rocks with steel-polymer anchor bolts of increased load-carrying capacity. This increases the support area of the roof on the sides of the working and decreases the specific pressure on the soil. The area of maximum support pressure in this case is shifted from the edge of the massif by the length determined value, incline and density of the near-soil anchors.

The distribution of stresses along the working contour in a 5 m claystone layer is shown in Figure 2. An unstable rock zone is formed around the working, mainly in the roof and soil, but also on the sides in the lower part of the sides of the working contour. The maximum value of normal stresses occurs in the rightmost anchor of the working top at the place of its anchoring, and the maximum longitudinal stress occurs in the anchor located on the right-side surface of the working (first from the bottom) (Figure 2).



1 - highly unstable zone; 2 - unstable zone; 3 - unstable zone; 4 - medium stability zone; at the minimum point the zone is stable

Figure 2 - Distribution of normal (a) and longitudinal (b) stresses in a 5 m thick claystone layer

We have established the dependences of stress changes in zones 1, 2, 3 on anchor length for the claystone layer:

$$\sigma(l) = -1{,}4 \cdot l - 8{,}8(1\,zone),$$
$$\sigma(l) = -2{,}4 \cdot l - 20{,}9(2\,zone), \qquad (1)$$
$$\sigma(l) = -3{,}5 \cdot l - 32{,}9(3\,zone).$$

The calculations of the SSS using Flac program [11] for different mining conditions of coal seams in Karaganda basin showed that the greatest effect of strengthening influence was obtained in rectangular cross-section of mine workings with side walls roof anchoring under combined scheme with their installation so that the upper side (usually, deep) anchor was located in the support pressure zone behind the workings contour in host rock. Such installation makes it possible to shift the peak of rock pressure deep into the massif beyond the zone of spreading deformation (destroyed rocks) in the zone of working influence. The lower deep anchor is placed in such a way as to create enclosing (isolating) zone preventing side soil rock spreading and extrusion into the working cavity (Figure 3). The results of SSS modeling show that the deformations and stresses in both side rocks and soil rocks are predominantly influenced by side anchors rather than near-soil ones, leading to reduction of the effective deformations in the rocks surrounding the working and decreasing of gas release from the coal-bearing massif.

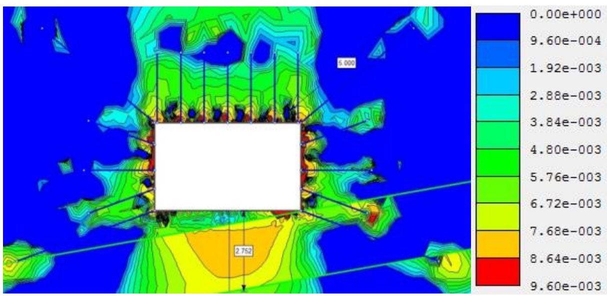


Figure 3 - Deformation pattern with displacement scales and strain distribution in the soil rock with 5 m upper side anchors and 5 m near-soil anchors

The evaluation of the required thickness of the strengthened rock layer in the soil, using the anchors installed in the soil to form supporting blocks to support the bearing vault of the working, is determined according to the method of Prof. P.M. Tsimbarevich. The depth of spreading of the heaving zone depending on the volume weight of soil and side rocks (σ t/m^3) and working height (h, m) are determined using a nomogram (Figure 4) [[6], [7], [8], [9], [10]].

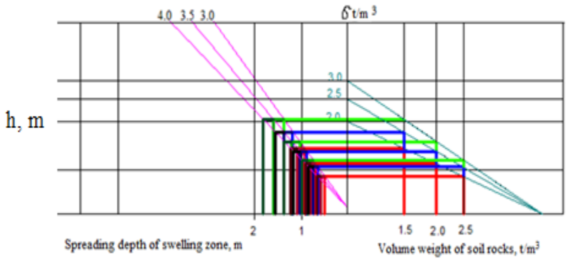
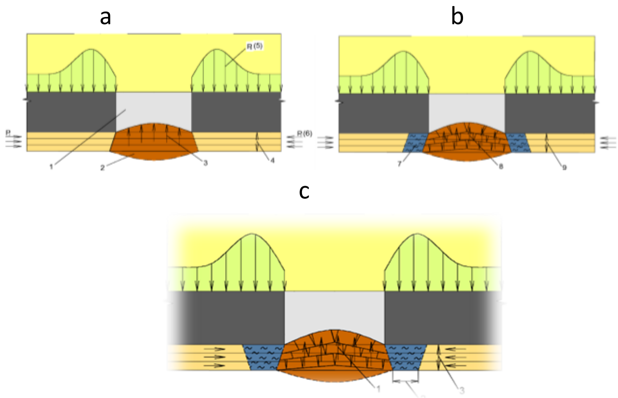


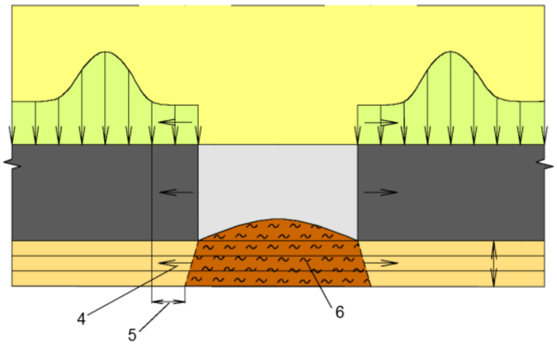
Figure 4 - Nomogram for determining spreading depth of heaving zones in the working soil depending on the influencing factors

In clay preparatory workings of the Karaganda coal basin when layered claystones and siltstones are deposited in the soil, three stages of deformation processes are distinguished: stratification along the layering surface without fracture of layered rocks (Figure 5, a); fracture of layered rocks under the workings into blocks in the form of multi-joint arches (Figure 5,b); destruction of soil under the workings sides with their squeezing into the workings (Figure 5,c). The character of stresses changes in the roof and decreasing of the soil friction intensity when strengthening the working contours with the steel-polymer anchorage (Figure 6) [[12], [13], [14], [15], [16], [17], [18]].



1 - cavity of the mine workings; 2 - soil deformations zone; 3 - deformations of heaving of mine workings; 4 - depth of delayering of mine workings; 5 – P_V =2kgH - vertical component of rock pressure; 6 – P_H - horizontal component of rock pressure; 7 - inelastic deformations zone; 8 - distraction deformations; 9 - distraction zone; a - rock extrusion deformations; b - zone subject to extrusion deformations; c - extrusion deformations

Figure 5 - Stages of deformation processes: a - delayering, b - fracture of stratified rocks, c - fracture of rocks in the sides of the working



4, 5 - direction and magnitude of maximum deformation zone movement deep into the rock mass; 6 – decreased deformation zone in the working soil

Figure 6 - Stress distribution pattern during strengthening of steel-polymer anchoring circuits

The general established regularity is that as the volume weight value of top roof grows, the spreading depth of the frost heave in the working soil decreases, while an increase in the side rock density and working height leads to an increase in the spreading depth of the heaving zone.

Discussion of results

The established patterns of stress-strain state change of coal-rock massifs (displacements, stresses, zones of delayering and cracking), depending on the main mining and geological-mining engineering factors allowed to determine the optimal parameters of soil rock anchoring. The technological schemes of heaving decreasing of soil rocks of mine workings are used in mines of Karaganda coal basin to increase the stability of preparatory mine workings. At the expense of effective and safe fastening of near-surface rocks when conducting mine workings on flat and inclined coal seams. The deformations and stresses both sides and in the soil rocks in the working are predominantly influenced by side anchors rather than near-soil ones. The schemes for anchoring the rock massif of the immediate soil are discussed below.

Near-soil anchors (Figure 7) are sunk into the soil along the faces of the mine in slanted boreholes at an angle of 20 to 40°. Their length is determined by the technical possibility of drilling (1.6; 2.4 and 2.9 m). The anchors are placed crosswise (at right angles) into the soil layers [[11], [19]].

The borehole has a larger diameter from the mouth to half of its depth and is not filled with a filler (Figure 7.b). This is necessary to unload the side rock in this area and then fill the 28 mm diameter borehole up to the face.

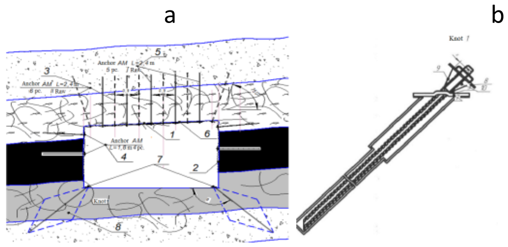


Figure 7 - Soil anchoring installation (a) and borehole design (b)

During the working for the next tunneling cycle, the boreholes are drilled in rows into the roof *1* and sides *2* of the excavation. The length, diameter and angles of the boreholes are determined by the work passport, as well as the size of the holes in the metal supports. The anchoring starts with the first row of six roof bolts *3* (2.4 m long) and four side glass fibre anchors *4* (1.8 m long). As the installation progresses, a second row of five roof steel-polymer anchors *5* (2.4 m long) is installed. Metal net *6* is pre-installed under the strips. Before excavation, before the start of cleaning works and after determining the thickness of the heaving layer, inclined steel-polymer anchors *7* (2,4 m long) are placed at a 30 - 45° angle to the rock stratum; as they are fastened in blast holes, cavities form rock blocks around the anchors, which are bound together by the cohesive forces of the rocks. As a result, a supporting dome (strengthening contour) *8* is created to reduce compressive forces from the sides of the excavation. To ensure the relief of soil from stresses, the boreholes *9* for anchor installation are drilled to the depth of 1.0-1.2 m with a diameter twice as big. This will disturb the integrity of the friable layer and slow down (exclude) the development of longitudinal and transverse bending of the layers. The rock layers cut through by the slot are relieved from horizontal stresses. In order to increase the carrying capacity and to ensure the suppleness of the anchor support elements, a cone spacer *10* is installed. Due to the support pressure ahead of the face, anchors are installed in the ground with irreducible advance of the working face by a value exceeding the length of the zone of advance support pressure by 1,5-2,0 times [[5], [6], [20]].

The length of the anchors to be installed in the working soil is determined according to an empirical formula:

$$L = \frac{К_э \cdot B \cdot П}{P}, \text{ m} \quad (2)$$

where $K_э$ is an empirical coefficient (for the Karaganda coal basin it is 6.75);

B is the width of the excavation, m;

П - value of soil heaving, m;

P is the compressive strength of the soil, MPa.

It is recommended that the spacing of the on-soil anchors should be double the number of arches of metal arch anchor per 1 metre of working.

Conclusions

The identified patterns of change in the stress-strain state of coal massifs (displacements, stresses, cracking zones), depending on the main mining-geological and mining-technical factors will allow to establish the optimal parameters of ground mountings, technological scheme for reducing frost heaving of rocks of mine workings to increase the stability of preparatory mine workings. There are substantiated development and improvement of the existing technologies of the effective and safe ground support during mine workings on the flat and inclined coal seams. It is established that the deformations and stresses both lateral and in-soil rocks in the working are influenced by lateral anchors rather than near-surface ones.

Conflicts of interest

On behalf of all authors, the author declares that there is no conflict of interest.

Cite this article as: Demin VF, Zhurov VV. Anchor bolt of rock massif in coal mines to decrease soil rock heaving of the workings. Kompleksnoe Ispolzovanie Mineralnogo Syra = Complex Use of Mineral Resources. 2023;325(2):80-86. https://doi.org/10.31643/2023/6445.21

Қазбалардағы топырақ жынысының қопсуын төмендету үшін көмір шахталарының тау-кен массивін анкерлік бекіту

Демин В.Ф., Журов В.В.

«Әбілқас Сағынов атындағы Қарағанды техникалық университеті» коммерциялық емес акционерлык қоғамы, Қарағанды, Қазақстан

Мақала келді: *18 сәуір 2022*
Сараптамадан өтті: *04 шілде 2022*
Қабылданды: *10 қазан 2022*

ТҮЙІНДЕМЕ

Пайдалану процесінде қазбаларды ұстау кезінде, әдетте, контурлық тау қысымының әсерінен оларды қазба қуысына сығып, пластикалық деформациялар кезінде пайда болатын топырақ жыныстарының шағылысуының салдарын жою бойынша жұмыстар жүргізіледі. Негізгі тау-кен-геологиялық және тау-кен техникалық факторларына байланысты көмір-жыныс массивтерінің (ығысулар, кернеулер, жарықшақ түзілу аймақтары) кернеулі-деформацияланған жай-күйінің өзгеруінің анықталған заңдылықтары топырақ жыныстарын бекітудің оңтайлы параметрлерін белгілеуге мүмкіндік береді. Тау-кен қазбаларын жұмсақ және көлбеу көмір қабаттарында жүргізу кезінде, контурға жақын жыныстарды тиімді және қауіпсіз бекітудің қолданыстағы технологияларын әзірлеу және жетілдіру негізделген. Қосымша күн салығын модельдеу, бүйір жыныстардағы, сондай-ақ топырақ жыныстарындағы деформациялар мен кернеулерде жер асты емес, жанама анкер басым болатындығын көрсетеді, бұл өндірісті қоршаған жыныстардағы қолданыстағы деформациялардың төмендеуіне және көмір жыныстарынан газ шығарудың төмендеуіне әкеледі. Бүйірлік және тау жыныстарындағы деформациялары мен кернеулерінде қазбада топырақ емес, бүйірлік анкер бар екендігі анықталды.

Түйін сөздер: тау-кен қазбалары, деформациялық процестерді зерттеу, бекіту параметрлері, геомеханикалық процестер, анкерлік бекітпе, тау-кен қысымының көріністері, технологиялық схемалар

Авторлар туралы ақпарат:

Демин Владимир Федорович — *Техника ғылымдарының докторы, профессор, «Әбілқас Сағынов атындағы Қарағанды техникалық университеті» коммерциялық емес акционерлык қоғамы, Қарағанды, Қазақстан. E-mail: vladfdemin@mail.ru*

Журов Виталий Владимирович — *Техника ғылымдарының кандидаты, «Әбілқас Сағынов атындағы Қарағанды техникалық университеті» коммерциялық емес акционерлык қоғамы «Жоғары математика» кафедрасының доценті м.а., Қарағанды, Қазақстан. E-mail: zhurvitv@yandex.ru*

Анкерное крепление горного массива угольных шахт для снижения пучения пород почвы выработок

Демин В.Ф., Журов В.В.

Некоммерческое акционерное общество «Карагандинский технический университет имени Абылкаса Сагинова», Караганда, Казахстан

Поступила: *18 апреля 2022*
Рецензирование: *04 июля 2022*
Принята в печать: *10 октября 2022*

АННОТАЦИЯ
При поддержании выработок в процессе эксплуатации, как правило, проводятся работы по устранению последствий пучения пород почвы, возникающего при пластических деформациях с выдавливанием их в полость выработки под действием контурного горного давления. Выявленные закономерности изменения напряженно-деформированного состояния угле-породных массивов (смещений, напряжений, зон трещинообразования), в зависимости от основных горно-геологических и горнотехнических факторов позволят устанавливать оптимальные параметры крепления пород почвы разработаны технологические схемы снижения пучения пород почвы горных выработок для повышения устойчивости подготовительных горных выработок. Обоснована разработка и совершенствование существующих технологий эффективного и безопасного крепления приконтурных пород при проведении горных выработок на пологих и наклонных угольных пластах. Моделирования НДС свидетельствует о том, что на деформации и напряжения в боковых породах, так и в породах почвы преимущественное оказывают не припочвенные, а боковые анкера, приводящих к уменьшению действующих деформаций в породах, окружающих выработку и снижению газовыделения из углепородного массива. Установлено, что на деформации и напряжения как боковых, так и в породах почвы в выработке оказывают не припочвенные, а боковые анкера.
Ключевые слова: горные выработки, исследование деформационных процессов, параметры крепления, геомеханические процессы, анкерная крепь, проявления горного давления, технологические схемы.

Информация об авторах:

Демин Владимир Федорович — *Доктор технических наук, профессор, некоммерческое акционерное общество «Карагандинский технический университет имени Абылкаса Сагинова», Караганда, Казахстан. E-mail: vladfdemin@mail.ru*

Журов Виталий Владимирович — *Кандидат технических наук, доцент кафедры «Высшая математика», некоммерческое акционерное общество «Карагандинский технический университет имени Абылкаса Сагинова», Караганда, Казахстан. E-mail: zhurvitv@yandex.ru*

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